To strengthen and promote the onsite and decentralized wastewater industry.

Troubleshooting Changing Water Flows

Dr. Sara Heger
sheger@umn.edu
http://septic.umn.edu
Presentation overview

- Research on changes in flow
- Related challenges for septic system
- Hydraulic versus organic loading
2016 Residential End Uses of Water

William B. DeOreo, Peter Mayer, Benedykt Dziegielewski, Jack Kiefer
Study objectives

• Collect and analyze current data on the indoor end uses of water in single-family residential settings across North America
• Evaluate changes in water use patterns over a 15-year period (compared to Mayer, et al, 1999)
• Identify variations in water used by each fixture or appliance
• Evaluate conservation potential
• Determine the factors influencing residential water use and evaluate their relative impact
Location of end use study sites
Study methods

• Random representative selection of single-family customers consumption
  • highly detailed information on water use
  • demographics
  • attitudes
  • physical nature of the houses and landscapes

• Data collected from 2010 through 2013 from 23 utilities
  • billing data with surveys ~ 2,000 homes
  • end use monitoring 762 homes
  • hot water use 94 homes
Magnetic sensor to the side of the water meter
Data loggers provide high resolution flow trace from meter Brainard Meter Master 100 EL
The sensor picks up the motion of the internal magnets in the meters.
The secret is in the flow profiles and Trace Wizard analysis tool.

Volume: 4.92 gallons per flush
Peak Flow: 5.56 gpm
Duration: 1 minute 20 seconds
Mode flow, start time, end time and other similar events are also listed.
Typical bathroom sequence: shower, toilet, faucet

A shower is followed by a toilet flush (with a bit of leakage) and a faucet use.

This is a very typical combination.
Typical household

- 1999
  - 177 gphd
- 2016
  - 138 gphd

22% DECREASE 1999-2016

Figure 4. Average daily indoor per household water use REU1999 and REU2016
Typical per capita

- **1999**
  - 69 gpcd
- **2016**
  - 59 gpcd

15% decrease per capita daily water use 1999 to 2016
Clothes washers from 1999 to 2016

- The biggest reduction - clothes washer category fell by 36%, from 15.0 → 9.6 gpcd
- 2% survey respondents reported having a high efficiency clothes washer → 67%
- Average of 41 to 31 gallons per load
- Average number of loads washed per day and per person per day has remained the same between the two studies
Toilet flushing from 1999 to 2016

• Toilet use fell by 23.2% from 18.5 to 14.2 gpcd
• 8.5% of the homes had an average toilet flush volume of less than 2.0 gal/flush → 37% in 2016
• Average toilet flush volume decreased from 3.65 gal/flush to 2.6 gal/flush
• Flushing frequency was unchanged at 5.0 flushes per person per day
Leaks

• About 5% of the study homes had no leakage at all during the data collection period
• 63% of the homes leaked some amount, but less than 10 gphd
• The other 32% of homes had higher leakage rates, as high as 600 gphd
Indoor water use as a percent of total volume
Distribution of indoor per capita use
Non-linear use per person

\[ y = -21.9 \ln(x) + 76.416 \]

\[ R^2 = 0.9408 \]
Key Findings

• 66.8% cold water
• 33.2% hot water
• Reductions in use are largely due to more efficient fixtures and appliances
  • Not the result of changes in either occupancy or behavior
• Significant reductions in off-the-shelf new homes
• Best reductions seen in high efficiency homes (retrofit homes and high efficiency new homes)
• This trend will continue into the future and should be used for future planning
CHALLENGES FOR SEPTIC SYSTEMS
System Sizing and Septic Impact

Septic are designed for peak flow and maximum capacity

- Annual estimates of actual use
  - Per person per year = 27,000 gal
  - Typical home ~ 3 persons = 58,000 gal/yr
  - 250 homes in a township = 14.5 million gallons/year

- Septic codes assume 2 people per bedroom

- Must account for mass loading which remains unchanged

  Peak Flow = Safety Factor
Loading Rates - The Thought Process

• For long term performance we chose a loading rate based on the soil characteristics to assure we will have:
  • Acceptance
  • Treatment

