Onsite Wastewater Treatment Technologies
CIDWT/University Disclaimer

These materials are the collective effort of individuals from academic, regulatory, and private sectors of the onsite/decentralized wastewater industry. These materials have been peer-reviewed and represent the current state of knowledge/science in this field. They were developed through a series of writing and review meetings with the goal of formulating a consensus on the materials presented. These materials do not necessarily reflect the views and policies of North Carolina State University, and/or the Consortium of Institutes for Decentralized Wastewater Treatment (CIDWT). The mention of trade names or commercial products does not constitute an endorsement or recommendation for use from these individuals or entities, nor does it constitute criticism for similar ones not mentioned.
Why are OWTS used?

- Treat and disperse wastewater where sewers are not available or desirable
- They fit nicely into the hydrologic cycle
Typical System

Source

Reserve area

Pretreatment

Final treatment & dispersal

B. Lenning, 2003
Treatment Processes

- Variety of physical, chemical and biological processes:
  - Filtration
  - Sedimentation
  - Aeration
  - Flotation
  - Inactivation
  - Adsorption
  - Ion-exchange
  - Anaerobic
  - Predation
  - Disinfection
## Treatment Processes

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Removal Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspended solids</td>
<td>Sedimentation, filtration</td>
</tr>
<tr>
<td>Organic material (BOD$_5$)</td>
<td>Aerobic/anaerobic, sedimentation, filtration</td>
</tr>
<tr>
<td>Pathogens</td>
<td>Filtration, predation, inactivation, disinfection</td>
</tr>
<tr>
<td>Nitrogen</td>
<td>Nitrification-denitrification, ion-exchange</td>
</tr>
<tr>
<td>Phosphorous</td>
<td>Adsorption in soil, physical-chemical, filtration, anoxic-aerobic</td>
</tr>
</tbody>
</table>

Adapted from USEPA, 2002
Wastewater Segregation

- Remove certain constituents from wastewater
  - Nitrogen or phosphorus
  - Fats, oils, and grease
- May simplify reuse of greywater
Wastewater Segregation

- Combined system – FOG removal

[Diagram showing a combined system with Grease Interceptor and Septic Tank]
Wastewater Segregation

- Separated systems – reduced N, P loads
  - incinerating toilets
  - composting toilets
Wastewater Segregation

Greywater systems
- Handle through regular components
- May be reduced size
- Normal site requirements applicable

Reuse
- Typically for toilet flushing and subsurface irrigation
- Disinfection is often required
- Proper operation, monitoring & maintenance needed
Conventional Septic Tank System

- Geotextile fabric
- Sand/loam soil
- Perforated pipe for effluent disposal
- Soil absorption field
- Two-compartment septic tank
Typical Septic System

- House
- basement
- septic tank
- effluent baffle
- trenches
- evapotranspiration
- soil absorption
- treatment
- ground water
- streams, lakes
- well
Tank Functions

- Solids removal by settling & floatation
  - 60-80% solids removal
- Anaerobic digestion
  - Gases produced (CO$_2$, CH$_4$, H$_2$S, etc.) vented back through building sewer and plumbing vents
- Storage of solids
  - Not all solids are biodegradable
SEPTIC TANKS

- Essential for small-scale wastewater management
  - Single or multi-chambered
  - Watertight vault
  - Model of simplicity, energy-free
  - Gravitational settling device
  - Provides relatively quiescent conditions, allows suspended solids to settle and floatables to rise to surface
  - Provides space for very complex physical, chemical and biological processes
  - Accomplishes approximately 50% of ultimate treatment
SEPTIC TANKS

Sizing - residential

- Directly related to number of bedrooms in residence

Common septic tank volumes

- One or two bedrooms: 1000 gal.
- Three bedrooms: 1500 gal.
- Four bedrooms: 2000 gal.
SEPTIC TANKS

- Sizing - non-residential systems
- Based upon expected daily flow from commercial, institutional, and recreational facilities.

