ANALYSIS OF CONTAMINANTS OF EMERGING CONCERN WITHIN ON-SITE WASTEWATER TREATMENT SYSTEMS – YEAR I

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Thank you to the Minnesota Department of Transportation for funding and continued support of this project.
To assess the ability for on-site wastewater treatment systems to degrade or transport contaminants of emerging concern (CEC)

- Field samples, from a variety of on-site treatment types, will be taken from wastewater, soil and groundwater and tested for CECs
CHEMICALS OF EMERGING CONCERN

- Those previously unidentified due to advances in analytical techniques
- Those previously identified but with new effects of concern
- Newly marketed chemicals
CEC UNITS

- Nanograms/liter
- 1 part per trillion
- 1 ng/l analogy – 1 oz. in 7.5 billion gallons of water
Thousands of unique chemicals are produced and used every day. Many are being found in the environment -- these chemicals are considered contaminants of emerging concern.

A subset of CECs are pharmaceuticals and personal care products. These are ingested by humans and deposited, via human waste, into wastewater treatment systems.

**Photo courtesy of the Minnesota Pollution Control Agency**
- Water sampled nearby wastewater treatment systems have been shown to contain CECs.

- Contaminated water can flow into surface waters or seep into groundwater, a key drinking water source for many Americans.

- CECs, have been found to negatively affect aquatic biota, even at very low concentrations.

- The long-term effects of CECs on human health is unclear.

**Photo courtesy of the Minnesota Pollution Control Agency and Department of Natural Resources**
SURFACE WATER STUDY

- Sampled downstream of urban areas, intense livestock areas, wastewater systems
- Sampled for 95 CEC
- 139 streams, 30 states
- 82 of 95 detected
- 80% of samples were contaminated

- Nanograms/liter
- 1 part per trillion
- 1 ng/l analogy – 1 oz. in 7.5 billion gallons of water
Organic Contaminants in US Surface Waters

Kolpin et al. 2002
TAP WATER EVALUATION

- 19 utilities serving 138 million people
- 2006-07
- Sampled for 55 chemicals – found 11 most frequently at levels <10 ng/L
- Atrazine found ~40-50 ng/L
SURVEY OF 19 US DRINKING WATER UTILITIES

Top 11 of 55 compounds
Median concentrations generally <10 ng/L

- Atenolol - betablocker
- Atrazine - herbicide
- Carbamazepine - anticonvulsant
- Estrone - hormone
- Gemfibrozil – antilipidemic
- Meprobamate – antianxiety
- Naproxen – anti-inflammatory
- Phenytoin – anticonvulsant
- Sulfamethoxazole - antibiotic
- TCEP - flame retardant
- Trimethoprim - antibiotic

Benotti et al. ES&T 2009
2007 study in an experimental lake in NW Ontario

Added 5 - 6 ng per trillion liters of water of a synthetic estrogen (similar to birth control pills)
- the equivalent of a few grains of sand in an Olympic size swimming pool

Found minnow populations began to collapse after prolonged exposure

Persistent discharge of even small concentrations could decimate wild fish populations
CECS AND WASTEWATER TREATMENT

- CECs are transported via human waste into treatment systems creating a mechanism for concentration and dispersal into the environment.

Photos courtesy of the Minnesota Pollution Control Agency

Wastewater Treatment Plants

On-site Sewage Treatment

**Photos courtesy of the Minnesota Pollution Control Agency**
WHY IS THE MINNESOTA DEPARTMENT OF TRANSPORTATION (MNDOT) INTERESTED IN CECS?

- MNDOT owns ~60 rest areas across Minnesota with flows from 1,000 – 5,000 gpd
- These rest areas septic system serve a very broad user population
- The likelihood for a wide range of pharmaceuticals is likely due to the predominance of toilet flushing
  - Overall concentrations for any one given pharmaceuticals may be lower that a single family home due to dilution by other users
- MnDOT has concerns about land application of septage from these facilities
SITE SUMMARIES

- All sites were Safety Rest Areas (SRA) or park visitor centers except for Milaca which was a domestic septage land application site.
SITE LOCATIONS AND TREATMENT DESCRIPTIONS

