Enhanced Perspective on Onsite Wastewater Systems: A Public Health Contribution to the Wellbeing of Communities

Max Zarate-Bermudez, Ph.D.
Epidemiologist

EPA Decentralized MOU - Public Health Webinar
August 23, 2012
OUTLINE

- Why an enhanced perspective on OWW systems and why is this a public health contribution to community wellbeing?

- Evaluating performance of OWW systems in Coastal North Carolina
  - Methodology
  - Findings
  - Accomplishments
  - Limitations

- Remaining promising and challenging aspects
WHY AN ENHANCED PERSPECTIVE ON ONSITE WASTEWATER SYSTEMS?
Why an enhanced perspective on OWW systems?

Conventional OWW System schematic in coastal areas (non-scale)
Why an enhanced perspective on OWW systems?

Conventional OWW System schematic in coastal areas (non-scale)

Basis for an enhanced perspective:

- Knowledge of OWW systems’ performance
- Fate of nutrients and microorganisms in the environment
- Water quality of wells in areas with high OWW systems’ density
- Existing OWW rules at state/local level (i.e. coastal areas)
Why an enhanced perspective on OWW systems?

Conventional OWW System schematic in coastal areas (non-scale)

Environmental conditions in OWW systems’ components:

- **Septic tank (facultative environment):**
  - Anaerobic (bottom): reduction processes $\rightarrow$ sulfide production
  - Aerobic (top): oxidation processes $\rightarrow$ nitrification starts (?)

- **Dispersion field:**
  - Aerobic (top): Oxidation processes $\rightarrow$ nitrification; possibly anaerobic pockets

- **Soil (may apply to shallow aquifer):**
  - Aerobic (if aerated): continued oxidation processes
  - Anaerobic (where biomat forms): reduction processes $\rightarrow$ denitrification
Why an enhanced perspective on OWW systems?

- Environmental issues that might be attributed to malfunctioning OWW systems
  - Excess nutrients transported to already nutrient-sensitive rivers
  - Microbial contamination – Closure of beaches and shellfisheries
    - 65% of shell-fishing waters in New Brunswick County closed in 1990s\(^a\)
  - Florida: 0.60 m (24\(\)”) vertical separation not safe for viruses (wet season)\(^b\)


Why an enhanced perspective on OWW systems?

- Public Health issues potentially attributed to malfunctioning OWW systems

  - Wisconsin:
    - Enteric viruses and *E. coli* isolated from samples of household wells near septage land application sites or in rural areas served by septic systems
    - Sites with densities <50 OWW systems/mile² were associated with endemic diarrhea in children

  - Wyoming: overloaded OWW system, not well suited to local soil/geologic conditions; drinking water system with no treatment or disinfection

  - Coastal North Carolina: densities of >100 (common) and of >200 (found) OWW systems/mile² with vertical separation of 0.45 m (18”)

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\[\text{References:}\]


WHY IS THIS A PUBLIC HEALTH CONTRIBUTION TO COMMUNITY WELLBEING?
Why is this a public health contribution to community wellbeing?

Base map is from the USGS Blounts Bay quadrangle (1993)
Why is this a public health contribution to community wellbeing?

Because of reasons related to the environment, human health, and economic development nexus:

- Enhanced knowledge of:
  - OWW systems and WW management at local level
  - Potential environmental and public health risks
- Design and implementation of corrective actions to prevent future risks –if needed
- Communities can benefit from assessing water resources in a more interconnected and integrated manner
Why is this a public health contribution to community wellbeing?

Because of reasons related to the environment, human health, and economic development nexus:

- Protection of the environment and public health
- Contribution to the economic development and wellbeing of communities
EVALUATING PERFORMANCE OF OWW SYSTEMS IN COASTAL NORTH CAROLINA
Methodology – 2 year project

- **Approach:**
  1. Multidisciplinary team (ECU, NCSU, NEHA, CDC)
  2. Site selection, soil morphology, and identification of OWW Systems’ components
  3. Characterization of the shallow aquifer (flow direction)
  4. Delineation of wastewater plume orientation
  5. Monitoring performance of OWW Systems a, b:
     - Septic tanks (installation of lids/tubing)
     - Network of piezometers in shallow aquifers doubled for the 2nd year compared to the 1st at Site 1

a Site 2 monitored only during year 1
b Wells of deeper aquifers were also sampled in Site 2’s neighborhood
Sampling points at Site 1, years 1 and 2
Findings

- **Characterization of the shallow aquifer and WW plume**
  - Flow direction and delineation of wastewater plume → estimated by electrical resistivity surveying
    - Geoprobe sediment cores collected up to depths of 5 m
      - Relatively homogeneous sandy soils
      - Low permeability organic-rich clays and wood debris found in deepest 0.20 m (site 2)
    - Characteristics of shallow aquifers: relatively homogeneous sandy sediments
  - OWW systems in coastal areas, depending on their location, can be vulnerable to the effects of severe weather events (i.e. Site 1, Year 2)
## Findings