• Key variables
  • Pore size
  • Surface area
  • Oxygen availability
Biomat Influences

- **System: Food**
  - Hydraulic loading
  - Organic loading

- **Site: Oxygen**
  - Soil type – Texture and Structure
  - Separation
  - Depth
  - Resting and dosing
  - Geometry [Width]
ALL SYSTEMS HAVE TWO LOADING RATES

#1 Hydraulic
#2 Organic
HYDRAULIC FLOW
Wastewater Loading

• Wastewater quantity
  • Hydraulic loading
  • Residential Design/Peak values are 100-200 gallons per bedroom
  • Typically residential average values are less then 1/2 of Peak
• Commercial facilities are very different
Importance of hydraulic load

• The daily flow must not exceed the system’s hydraulic capability
  • Hydraulic detention time (HDT)
    • Example: solids are not able to settle in a septic tank if the water moves through too quickly.
  • Hydraulic overload of the soil
    • Effluent surfacing
    • Reduces in water use WILL increase retention times
Too much use

- Clean water
  - Groundwater drainage
    - Footing drain
  - Treated water
  - Water conditioning backwash

- Too much use
  - Over use
  - Wash day
  - Cleaning service
  - Change in use
    - In home business
    - Added water using devices
Infiltrative surface

• Sized by the loading rate in gpd/ft$^2$
• Loading rate determined by
  • Natural soil properties
  • Separation distance
  • Natural site conditions
ORGANIC LOADING
# Domestic effluent constituent concentrations

<table>
<thead>
<tr>
<th>Source</th>
<th>Oxygen Demand BOD$_5$, (mg/L)</th>
<th>Total Suspended Solids, TSS (mg/L)</th>
<th>Nitrogen Total N (mg/L)</th>
<th>Fecal Coliform (org. /100 mL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Septic Tank</td>
<td>140-200</td>
<td>50-100</td>
<td>40-100</td>
<td>$10^6$-$10^8$</td>
</tr>
<tr>
<td>Aerobic Treatment Unit</td>
<td>5-50</td>
<td>5-100</td>
<td>25-60</td>
<td>$10^3$-$10^4$</td>
</tr>
<tr>
<td>Sand Filter</td>
<td>2-15</td>
<td>5-20</td>
<td>10-50</td>
<td>$10^1$-$10^3$</td>
</tr>
<tr>
<td>Foam or Textile Filter</td>
<td>5-15</td>
<td>5-10</td>
<td>30-60</td>
<td>$10^1$-$10^3$</td>
</tr>
</tbody>
</table>
Commercial wastewater

• **Strength**
  • Usually greater than residential

• **Operation based**
  • Food preparation
  • Restrooms
  • Laundry
High Strength Wastewater

• National glossary definition
• Effluent from a septic tank or other pretreatment component that has:
  • BOD5 > 170 mg/L,
  • and/or TSS > 60 mg/L,
  • and/or (FOG) > 25 mg/L and is applied to an infiltrative surface

• Nitrogen - concentrations are on the rise
2009 Influent Constituent Characteristics of the Modern Waste Stream from Single Sources

Kathryn S. Lowe, Maria B. Tucholke, Jill M.B. Tomaras, Kathleen Conn, Christiane Hoppe, Jörg E. Drewes, John E. McCray, Junko Munakata-Marr
BOD in raw and septic tank effluent (STE)

Median STE: 216 mg/L
Total nitrogen in raw and septic tank effluent

Median 60 mg/L
Restaurant data

• 28 restaurants located in Texas
• Sampled during June, July, and August 2002
• 12 samples per restaurant and 336 total observations
Geometric mean plus one std. dev.

