Septic Tank Design, Function and Performance

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Overall Project Objective

WERF project to identify, compile, analyze, and report on the existing body of literature and other data sources addressing the performance of primary treatment units (septic tanks and grease traps) in onsite wastewater systems and the factors impacting their performance

– What is known?
– What is not known?
– What additional research is needed?
Presentation Outline

- Introduction
- Background – History and Current Standards
- Factors Influencing Performance
- Potential Research Needs
- Conclusions
Why? (aren’t septic tanks simple?)

- Primary treatment is often the single most important unit process in onsite treatment systems
  - They are used in virtually all onsite systems
  - They remove > half of all contaminants in raw wastewater
  - Downstream problems are frequently traced back to the performance of the primary unit(s)

- There is wide variability in performance among individual primary treatment units (they are complex)

- There is disagreement about fundamental design and operational considerations

- There is a lot of very diffuse information that needs to be brought together
What are we looking at?

- Septic tank/grease trap process design and performance
  - Sizing, geometry, compartmentation
  - Appurtenances
  - Wastewater source and characteristics
  - Location/climatological factors

- Operation and maintenance
  - Sludge/scum accumulation, pumping
  - Additives
  - Inspection, sampling, troubleshooting

- Tank construction and installation
  - Materials and construction practices
  - Watertightness
  - Installation, abandonment
  - Quality control
Project Products

- Comprehensive white paper
- Bibliographic database which will be delivered as companion piece to the white paper
- Extension service-style communications pieces
  - Policy piece
  - Research piece
  - Technical piece
- User-friendly CD-ROM containing the white paper, the extension-style pieces, the bibliographic database
Modern History of Septic Tanks

- Late 1940s building boom after WWII
- Federal Housing and Home Finance Agency (HHFA) recognized exurban housing trends and had mortgage defaults due to failing septic systems
- In 1946, HHFA initiated studies aimed at developing “a factual basis on which (onsite systems) could be designed, installed and maintained”
  - US Public Health Service (USPHS) Studies (1940s-1950s)
  - UC-Berkeley Sanitary Engineering Research Lab (1950s-1960s)
  - University of Wisconsin SSWMP (1970s-1980s)
- More diffuse study specific to septic tanks since then
Objectives were to:

- Establish the regulatory landscape for septic tanks and grease traps
- Determine the scope of existing regulations
- Assess specifics of existing regulations and their bases
- Identify unique or noteworthy regulations/programs to highlight
## Existing Standards: Industry Standards

<table>
<thead>
<tr>
<th>Organization</th>
<th>Standard Number</th>
<th>Standard Title</th>
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<tbody>
<tr>
<td>ASTM</td>
<td>C890-06</td>
<td>Standard Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures</td>
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<td>ASTM</td>
<td>C1227-05</td>
<td>Standard Specification for Precast Concrete Septic Tanks</td>
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<td>ASTM</td>
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<td>ASTM</td>
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<td>Recommended Procedures for Design, Construction and Installation of Commercial Kitchen Grease Interceptors</td>
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<td>CSA</td>
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<td>Design, Material, and Manufacturing Requirements for Prefabricated Septic Tanks and Sewage Holding Tanks</td>
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<td>NSF/ANSI</td>
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<td>Evaluation of components and devices used in wastewater systems</td>
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<td>ICC</td>
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<td>UL</td>
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<td>CEN</td>
<td>EN 12566, Part 1</td>
<td>Prefabricated Septic Tank</td>
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<tr>
<td>CEN</td>
<td>EN 12566, Part 4</td>
<td>Septic Tanks Built <em>In Situ</em> from Prefabricated Kits</td>
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Summary of Existing Standards

- US PHS studies and the Design Manuals (PHS and EPA) are still the dominant influence on today’s regulations and standards
  - The proportion of onsite systems (new and existing) hasn’t changed significantly since the 40s-50s
  - Water use (dilution) has changed significantly and modern practices have affected sewage characteristics

- There are many redundant, conflicting industry standards, but there appears to be an increasing amount of cooperation and coordination among standards-setting efforts

- Industry standards and regulations are generally conservative and slow to change and stifle innovation
Typical Two-Compartment Tank

courtesy of Texas A&M University
Meander Tanks

- Longitudinal baffle placement increases L:W
- Used in engineered systems, but limited comparative data

Courtesy of Bounds, T.R.
Closed Conduit Laminar Flow Tanks

- Similar to meander tank, but with no headspace
- Being developed by Waterloo Biofilter; limited comparative data is promising

Airspace functionally has been questioned – some believe it is necessary for surge storage and venting while others believe it is unnecessary and contributes to the formation of a nuisance scum layer.