- **Dresbach**
  - Siphon distribution with an engineered soil bed

- **Grand Portage**
  - Pressurized mound with secondary treatment unit

- **Marion**
  - Pressurized distribution with an engineered subsurface soil bed

- **Milaca**
  - Land application site; domestic septage

- **Rum River**
  - Pressurized mound with secondary treatment unit

- **Tettegouche**
  - Below-grade pressurized trenches
Contaminant of Emerging Concern (CEC)
<table>
<thead>
<tr>
<th>Site</th>
<th>Description</th>
<th>Septic Tank Size (gal)</th>
<th>Average Daily Flow (gal/day)</th>
<th>USDA Soil Texture</th>
<th>Groundwater Separation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dresbach</td>
<td>Siphon distribution with an engineered soil bed</td>
<td>7,363</td>
<td>3,813</td>
<td>Sandy loam</td>
<td>3.0</td>
</tr>
<tr>
<td>Grand Portage</td>
<td>Pressurized mound with secondary treatment unit</td>
<td>5,341</td>
<td>1,000</td>
<td>Sandy loam</td>
<td>3.17</td>
</tr>
<tr>
<td>Marion</td>
<td>Pressurized distribution with an engineered soil bed</td>
<td>12,653</td>
<td>2,000</td>
<td>Loam</td>
<td>3.0</td>
</tr>
<tr>
<td>Milaca</td>
<td>Land application site; septage</td>
<td>NA</td>
<td>NA</td>
<td>Loam / Silty loam</td>
<td>NA</td>
</tr>
<tr>
<td>Rum River</td>
<td>Pressurized mound with secondary treatment unit</td>
<td>5,470</td>
<td>1,303</td>
<td>Silt loam</td>
<td>3.0</td>
</tr>
<tr>
<td>Tettegouche</td>
<td>Below-grade pressurized trenches</td>
<td>10,000</td>
<td>2,165</td>
<td>Loamy sand</td>
<td>1.5</td>
</tr>
</tbody>
</table>
SITE EXAMPLES

Marion drainfield

Grand Portage ATU and mound
Aerates effluent sewage water to facilitate treatment in aerobic conditions

Only Rum River was sampled directly from its STU and septic tank

- Rum River used an Advantex system
- Grand Portage has an aerobic treatment unit
LAND APPLICATION OF DOMESTIC SEPTAGE

• Domestic septage is either the liquid or solid material removed from a septic tank, cesspool, portable toilet, or similar source.
METHODS: SAMPLING AND DATA COLLECTION

Soil sample location

Monitoring well

Septic effluent drain field

Soil sample location

Monitoring well
METHODS: DATA ANALYSIS

Measurements

- Occurrence of CECs within sample size
- CEC concentration

Sources

- Septic tank
- Secondary treatment unit
- Septage
- Soil
- Groundwater

Categories

- Antibiotics
- Chronic disease prescription
- Veterinary medicine
- Stimulant
- Hormone
- Antihistamine
- Pain and fever relief
STUDY LIMITATIONS

- Variable locations and small sample sizes
- Many CECs sampled (n = 58)
- Lab splits CECs in lists based on analytical techniques
- List 1 and 3 chosen based on toilets being the primary source and funding

<table>
<thead>
<tr>
<th>Source Groups</th>
<th>Dresbach</th>
<th>Grand Portage</th>
<th>Marion</th>
<th>Milaca</th>
<th>Rum River</th>
<th>Tettegouche</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sewage</strong></td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>16</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td><strong>Soil</strong></td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>12</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Groundwater</strong></td>
<td>3</td>
<td>2</td>
<td>2</td>
<td>8</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Characteristics</td>
<td>Soil Type</td>
<td>Groundwater separation (ft)</td>
<td>Number of Individual CECs Detected</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
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<td>-----------------------------</td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>List 1 (n = 46) List 3 (n = 12) Antibiotic (n = 29) Antihistamine (n = 1) Chronic disease prescriptions (n = 10) Hormone (n = 3) Pain and fever relief (n = 4) Plasticizer (n = 1) Stimulant (n = 2) Veterinary medicine (n = 7)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Site</td>
<td></td>
<td></td>
<td>Sewage Soil Groundwater Sewage Soil Groundwater Sewage Soil Groundwater Sewage Soil Groundwater Sewage Soil Groundwater</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dresbach (SRS)</td>
<td>Sandy loam</td>
<td>3</td>
<td>43 22 27 2 17 2 12 0 5 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grand Portage (SRS)</td>
<td>Sandy loam</td>
<td>3.17</td>
<td>47 21 23 3 22 3 10 0 6 1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marion (SRS)</td>
<td>Loam</td>
<td>0.33</td>
<td>67 38 39 4 34 4 16 0 8 0</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Milaca (SPTG)</td>
<td>Loam/Silty loam</td>
<td>NA</td>
<td>199 109 126 16 54 10 64 3 32 3</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Scum River (SRS)</td>
<td>Silt loam</td>
<td>3.0</td>
<td>120 69 60 8 64 8 31 0 16 2</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>St. Croix (SRS)</td>
<td>Loamy sand</td>
<td>1.42</td>
<td>66 32 37 4 27 4 16 0 8 2</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

Compared to septic and septage:
- Groundwater had fewer occurrences but similar concentrations
- Soil had few occurrences and low concentration

CEC Concentrations across Sample Sources

- Septic Tank
- STU
- Septage
- Soil
- Groundwater
In order to show the trends over time a subset of the full dataset has been selected.

This new dataset only includes CECs from list 3.

Other parameters will be adjusted and explained for each respective comparison.

