THE TIDE IS HIGH BUT I'M HOLDING ON

(HOW CLIMATE CHANGE IS AFFECTING ONSITE WASTEWATER TREATMENT SYSTEMS)

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CLIMATE CHANGE’S EFFECTS ON SOUTHERN NEW ENGLAND COASTS

- Increased storm activity
  - More frequent
  - More intense
  - Trend expected to accelerate!
  - Result: Flooding & erosion

- Changes in precipitation patterns
  - Droughts & excess precipitation
  - Implications for groundwater tables

- Sea Level Rise
  - Makes everything worse!
  - More flooding
    - Surface flooding during storms & high tide events
    - Elevated groundwater tables
RI’S SOUTHERN COAST = DENSELY POPULATED & SERVED BY SEPTIC SYSTEMS
Coastal septic systems

Rising groundwater tables

Coastal storms
COASTAL SEPTIC SYSTEMS

Cross-section of Drainfield Trenches

- Drainfield Crushed Stone
- Perforated Pipe
- Infiltrative Surface
- Wastewater
- Seasonal High Water Table
- Groundwater

Separation Distance

Salt Water

Inadequate Separation Distance

Raised Seasonal High Water Table

Salt Water
IS SEPARATION (DISTANCE) ANXIETY JUSTIFIED ALONG SOUTHERN RI COAST?

- APPROACH 1: LOOK AT HISTORIC DATA
- APPROACH 2: LOOK AT 10 EXISTING DRAINFIELDS IN THE FIELD
HISTORIC DATA: COASTAL GROUNDWATER TABLES IN SOUTHERN RI RISING

Rate varies with location along coast

Septic System Permit
(RI Dept. Env. Management)

[Newport SLR: 2.8 mm / year ]

14 mm/year
(p < 0.001; R² = 0.05)
INVESTIGATING GROUNDWATER TABLES AND SEPTIC SYSTEMS IN THE FIELD (10 SITES)
ASSESSING SEPARATION DISTANCE
GROUND-PENETRATING RADAR (GPR)
MONITORING WELLS
BENCHMARKS AND ELEVATIONS
FIELD INVESTIGATIONS: IMPAIRED SEPARATION DISTANCE A COMMON PROBLEM

No Problem: 20% of systems

Sometimes Problem: 50% of systems

ALWAYS Problem: 30% of systems

Water @ infiltrative surface 2% days
IMPAIRED SEPARATION DISTANCE = CURRENT & FUTURE PROBLEM FOR SEPTIC SYSTEMS ALONG COAST!
IMPAIRED SEPARATION DISTANCE ... SO WHAT?!
REMINDER: WHAT DO WE WANT FROM OUR STA?

- Keep wastewater away from people
- Groundwater recharge/stream flow
- Remove
  - Suspended solids
  - BOD, N, P
  - Emerging pollutants
  - Pathogens
HOW DOES THE STA DO ITS THING?

- Infiltrative surface and biomat
- Geotextile
- Distribution pipe
- Perched water table
- Restrictive horizon
- Capillary zone
- Groundwater surface
- Vadose zone
- Backfill

Adsorbent
Sea level rise

Increased temperature

Change in precipitation

OWTS Function
**WHAT’S AFFECTED BY WATER AND HEAT?**

<table>
<thead>
<tr>
<th>WATER</th>
<th>HEAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>• FILTRATION</td>
<td>• MICROBIAL ACTIVITY</td>
</tr>
<tr>
<td>• OXYGEN DIFFUSION</td>
<td>• PATHOGEN SURVIVAL</td>
</tr>
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<td>• MICROBIAL ACTIVITY</td>
<td>• OXYGEN SOLUBILITY</td>
</tr>
<tr>
<td>• PATHOGEN SURVIVAL</td>
<td>• SPEED OF CHEMICAL</td>
</tr>
<tr>
<td>• REDOX POTENTIAL</td>
<td>REACTIONS</td>
</tr>
<tr>
<td>• ...</td>
<td>...</td>
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</tbody>
</table>
Δ IN SOIL MOISTURE = Δ MICROBIAL ACTIVITY

Fig. 1—The relationship between water-filled pore space and relative amount of microbial nitrification (after Greaves and Carter, 1920), denitrification (after Nommi, 1956), and respiration [O₂ uptake (O·O) and CO₂ production (●●●●)] as determined in this study. Data for nitrification originally expressed as percentage water-holding capacity.