Lesikar et. al (2006)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD$_5$</td>
<td>1523</td>
</tr>
<tr>
<td>TSS</td>
<td>664</td>
</tr>
<tr>
<td>FOG</td>
<td>197</td>
</tr>
</tbody>
</table>
MASS LOADING
Mass loading

• Calculate mass loading to a system
  • Concentration of constituent in the wastewater
  • Mass loading based on number of people

• Mass (lb) = C (mg/l) x Q (gpd) x 0.00000834

• Mass (lb) = P (# of people) x OL (lbs per capita- day)
Mass loading residential vs commercial

\[ \text{Mass (lb)} = C \ (\text{mg/l}) \times Q \ (\text{gpd}) \times 0.00000834 \]

**Residential**

- Mass (lb) = 140 mg/l  x 200 gpd x 0.00000834
- Mass (lb) = 0.23 lbs per day

**Commercial strength**

- Mass (lb) = 500(mg/l) x 600(gpd) x 0.00000834
- Mass (lb) = 2.5 lbs per day
Mass loading per person

• Calculate mass loading to a system
  • Number of people
  • Organic loading rate

• Mass (lb) = P (# of people) x OL (lbs per capita-day)

• Mass (lb) = 5 (# of people) x 0.17 lbs per capita-day

• Mass (lb) = 0.85 lbs per day
Comparative biological loads (BOD$_5$)

<table>
<thead>
<tr>
<th>Waste Source</th>
<th>Pounds per Day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Home (3 Bdrm)</td>
<td>0.6</td>
</tr>
<tr>
<td>Restaurant</td>
<td>13.67</td>
</tr>
<tr>
<td>Supermarket</td>
<td>32.1</td>
</tr>
<tr>
<td>Large Restaurant</td>
<td>44.4</td>
</tr>
</tbody>
</table>

Credit: Bill Stuth
Water saving devices

• Decrease water quantity
• Assuming no change in mass load
• Wastewater strength increases
Water saving device example

• A 4 person household produces 0.56 lbs/day TSS without water saving devices (75 gpd/person)
• Then that family switches to water savings devices, and so they only use 60 gpd/person
• What is the change in TSS concentration after water saving devices are installed?
Example cont.

TSS Concentration (before)

\[
\frac{0.56 \text{ lbs/day}}{300 \text{ gal} \times 0.00000834 \text{ L}} = 224 \text{ mg}
\]

TSS Concentration (after)

\[
\frac{0.56 \text{ lbs/day}}{240 \text{ gal} \times 0.00000834 \text{ L}} = 280 \text{ mg}
\]
Residential soil treatment area

• Soil absorption area based on hydraulic loading
  • \( A = \frac{Q}{\text{Loading Rate (soil hydraulic)}} \)

• Soil absorption area based on organic loading
  • \( A = \frac{\text{organic loading/loading rate (soil organic)}} \)
## Organic loading to soil (MN Values)

<table>
<thead>
<tr>
<th>Soil Texture Group</th>
<th>Loading Rate gpd/ft²</th>
<th>lbs of BOD₅/ft²/day</th>
<th>lbs of TSS/ft²/day</th>
<th>lbs of O&amp;G/ft²/day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sands</td>
<td>1.2</td>
<td>0.0017</td>
<td>0.00065</td>
<td>0.00025</td>
</tr>
<tr>
<td>Fine sands</td>
<td>0.6</td>
<td>0.00087</td>
<td>0.00033</td>
<td>0.00013</td>
</tr>
<tr>
<td>Sandy loam</td>
<td>0.78</td>
<td>0.0011</td>
<td>0.00042</td>
<td>0.00016</td>
</tr>
<tr>
<td>Loam</td>
<td>0.6</td>
<td>0.0007</td>
<td>0.00027</td>
<td>0.0001</td>
</tr>
<tr>
<td>Silt loam</td>
<td>0.5</td>
<td>0.0006</td>
<td>0.00024</td>
<td>0.00009</td>
</tr>
<tr>
<td>Clay loam, clay</td>
<td>0.45</td>
<td>0.00035</td>
<td>0.00013</td>
<td>0.00005</td>
</tr>
</tbody>
</table>
Calculating soil mass loading rate

• 200 (GPD) X 140 (BOD5) X 0.00000834
  = 0.23 pounds/day

For Soil Loading

0.23 / absorption area square feet = lb/day/square foot
Drainfield area requirements

Example: Size a soil trench system in silt loam soils for a system that is treating 400 gpd with BOD5 effluent from septic tank of 400 mg/L