<table>
<thead>
<tr>
<th>List 3 Compounds</th>
<th>Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triclocarban</td>
<td>Antibiotic</td>
</tr>
<tr>
<td>Triclosan</td>
<td>Antibiotic</td>
</tr>
<tr>
<td>Furosemide</td>
<td>Chronic Disease Prescriptions</td>
</tr>
<tr>
<td>Gemfibrozil</td>
<td>Chronic Disease Prescriptions</td>
</tr>
<tr>
<td>Glipizide</td>
<td>Chronic Disease Prescriptions</td>
</tr>
<tr>
<td>Glyburide</td>
<td>Chronic Disease Prescriptions</td>
</tr>
<tr>
<td>Hydrochlorothiazide</td>
<td>Chronic Disease Prescriptions</td>
</tr>
<tr>
<td>Warfarin</td>
<td>Chronic Disease Prescriptions</td>
</tr>
<tr>
<td>2-Hydroxy-ibuprofen</td>
<td>Pain and fever relief</td>
</tr>
<tr>
<td>Ibuprofen</td>
<td>Pain and fever relief</td>
</tr>
<tr>
<td>Naproxen</td>
<td>Pain and fever relief</td>
</tr>
<tr>
<td>Bisphenol A</td>
<td>Plasticizer</td>
</tr>
</tbody>
</table>
Graph shows dataset for septic tanks and their secondary treatment unit (STU) samples only.

- STU concentrations tended to be lower than the waste source and have a larger range.
- Many more CECs were detected in septic samples than in STUs

For this example, detection occurrences are:
- Septic (n = 136)
- STU (n = 46)
Graph shows dataset for septic tanks and septage samples only.

- Septic concentrations tended to be higher than septage.
- A similar number of CECs were detected in septage samples than septic but more individual CECs were detected in septage.

For this example, detection occurrences are:
- Septic (n = 136)
- Septage (n = 109)
Graph shows dataset for septic tanks and their soil samples only.

- Soil concentrations tended to be far lower than the waste source.

- Very few CECs were detected in soils.

For this example, detection occurrences are:
- Septic (n = 136)
- Soil (n = 15)
Graph shows dataset for septic tanks and their groundwater samples only.

- Groundwater concentrations tended to be lower than the waste source and have a larger range.
- Many more CECs were detected in septic samples than in groundwater.

For this example, detection occurrences are:
- Septic (n = 136)
- Groundwater (n = 61)
**RESULTS**

**Categorical groups:**
- Followed similar trends in concentration and occurrence between sources
- Concentration ranges between categorical groups similar between sources

- Antihistamine had many relative occurrence ($n = 1$) with high concentrations
- Stimulants, like caffeine, were among the most common and most concentrated
- Plasticizer was only found in septage
- Hormones were found at low concentrations but they are designed to function at low concentrations
STUDY CONCLUSION

Break down
- On site wastewater treatment systems were able to degrade CECs, especially within the drain field soil

Transport
- If CECs were not degraded in treatment, they were hydraulically transported into groundwater at concentrations similar to their waste source.
FUTURE RESEARCH

This study laid the foundation for new research questions to be explored

Potential research options:

- Specific CECs
- Sampling of multiple on-site treatment systems of the same type
- Effects of soil type and hydric soil prevalence
- Breakdown of CECs within a system at controlled effluent water discharge rates
- Distance of hydraulic transport potential
- And more!
RELATED RESEARCH
Chloride concentrations in five MnDOT rest area septic tanks ranged from 408-1730 mg/L.

On average, water softening salt was estimated to contribute over 80% of the chloride in the rest area septic systems.
To protect aquatic life, the EPA set a chronic water quality standard for chloride at 230 mg/L. This is equivalent to 1 teaspoon salt in 5 gallons water.

Sodium concentrations greater than 3,500 mg/L have been reported to inhibit anaerobic digestion.

Chloride concentrations greater than 180 mg/L have an inhibitory effect upon nitrifying microorganisms.

Chloride concentration in regenerate can reach into the 10,000 mg/L range, with sodium in the 6,000 mg/L range.
### MINNESOTA DEPARTMENT OF NATURAL RESOURCES – CAMPGROUND DATA – SCENIC STATE PARK

<table>
<thead>
<tr>
<th>Site/Sampling Location</th>
<th>TKN</th>
<th>BOD5</th>
<th>TSS</th>
<th>Phosphorous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Campground Scenic – Raw Dump Station</td>
<td>769</td>
<td>1280</td>
<td>230</td>
<td>56.4</td>
</tr>
<tr>
<td>Campground Scenic - Raw Shower House</td>
<td>135</td>
<td>195</td>
<td>74</td>
<td>17.8</td>
</tr>
</tbody>
</table>
## MINNESOTA DEPARTMENT OF NATURAL RESOURCES – CAMPGROUND DATA – VERMILLION STATE PARK

<table>
<thead>
<tr>
<th>Sampling Location</th>
<th>TKN</th>
<th>NO3-</th>
<th>BOD5</th>
<th>TSS</th>
<th>Phosphorous</th>
<th>Fecal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septic Tank Effluent Dump Station</td>
<td>757</td>
<td>1530</td>
<td>92</td>
<td></td>
<td>85.5</td>
<td></td>
</tr>
<tr>
<td>Nibbler Effluent Dump Station</td>
<td>154</td>
<td>119</td>
<td>ND</td>
<td>15</td>
<td>32.3</td>
<td>74</td>
</tr>
</tbody>
</table>
MORE INFORMATION

READ THE PAPER IN THE PROCEEDINGS

SEE OUR WEBSITE AT: SEPTIC.UMN.EDU/RESEARCH

SHEGER@UMN.EDU