Linn and Doran (1984)

Δ IN SOIL MOISTURE = Δ MICROBIAL ACTIVITY

Davidson et al. (1998)

Fig. 7 Correlations of volumetric water content and soil respiration. The plotting symbol represents the month of the year that the measurements were made. Each datum is a mean of 3 or 4 TDR water content measurements and 6 flux measurements for a study area on a given date. The August (8) and September (9) data where water content was < 0.12 cm³ cm⁻³ were fitted to the linear regression: flux = -1.28 + (2852 × water content); R² = 0.48, which is significant at α = 0.05 (d.f. = 21). The data from the rest of the year where water content was > 0.12 cm³ cm⁻³ were fitted to the linear regression: flux = 201 – (198 × water content); R² = 0.22, which is significant at α = 0.01 (d.f. = 131).
**TEMPERATURE = LESS DISSOLVED $O_2$**

![Graph showing the relationship between temperature and dissolved oxygen concentration.](image)
OWTS Function

- Increased temperature
- Sea level rise
- Change in precipitation
HOW WILL CLIMATE CHANGE AFFECT STAs?

• Intact Soil Core Mesocosms

• Three Drainfield Types:
  • Pipe & stone – P&S
  • Shallow narrow – SND
  • Shallow narrow – GeoMat

• Climate Conditions:
  • Present climate: 70°F
  • Climate change: 77°F; Water table up 1 ft

OXYGEN IN SOIL PORES
FECAL COLIFORM BACTERIA

- SND
- GEO
- P&S

FC (CFU/100mL)

Present Climate  Climate Change

0  2  4  6

0  2  4  6
PHOSPHORUS REMOVAL

SND

Present Climate  Climate Change

GEO

Present Climate  Climate Change

P&S

Present Climate  Climate Change

TP removal (%)
NITROGEN REMOVAL

SND

GEO

P&S

TN removal (%) vs. Present Climate and Climate Change
• IMPAIRED SEPARATION DISTANCE (& HIGHER TEMPERATURE)...
SO WHAT?!

• Lower BOD
• Increased FCB
• Increased P
• Some increase in N
Coastal septic systems

Rising groundwater tables

Coastal storms
COASTAL STORMS = EPIC DESTRUCTION!
Army Corps proposes raising homes
COASTAL STORMS – “PREPAREDNESS” ... ?!

Army Corps proposes raising homes

(No public sewers along most of coast)
GOAL: QUANTIFY STORM IMPACTS!

• MODEL DIFFERENT STORM CONDITIONS ALONG SOUTHERN RI COAST...

• COUNT NUMBER OF SEPTIC SYSTEMS AFFECTED
DAMAGE POST-SUPERSTORM SANDY (2012)

“fully exposed septic tank ocean side undermined, no outlet pipe, building sewer broken, covers off, tank full, likely destroyed”

“system in front, building sewer un-supported due to erosion, appears intact, system inundated, requires assessment”

“building sewer ok, system appears inundated but ok”
17,760 Total Parcels rely on Septic Systems

+ Flood Maps
  • 25, 50, 100 & 500-Year Storm Events
  • Hurricane Worst Case Scenarios (Categories 1-4)
+ 2-foot Contour Lines
• CREATED INTERSECTS OF SEPTIC SYSTEM PARCELS INUNDATED BY EACH STORM

<table>
<thead>
<tr>
<th>Impact Category</th>
<th>Effect on Septic System</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Serious”</td>
<td>Major Repairs / Total Replacement</td>
<td>During Storm &amp; Weeks – Months after Storm</td>
</tr>
<tr>
<td>“Moderate”</td>
<td>Minor Repairs</td>
<td>During Storm &amp; Days – Weeks after Storm</td>
</tr>
<tr>
<td>“Ephemeral”</td>
<td>No Long-term Effects</td>
<td>During Storm</td>
</tr>
</tbody>
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COASTAL STORM IMPACT SUMMARY
(SOUTHERN RI COAST)

25-Y TO 500-Y STORM

- 3 – 4K SYSTEMS AFFECTED BY FLOODING
  - ~200 SERIOUSLY IMPACTED
  - ~65 MODERATELY IMPACTED
  - REST EPHEMERALLY IMPACTED

- REST EPHEMERALLY IMPACTED

HURRICANES (CAT 1 – 4)

- 2 – 5K SYSTEMS AFFECTED BY FLOODING (?)
  - ~200 SERIOUSLY IMPACTED
  - ~65 MODERATELY IMPACTED
  - REST EPHEMERALLY IMPACTED

+ 30cm SLR => + ~200 ephemerally impacted systems

Require repairs!

Cox et al. (2020B)
WHY STORM DAMAGE IS CONCERNING FOR SEPTIC SYSTEMS...

- Septic system repairs & replacements...
  - Take weeks – months!
  - Expensive!
    - Repairs: $1k – $15k
    - Installing Advanced Treatment Tech: $23k – $30k
      ...PER SYSTEM!
- ...what happens to wastewater in the meantime?
Coastal septic systems

Rising Groundwater Tables

Failing / failed septic systems

Nutrient & Pathogen Pollution

Contaminated wells

Human Health Problems

Contaminated Coastal Waters

Environmental Health Problems

Coastal Storms

Why worry?

Algal Blooms
QUESTIONS?

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USDA NIFA - NE 1545 Multi-state HATCH Project
CITATIONS