<table>
<thead>
<tr>
<th>Facility</th>
<th>Unit</th>
<th>Flow, gallon/unit/day</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Range</td>
<td>Typical</td>
</tr>
<tr>
<td>Airport</td>
<td>Passenger</td>
<td>2-4</td>
</tr>
<tr>
<td>Apartment house</td>
<td>Person</td>
<td>40-80</td>
</tr>
<tr>
<td>Automobile service station</td>
<td>Vehicle served</td>
<td>8-15</td>
</tr>
<tr>
<td></td>
<td>Employee</td>
<td>9-15</td>
</tr>
<tr>
<td>Bar</td>
<td>Customer</td>
<td>1-5</td>
</tr>
<tr>
<td></td>
<td>Employee</td>
<td>10-16</td>
</tr>
<tr>
<td>Boarding house</td>
<td>Person</td>
<td>25-60</td>
</tr>
<tr>
<td>Department store</td>
<td>Toilet room</td>
<td>400-600</td>
</tr>
<tr>
<td></td>
<td>Employee</td>
<td>8-15</td>
</tr>
<tr>
<td>Hotel</td>
<td>Guest</td>
<td>40-60</td>
</tr>
<tr>
<td></td>
<td>Employee</td>
<td>8-13</td>
</tr>
<tr>
<td>Industrial building (sanitary waste only)</td>
<td>Employee</td>
<td>7-16</td>
</tr>
</tbody>
</table>
Tank Sizing

- Generally prescribed by the permitting agency for individual homes based on home size
- Criteria: Hydraulic retention time plus solids storage
  - 1 to 2 days detention of design flow
  - Add solids storage volume equal to $\frac{1}{3} - \frac{1}{2}$ of the volume for hydraulic retention
Septic Tank Sizing Example

- Consider a 3-bedroom home
- Design flow: 3 br, 2 people/br, 75 gpd/person
  - Flow = 3 x 2 x 75 gpd = 450 gpd
  - Provide for 2 day retention → 2 x 450 = 900 gal
- Add solids storage
  - 1/3 of the above = 1/3 x 900 = 300 gal
- Total tank volume = 900 + 300 = 1200 gal
- This is the minimum recommended tank size
- The tank should have two compartments
- Many regulatory agencies now require 1500 gal tank for a 3-br home, but sizing starts with a procedure like this.
Section view of single compartment concrete tank, 1,000 gal
TYPICAL RIBBED FIBERGLASS SEPTIC TANKS

Section view of single compartment tank, 1,500 gal
Septic Tanks
Septic Tank Performance

- Results are comparable with most municipal primary wastewater treatment plants

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Average Raw Sewage Influent</th>
<th>Average Septic Tank Effluent</th>
<th>% Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>BOD mg/L</td>
<td>308</td>
<td>122</td>
<td>60</td>
</tr>
<tr>
<td>Total Suspended Solids</td>
<td>316</td>
<td>72</td>
<td>77</td>
</tr>
<tr>
<td>mg/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grease mg/L</td>
<td>102</td>
<td>21</td>
<td>79</td>
</tr>
</tbody>
</table>
Septic Tank Solids Accumulation

- Need to estimate the rate of septage (sludge + scum) accumulation
- Determines pump out intervals
- Empirical relationships show (sludge + scum) accumulation in gal / capita / year
Septic Tank Sludge Accumulation

\[ \text{gpc} = \text{gallon per capita} \]
Factors to consider:
- tank volume
- clear zone
- number of occupants

Pump out interval varies (1,000 gal tank single family)
- EPA - 3 to 5 years
- Bounds - 7 to 11 years

Buoyancy in areas of high groundwater may cause problems during pumping
- add soil or concrete over tank
- horizontal flanges on tank
- anchor straps
Oil and Grease

- Septic tank may retain most oil and grease from normal household wastewater.
- Oil, liquid and grease solids very troublesome if effluent is to receive additional treatment by media filters.
- Restaurants and other such facilities must have a grease interceptor (trap).
Double-compartment Grease Trap
Adapted from US EPA Design Manual 1980
TRACE ORGANICS

