

TECHNICAL GUIDE

Primary Treatment in Decentralized Wastewater Systems

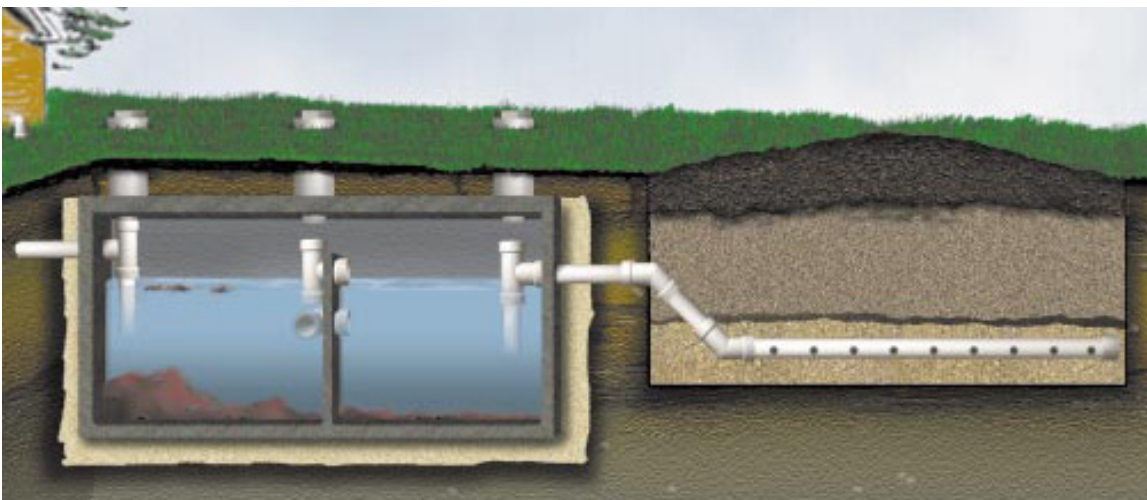
PRIMARY TREATMENT OBJECTIVES

This document provides a brief summary of some of the main technical results of WERF project 04-DEC-7, which compiled and synthesized existing information regarding the performance of primary treatment units (septic tanks, grease traps) in decentralized wastewater systems. This summary is intended for designers, engineers, regulators, educators, and others interested in technical guidance on primary treatment units.

Septic tanks are generally expected to serve as a settling device, separating settleable solids as sludge and less dense floatable materials into a surface scum layer; and to temporarily store separated materials enabling digestive processes to reduce volume and improve effluent quality. The goal is to produce a consistent and clarified effluent suitable for secondary treatment downstream, typically via soil absorption systems or advanced pretreatment.

Grease traps are expected to cool incoming food service wastewater for gravity separation and storage of fats, oils, and grease (FOG), via physical and physiochemical processes. Like septic tanks, the overall objective of grease trap treatment is to reduce challenges to downstream system components.

Despite the critical role of primary treatment in onsite systems, standard practice generally follows prescriptive criteria developed based on tradition, experience, and cost considerations and only limited and somewhat dated scientific information.



Septic tank and soil absorption field system (Courtesy of Texas A&M University, Texas Agricultural Extension Service) <http://theurbanrancher.tamu.edu/construction/conventionalseptic tanks.pdf>

WHAT IS KNOWN?

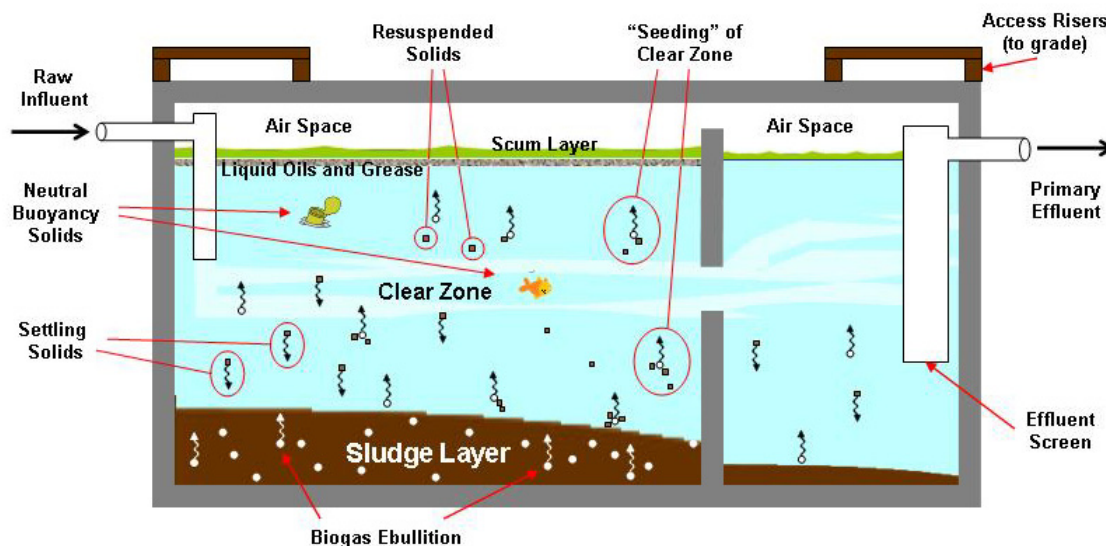
Dual Function as Settling Tank and Anaerobic Digester: A balance between the processes of solids settling and sludge digestion is necessary; gas ebullition from solids digestion processes can disrupt settling activity.