• Based on hydraulic loading
  \[ Ra = 0.50 \text{ gal/ft}^2\text{-day} \]
  \[ \text{Drainfield} = \frac{400 \text{ gal/day}}{0.50 \text{ gal/ft}^2\text{-day}} = 800 \text{ ft}^2 \]

• Based on organic loading
  \[ \text{ROL} = 0.0006 \text{ lbs/ft}^2\text{-day} \]
  \[ \text{BOD5 lbs/d} = 400 \text{ mg/L} \times 400 \text{ gal/d} \times 0.00000834 = 1.33 \text{ lbs/d} \]
  \[ \text{Drainfield} = \frac{1.33 \text{ lbs/day}}{0.0006 \text{ lbs/ft}^2\text{-day}} = 2217 \text{ ft}^2 \]
Domestic versus commercial example

WASTE STRENGTH
RESIDENTIAL STRENGTH

Hydraulic and Organic Effects On The System

Pounds of BOD = FLOW \times WASTE STRENGTH \times \frac{8.34}{1,000,000}
Site constraints

FILL SPACE

Home or Restaurant?

60x100 Area Available for Drain Field

TANKS AND GARDEN
Domestic vs commercial example

RESIDENTIAL DOMESTIC STRENGTH

600 GPD x 170 mg/L BOD X 8.34 /1,000,000

= 0.9 lbs of BOD/Day
Domestic vs commercial example

COMMERCIAL HIGH STRENGTH
600 GPD x 1200 mg/L BOD x 8.34 / 1,000,000
= 6 lbs of BOD/Day
## Drainfield Sizing

### Residential Strength Waste
- **4 bedroom home** = 600 gpd
- **Sandy Loam** = 0.4 g/ft²
- **Residential BOD** = 170 mg/L
- **LBS of BOD/Day** = 0.9 #of BOD
- **Area Needed** = 1500 ft²
- **# of BOD/ft²** = 0.00073

### High Strength Waste
- **RESTAURANT** = 600 gpd
- **Sandy Loam** = 0.4 g/ft²
- **High Strength BOD** = 1200 mg/L
- **LBS of BOD/Day** = 6 #of BOD
- **Area Needed** = 8220 ft²
- **# of BOD/ft²** = 0.00073

---

**SIZING DRAINFIELDS FOR ORGANIC LOADS**
60x60 4 bed room Home

60x100 Area Available for Drain Field

1500 ft²

TANKS AND GARDEN
600 GPD
RESTAURANT

FILL SPACE

8200 ft²

TANKS AND GARDEN
## Drainfield sizing

<table>
<thead>
<tr>
<th></th>
<th>Residential Strength Waste</th>
<th>High Strength Waste</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4 bedroom home= 600gpd</td>
<td>RESTAURANT= 600gpd</td>
</tr>
<tr>
<td>Sandy Loam=</td>
<td>.4 g/ft2</td>
<td>Sandy Loam= .4 g/ft2</td>
</tr>
<tr>
<td>Residential BOD=</td>
<td>170 mg/L</td>
<td>High Strength BOD= 880mg/L</td>
</tr>
<tr>
<td>LBS of BOD/Day=</td>
<td>0.9 #of BOD</td>
<td>LBS of BOD/Day= 4.4 #of BOD</td>
</tr>
<tr>
<td>Area Needed=</td>
<td>1500 ft2</td>
<td>Area Needed= 6000 ft2</td>
</tr>
<tr>
<td># of BOD/ft2=</td>
<td>.00073</td>
<td># of BOD/ft2= .00073</td>
</tr>
</tbody>
</table>

**SIZING DRAINFIELDS FOR ORGANIC LOADS**
WHAT IS MISSING???

600 GPD RESTAURANT

6000 ft²

FILL SPACE

TANKS AND GARDEN
The future

• Flow volumes will continue to reduce
• 110 gphd and 36.7 gpcd in the coming years
  • < 110 gphd can be expected as high-efficiency fixtures and appliances are widely installed
• Concentrations will rise
• Organic versus hydraulic loading will become more important even in residential design
To strengthen and promote the onsite and decentralized wastewater industry.

Questions & more information

septic.umn.edu
sheger@umn.edu