- May gain entrance from household activities
- Paint thinners, grease removers, rug shampoo liquids, etc.
- Chemicals in solution that are nonbiodegradable
- Little or no removal in septic tank
Septage

- Highly variable odoriferous (stinky!) material in septic tank requiring periodic removal
  - Solids content 3 to 10%
  - Land application
    - Spreading by hauler truck or farm equipment
    - Spray irrigation
    - Ridge and furrow
    - Subsurface incorporation
  - Disposal at wastewater treatment plant
    - Upstream manhole
    - Treatment headworks
    - Special sludge handling process
    - Special septage handling and treatment plant
State and local health departments promulgate and enforce laws.

Early codes relied on soil percolation test.

Regulations became standardized in spite of differing climate and soil conditions.
- Led to prescriptive designs.

By late 1970s there was a gradual increase in sizes of septic tanks and drainfields.

Present emphasis
- system performance
- pollutant transport fate
- environmental impacts
Final Treatment & Dispersal Options

Purpose
- Provide further treatment
- Assimilate treated effluent into the receiving environment in such a way that neither public health nor environmental quality are adversely impacted.

Subsurface dispersal
- in ground – drainfield
- in ground – mound system

Atmospheric dispersal

Surface dispersal

Aerobic treatment
Subsurface Dispersal

- Discharge effluent into the soil
- Most cases – original, undisturbed, unsaturated soil
  - Typical minimum vertical distance is 18-36 inches measured from point of application into soil to water table, excessively coarse soil, or impermeable soil
- As effluent quality increases, the focus is more on dispersal
- Point of application – top 2-3 feet of soil
Subsurface Dispersal

➢ Usually, reserve/replacement area needed
Subsurface Dispersal

- In ground – drainfield
- Why/Where used?
  - Where soil and site meet code requirements
  - It’s the simplest and least expensive option
Subsurface Dispersal

- In ground – drainfield
  - Infiltrative surface – bottom surface
  - Gravel or gravelless product fills trench/bed
  - Barrier material: geotextile fabric to retain soil
  - Observation ports

![Diagram of subsurface dispersal system](image)
Subsurface Dispersal

- In ground – drainfield

- Design considerations
  - Sized by soil and design flow (gallons/ft$^2$/day)
  - Bottom and/or sidewall
  - Need aerated soil below (unsaturated soil)
  - Long & narrow as possible, follow contours
  - Maximum slopes typically of 20% - 45%

![Diagram of a subsurface dispersal system](image)
Subsurface Dispersal

- In ground – mound system drain field
  - for shallow placement of drain lines
  - Used in areas with high groundwater tables
Subsurface Dispersal

- In ground – mound system drain field
- for shallow placement of drain lines
- Used in areas with high groundwater tables
Final Treatment & Dispersal Options

- Atmospheric dispersal
- Evapotranspiration (ET) system
Surface Dispersal

- Spray irrigation
  - Treatment for pathogens required before spraying
  - Proper nozzle selection is critical
  - Want to minimize aerosols
  - Discharges may be permitted only during night hours
Purpose:
- Effluent must flow from one component to the next
- Effluent must then be distributed or applied to infiltrative surface

Two general options available:
- Gravity-flow
  - Distribution considered to be non-uniform over infiltrative surface
  - Unless properly managed, the biomat may become too restrictive
- Dosed-flow (pump system)
Gravity-flow Distribution

- Parallel distribution
  - Network of equal length laterals
    - Receive flow by gravity
    - Distribute flow by gravity
  - Typically 4-inch pipe
  - Could be improved with a reliable, managed flow-splitting device
Aerobic Treatment Units

- Used when insufficient conditions for traditional subsurface dispersal
  - Insufficient soil depth
  - Insufficient area for dispersal
  - Heavy clay soils
  - High groundwater tables
- Need to maintain a high rate of digestion to provide sufficient treatment
Aerobic Treatment Units

- Wastewater Treatment System
- Disinfection System
- Pump Tank
- Spray Heads