- Compartmentation aims to restrict most digestion to the first compartment and mitigate interferences in the outlet zone; two-compartment tanks have been shown to typically out-perform single-compartment tanks
- Effluent screens and baffles help to prevent resuspended (and neutral buoyancy) solids from entering outlet devices

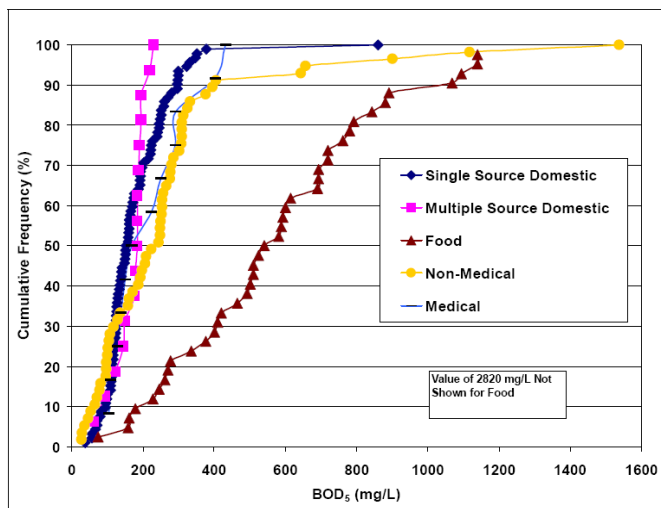
Biological Model of Septic Tank Operation: Septic tanks are horizontal flow reactors that facilitate biochemical processes in a primarily anaerobic system.

- 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

Solids separation and digestion processes are critical and sometimes conflicting elements affecting septic tank performance.



Properly operating tanks stratify into distinct zones. Lack of stratification is indicative of a severe operational problem that may be traced to biological toxicity, large flow surges, or poor hydraulics among other reasons.



Cumulative frequency diagrams (CFD) are a potentially useful tool for characterizing raw wastewater and septic tank effluent. The CFD graphically depicts constituent concentrations in relation to cumulative frequencies, expressed as a percent. This relationship allows a designer to select design values with greater emphasis on probability and risk of exceeding specific design criteria.

CFD for Septic Tank Effluent BOD₅ Concentration (Lowe et al., 2007) – This diagram shows, for example, that ~70 percent of the STE BOD₅ results reported in the literature for single-source domestic systems are 200 mg/L or less.

Factors Affecting Septic Tank Performance

Surface Area and Hydraulic Efficiency are main determinants of settling function.

- Greater surface areas yield lower surface overflow rates and more efficient settling for a specified volume; however, there will be less depth for the storage of sludge and scum, resulting in a compressed clear zone. Maximizing surface area also minimizes hydraulic head, modulating discharge rates, and results in shorter tanks, requiring less deep excavations for installation.
- Hydraulic efficiency can be improved by:
 - using relatively long, narrow tanks
 - taking measures to disperse flow uniformly across the influent zone and collect it uniformly across the effluent zone
 - increasing outlet device cross-sectional flow area, thereby lowering exit velocity and disruption to the settled sludge layer
 - using multiple compartments connected via transfer devices that minimize intercompartmental mixing

Sizing of septic tanks influences performance and is typically based on hydraulic residence time, storage volumes allocated to sludge, clear zone, scum and air space and solids removal frequency (Bounds, 1997).

- The impact of tank sizing on pumping frequency can be dramatic: 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.