- **Monitoring performance of OWW Systems: parameters measured**

<table>
<thead>
<tr>
<th>Physical-chemical</th>
<th>Physical-chemical (cont’d)</th>
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<tbody>
<tr>
<td>pH</td>
<td>Pharmaceuticals and Personal Care Products (PPCPs)</td>
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<td>Temperature</td>
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<td>Turbidity and Total Suspended Solids</td>
<td>Microbiological</td>
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<tr>
<td>Chloride</td>
<td><strong>Escherichia Coli</strong></td>
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<td>Specific conductance</td>
<td><strong>Enterococci</strong></td>
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<tr>
<td>Dissolved Oxygen</td>
<td><strong>Clostridium Perfringens</strong></td>
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<tr>
<td>Biochemical Oxygen Demand (5 and 7)</td>
<td>MS2 – F+ phage</td>
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<tr>
<td>Total Nitrogen</td>
<td>Somatic phage (ΦX174)</td>
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<td>Nitrogen species: ammonia (ion ammonium), nitrite, nitrate, dissolved Kjeldahl nitrogen</td>
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</tbody>
</table>

**Isotopic analyses:**

\[ ^{15}\text{N} \text{ and } ^{18}\text{O } \rightarrow \delta^{15}\text{N}^{18}\text{O}_3^- \]

\[ \text{N}_2/\text{Ar} \]

Additional data gathered in the field: hourly fluctuations of water level and rainfall
Findings

Nutrients fate

- Nutrients observed at ~40-50 m from the dispersion field
- OWWs in sandy soils may add dissolved organic nitrogen (DON) loading to adjacent surface waters

Microbial fate

- Indicator data more spatially and temporally variable than nutrient data
- *E.coli* and enterococci densities declined to less than background levels at within and outside dispersion field area
- Found elevated microbial densities during several sampling events in background wells or in wells >30 m from dispersion field
- Deeper aquifers appear not to be contaminated (year 1, site 2)
Monitoring performance of OWW Systems:

- Median TDN and DON, NO$_3^-$-N, and NH$_4^+$-N in OWW systems. TDN levels in septic tank, dispersion field piezometers and lysimeters, and background piezometers and lysimeters.

![Graphs showing monitoring results](image-url)
Findings

Microbial indicators:
Accomplishments

- **Capacity building:**
  - Future environmental scientists addressing local needs
  - Network of collaborators (e.g. LHDs, neighborhood associations)

- **Enhanced understanding of OWWT systems adjacent to nutrient-sensitive waters – Products:**
  - Two Master’s Theses in Geological Sciences – Spring 2012
  - Dissemination of study findings at numerous events nationwide (e.g. NEHA AEC, ASCE, GSA)
  - Manuscripts submitted to the *JEH*; others in preparation

- **New funding opportunities (e.g. NC-DENR, ECU)**
Limitations

Reduced funding impacted on:

- **Initial study duration reduced from 3 to 2 years:**
  - 3rd year included the conduct an epidemiologic study
  - Monitoring water quality from private wells (quarterly sampling)

- **Low number of households studied**
  - Robustness of data set
  - Number of private wells tested; duration of monitoring

- **Human resources:**
  - Limited personnel (field and laboratory work are labor intensive)
REMAINING PROMISING AND CHALLENGING ASPECTS
Remaining promising and challenging aspects

Challenging aspects – after findings of NC study:

- Elevated nutrient concentrations observed at ~40-50 m from dispersion field can be an effect of wastewater input
- Dissolved P returns to background levels over a shorter distance than dissolved N concentrations
- Microbial indicators in groundwater more spatially and temporally variable than nutrients:
  - *E.coli* and Enterococci densities declined from septic tank to dispersion field
Remaining promising and challenging aspects

Challenging aspects – after findings of NC study

- Need of a more comprehensive tracing of human waste in subsurface:
  - Tracers to consider: bacterial source tracking, specific conductance, PPCPs, O\textsuperscript{18}

- Extreme meteorological events contribute to data variability:
  - Groundwater data shown that most of the site was affected
  - Septic tank flooded
Remaining promising and challenging aspects

Challenging aspects – after findings of NC study

- Denitrification:
  - Powerful greenhouse gas $\text{N}_2\text{O}$ could be generated

- Climate change may have a large influence on OWW treatment in coastal areas
Remaining promising and challenging aspects

Promising aspects – after findings of NC study:

- Denitrification – Coastal NC study (Years 1-2):
  - Positive: apparent reduction of $\text{NO}_3^-\text{-N}$ levels in groundwater by conversion to $\text{N}_2\text{(g)}$

- Data from study and other ongoing coastal NC studies useful in:
  - Building database of groundwater quality down-gradient from OWW systems.
  - Future modeling approaches to scale up estimates of nutrient loading to surface water bodies in coastal NC
Remaining promising and challenging aspects

Promising aspects – additional information:

- Decentralized reuse applications widened due to onsite energy and resource efficiency (water-energy nexus):
  - Industrial and commercial applications
  - Buildings seeking Leadership in Energy and Environmental Design (LEED) certification – it can be energy intensive though

- Decentralized, OWW systems can save a high portion of the tremendous energy costs and emissions associated with pumping in centralized WWTFs:
  - Almost 20% of California’s electricity is consumed by water-related energy use, which includes WW collection, treatment, and disposal

Acknowledgements

- **ECU:**
  - Michael O’Driscoll
  - Charles Humphrey Jr.
  - Shawn Thieme
  - Keaton Henry
  - Staff at the Central Environmental Laboratory

- **NCSU:**
  - David Lindbo
  - Nancy Deal

- **CDC/NCEZID:**
  - Vincent Hill
  - Chandra Scheeneberger
Questions?

For more information please contact Centers for Disease Control and Prevention

1600 Clifton Road NE, Atlanta, GA 30333
Telephone, 1-800-CDC-INFO (232-4636)/TTY: 1-888-232-6348
E-mail: cdcinfo@cdc.gov Web: www.cdc.gov

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