*Courtesy of Waterloo Biofilter (Jowett, 2006)*
UASB-Septic Tanks

- Also called Baffled Anaerobic Reactors
- Enhanced flocculation, solids retention and biological contact by passing wastewater through sludge blanket
- Popular in developing countries in tropical regions
- In cooler climates, gas can be collected and used to heat reactor
Purpose of Septic Tank

- **Treatment**
  - Solids removal (60-80%)
  - BOD removal (50-60%)
  - O&G removal (up to 80%)
  - Limited removal of nutrients, pathogens, metals, etc.

- **Storage and digestion of solids/scum**

- Conditioning of wastewater for further treatment

- **Flow modulation**

- **Protection of drainfield/downstream components**

- Advanced pretreatment system component (e.g., recirc.)

- Resource recovery (nutrients, biogas)
Ideal Settling Theory

- Ideal settling theory affects design approach with regards to compartmentation and geometry

**Type 1: (Discrete Particle)** Particles settle as individual entities with little or no interaction with adjacent particles.

**Type 2: (Floculent)** Individual particles tend to flocculate, increasing their mass and settling rate.

**Type 3: ( Hindered or Zoned)** Particles tend to remain in fixed positions with respect to each other, a solids-liquids interface develops which settles as a unit.

**Type 4: (Compression)** Consolidation and compression of sediment take place from the weight of particles which are constantly being added.

*from: Seabloom, et al. (2004)*
Ideal Settling Theory

- If ideal discrete particle settling is applied to septic tank design, settling performance is a function of surface loading rate and hence, tank surface area.

- However, have to consider storage required for sludge and scum, biological activity, inlet and outlet effects, etc.

*from: Seabloom, et al. (1982)*
Biological Model

- Organic molecules are converted into more easily degradable simple sugars and organic acids (through hydrolysis) followed by further degradation by methane forming organisms.
- Distinct layers of settled sludge, a clear zone and floating scum form.
- Biogas bubbles rise from the sludge layer to seed the upper layers with microorganisms (and disrupt settling).
Performance Factors

Treatment (Removal) Efficacy

- BOD, TSS, FOG removal
- Limited nutrient removal; some uptake, but also resolubilization
- Limited info on other constituents: metals, VOCs, “emerging” contaminants, household chemicals & products

Wastewater Source and Characteristics

- Almost all data is for residential; some clusters
- Very little published data for other facility types
- WERF 04-DEC-1 characterizing influent/effluent, mostly for single residential

*STE BOD$_5$* by Source (Lowe et al., 2007)
Performance Factors

Geometry
- Shape doesn’t appear as important as L:W, surface area and compartmentation
- Compartmentation restricts most digestion to the first compartment and mitigates interferences in the outlet zone
  - Two-compartment tanks have been shown to typically outperform single-compartment tanks
- Connection between compartments likely important, but studies inconclusive

Influent/Effluent Appurtenances
- Effluent screens and baffles help to prevent resuspended and neutral buoyancy solids from entering outlet devices
- Effects of specific devices difficult to isolate in experiments
- Minimal published data on effluent screens (there is an industry testing standard, NSF 46)
Performance Factors

Hydraulic Design

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<td>Influent flow modulation</td>
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<td>Flow characteristics (short circuiting)</td>
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<td>Effluent hydraulic control</td>
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<td>Surface area</td>
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- 25% of daily loading to septic tank occurs in one hour or less
- Computational Fluid Dynamics (CFD) can be used to hydraulically model septic tanks and grease traps
Performance Factors

Septic Tank Sizing

- Size has more of an impact on pumping frequency than settling: larger tanks have higher capital costs but require less frequent pumping and thus have lower operation and maintenance costs.

- Larger tanks with less frequent pumping may take longer to reach biological maturity but are ultimately more efficient digesters.