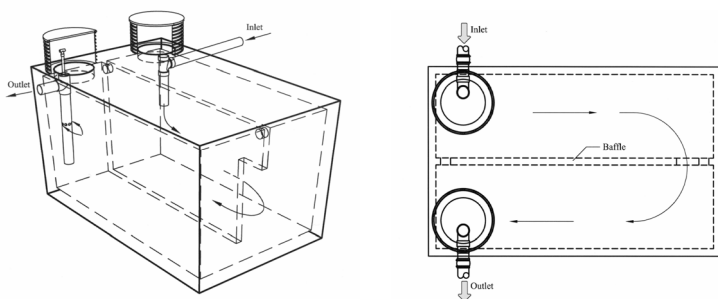
Climatic Considerations - the rate of anaerobic digestion is influenced by temperature.

- Under warmer conditions, digestion rates are higher resulting in lower solids accumulations but with increased turbulence caused by biogas ebullition, thereby increasing suspended solids.
- In cooler conditions, settling function is improved but tanks will accumulate solids more quickly.
- These factors can be considered in design for installations in warm or cool climates as well as for seasonal operational strategies and trouble-shooting.

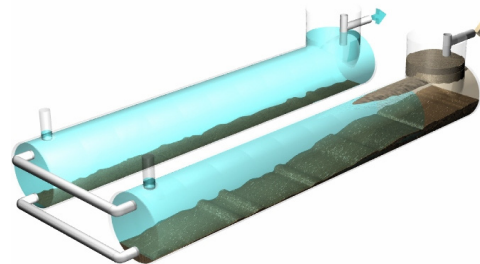
DESIGN ALTERNATIVES

These alternatives are presented only for information and to illustrate examples of potential directions in tank design and configuration. Their inclusion is not intended to promote these designs or to validate claims made by their proponents. Figures provided are schematic and for basic communication of concepts only.

Meander tanks (below) utilize longitudinally placed baffle walls (as opposed to the more common practice of baffle walls placed perpendicular to flow) increasing effective length-to-width ratio and potentially improving settling in low-velocity zones adjacent to the bends.



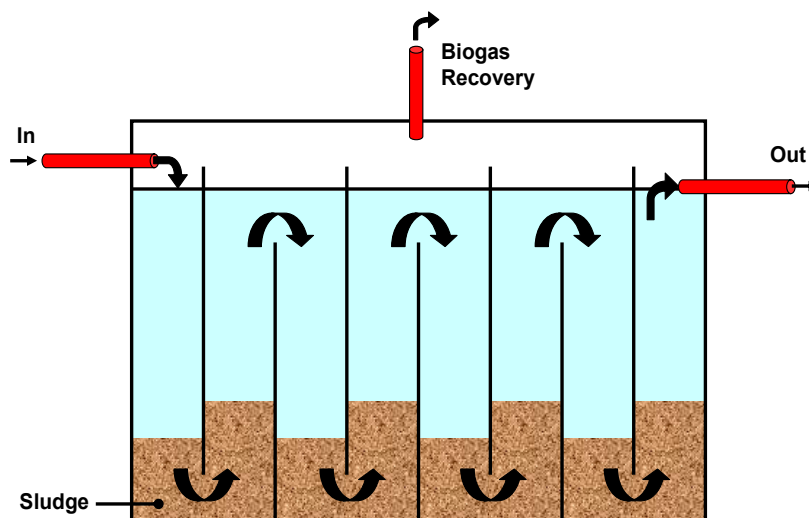
(courtesy of T.R. Bounds)



Closed-conduit, laminar flow tanks (above) are a newly developed variation on the meander tank consisting of a series of long narrow tanks with no airspace and little hydraulic dead space, the objectives of which are to encourage laminar flow and reduce the formation of scum (Jowett and Lay, 2006).

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.

Upflow Anaerobic Sludge Blanket (UASB) septic tanks (right) have a series of compartments separated by baffle walls where effluent from one compartment is directed downward to flow up through the settled sludge blanket of the next compartment in series. Flow through the blanket enhances solids retention and biological contact. These are sometimes also called “baffled anaerobic reactors”.



Imhoff tanks (not pictured) are two-compartment tanks with compartments separated vertically, with flow only through the top, or settling, compartment. Settled solids slide down inclined walls into a lower digestion compartment and internal baffling prevents biogas-driven resuspension of solids into the clear settling zone.

The dominance of prescriptive regulatory codes and standards as the basis for septic tank design has restricted the development of potentially improved designs.

OVERSIGHT

Inspection, Operation, and Maintenance

- 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 and function by evaluating biological characteristics in the field and in the lab

Watertightness

- One of the most critical requirements of a properly functioning tank
- Requires improved construction (particularly at all joints and penetrations), testing, and installation procedures

- The National Precast Concrete Association (www.precast.org), the National Onsite Wastewater Recycling Association model code (www.nowra.org) and others contain suggestions for addressing watertightness

Construction and Installation

- The locations and quality of seams are primary construction considerations for watertightness
- Materials and construction techniques must yield structurally sound tanks considering the range of stresses to which they may be subjected
- During installation, prevent differential settling through proper preparation during excavation, the use of clean gravel or sand bedding and backfilling with clean soil or other suitable materials tamped in short lifts
- At-grade access is critical; landscaping should shed water away from the tank

There is an imperative need for more robust QA/QC procedures, particularly in tank manufacturing and installation practices for watertightness.

Existing Standards and Codes

Organization	Standard Number	Standard Title
ASTM	C890-06	Standard Practice for Minimum Structural Design Loading for Monolithic or Sectional Precast Concrete Water and Wastewater Structures
ASTM	C1227-07	Standard Specification for Precast Concrete Septic Tanks
ASTM	C1644-06	Standard Specification for Resilient Connectors Between Reinforced Concrete On-Site Wastewater Tanks and Pipes
ASTM	C1613-06	Standard Specification for Precast Concrete Grease Interceptors
IAPMO	PS 001-2006	Prefabricated Septic Tanks
IAPMO	PS 080-2006	Grease Interceptors and Clarifiers
IAPMO	Appendix H, UPC	Recommended Procedures for Design, Construction and Installation of Commercial Kitchen Grease Interceptors
CSA	B66-05	Design, Material, and Manufacturing Requirements for Prefabricated Septic Tanks and Sewage Holding Tanks
NSF/ANSI	Standard 46	Evaluation of components and devices used in wastewater systems
ICC	IPC	International Plumbing Code
ICC		International Private Sewage Disposal Code
UL	UL 70	Septic Tanks, Bituminous-Coated Metal
AS-NZS ¹	1546, Part 1	Septic Tanks (1998)
CEN ²	EN 12566, Part 1	Prefabricated Septic Tank
CEN ²	EN 12566, Part 4	Septic Tanks Built <i>In Situ</i> from Prefabricated Kits

¹ Australia-New Zealand ² European Union

FOOD SERVICE FACILITIES AND GREASE TRAPS

Very little is known about the factors impacting the performance of grease traps and it appears that almost nothing has been done to optimize design or to confirm the sizing criteria in use today (which varies widely).

- Large outdoor grease traps similar in design to septic tanks are necessary to remove substantial amounts of grease in onsite wastewater treatment systems treating food service facilities.
- Management and operating practices of restaurants are critically important for grease control.
- Blackwater from toilets should only be co-mingled downflow of the grease and oil separation units to assure that removal of accumulated materials for rendering is viable.

OPEN FOR INQUIRY

- Little is known about the factors affecting the performance of septic tanks in cluster systems and design parameters for systems serving non-residential facilities.
- Effluent screens modulate flow and retain gross solids and neutral buoyancy solids in the tank, but little peer reviewed scientific evaluation data exists concerning their effectiveness.
- Water softener regeneration brines have been anecdotally implicated in septic tank biological failures; however, properly operating water softener systems may be safe. More research needs to be done to determine actual impacts and how to best mitigate them.
- Septic tank additives have generally been shown to be ineffective; however much more testing of specific products is needed. Likewise the impacts of household chemical use can be assessed using a suite of currently available methods.
- Investments in developing design improvements should be weighed against the potential for such improvements to benefit overall system performance.

References*

- Bounds, T.R. 1997. *Design and performance of septic tanks*. Site Characterization and Design of On-Site Septic Systems. ASTM STP 1324. ASTM International.
- Jowett, C. and R. Lay. 2006. *Comparative performance of closed-conduit, laminar flow septic tanks*. Small Flows Quarterly.
- Lowe, K.S., N.K. Rothe, J.M.B. Tomaras, K. DeJong, M.B. Tucholke, J. Drewes, J.E. McCray, and J. Munakata-Marr. 2007. *Influent characteristics of the modern waste stream from single sources: literature review*. Water Environment Research Foundation, Project No. 04-DEC-01.

* Only directly cited references are listed. The *Research Digest and Bibliographic Database* should be consulted for a much more comprehensive list of critical references

Additional Information

The following resources are available at www.werf.org and www.ndwrcdp.org:

- Research Digest: Factors Affecting the Performance of Primary Treatment in Decentralized Wastewater Systems
- Bibliographic Database of Research and Data on Performance of Primary Treatment Units in Decentralized Wastewater Systems

WERF Project 04-DEC-7

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