(Bounds, 1994)
Performance Factors

Seasonal Performance

- Better settling in cold conditions; better digestion in warm conditions
- Seasonal changes can result in solids burping
- For grease traps: likely better separation in cold conditions

Septic Tank Monitoring and Maintenance

- At least 8 studies published on sludge/scum accumulation rates suggest that 3-5 year pumping frequency is generally conservative
- Base pump-out intervals for sludge and scum removal on reliable field measurements; overly frequent pumping can be detrimental to biological function, digestion efficiency and effluent quality
- Simple remote monitoring tools can be used to assess tank function on a real-time basis
- New techniques are evolving to diagnose tank performance by evaluating biological characteristics in the field and in the lab
Performance Factors

Water Softeners:

- Only two limited studies have been done to assess impacts on septic tanks.
- US PHS found that salt accumulated at bottom of tank in colder weather.
- Tyler, Corry and Olutu measured salt concentrations, SAR and osmotic potential households and compared that with literature on salt tolerance of bacteria.
- Anecdotal reports of septic tank upsets on homes with water softeners.
- NOWRA/WQA field survey in the works.
Performance Factors

**Grease Traps:**

- Cool incoming food service wastewater for gravity separation and storage of FOG
- Very little has been verified (and published) about design factors affecting performance
- Large outdoor grease traps are needed for onsite systems
- Characteristics (including management and operating practices) of food service facilities are important
- Blackwater from toilets should only be co-mingled downflow of grease traps to assure the viability of rendering of accumulated materials
- Ongoing WERF project (03-CTS-16T)
Other Performance Topics

- Garbage grinders/disposals
- Additives
- Blackwater/graywater
- Collection system type: grinder vs. conventional
- Construction materials and practices
- Watertightness
- Corrosion
- Accessibility
- Installation practices
- QA/QC and inspection
- Decommissioning/abandonment
Potential Research Needs

- Complete NOWRA/IWA field survey to determine impacts of **water softeners**
- Assess the field performance of primary unit **effluent devices**
- Assess performance of septic tanks serving specific **non-residential facilities** and conduct an engineering study on scientifically-defendable design modifications
- Study the performance of **alternative septic tank designs**, including meander tanks and UASB-septic tanks and their applicability for various types of systems and/or sites
Potential Research Needs

- Study *seasonal and regional differences* in primary unit function and optimize design, operation and maintenance recommendations accordingly.

- Study the evolution/maturation of septic tank biological function; develop *solids pumping protocols* with holistic understanding of biology.

- Develop methods to better *assess biology* and septic tank function in the field and improve laboratory/microscopic techniques for *diagnosing upsets*.

- Develop and calibrate *CFD models* and use in concert with pilot and full-scale testing, to evaluate potential primary treatment design enhancements.
Potential Research Needs

- Test **grease trap performance** versus sizing and design modifications, considering food service characteristics which are likely to be influential.

- Develop and validate standard protocols for testing the safety/fate of **household chemicals** in septic tanks for adoption by the industry.

- Develop and validate standard protocols for testing the effectiveness of **septic tank additives** for adoption by the industry.

- Develop a model **tank construction and installation QA/QC program** that can be adopted and implemented by manufacturers, engineers and regulatory authorities.

- Develop and validate standard methods for **measuring and monitoring septic tank performance** (e.g., influent and effluent sample collection and analysis) for use in future studies and in routine system monitoring efforts.
Potential Research Needs

- Develop and validate standard methods (manual and automatic) for measuring sludge and scum accumulations in septic tanks for use in future studies.

- Generate a statistically-sufficient set of paired influent and effluent data for in-service septic tanks in various geographies and under different design and operating conditions to better assess performance under real-world conditions.

- Further develop and test tank intercompartment connectors and inlet devices to optimize existing, common septic tank designs.

- Evaluate viable energy efficiency and recovery strategies for primary treatment units.

- Evaluate fate, occurrence and treatability of priority pollutants and contaminants of emerging concern in primary treatment units.
Conclusions

- Relatively little innovative research has been done; research tends to be more reactive to existing design practices than proactive.

- Enhancements in design have typically been derived from convenience and perceived safety factors than from real analysis.

- Efforts to minimize investment costs have resulted in expenditures toward research of little value.

- Conducting studies which isolate independent performance factors can be difficult and costly.

- Sampling frequency is often compromised and statistically insufficient to answer specific questions concerning system design.
Conclusions

- Different types of experimental approaches may be applicable including field surveys, controlled pilot tests, and laboratory testing.

- A comprehensive research strategy and agenda should be developed to determine which research questions are worthy of further study relative to costs/benefits and risk management.

- What information that is available in the decentralized wastewater arena could be better managed and distributed; some of the most useful and applicable data, particularly field survey and monitoring data, exists in quantity but is not accessible in a practical way.
More Information

- Water Environment Research Foundation (WERF): www.werf.org (WERF Project 04-DEC-7)
- Final products should be available summer 2007