Onsite Wastewater Concepts, Materials, Regulations & The Application Process Part I

A – Basic Concepts in Wastewater Treatment

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Objective

To give a clear understanding of the basic concepts of wastewater treatment including wastewater composition, treatment in the tank, pollutants in wastewater, effluent characteristics and advanced treatment units

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Onsite Sewage Treatment and Disposal Systems

3

Advantages and Importance of Onsite Systems

- Simple and effective
- Minimal moving parts
- Less disruptive to the environment to install and maintain
- Provide wastewater treatment to areas where otherwise it would not be available
- A source of **groundwater recharge**
- Lower cost compared to central sewer

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“Public health and environmental protection officials now acknowledge that onsite systems are **not just temporary installations** that will be replaced eventually by centralized sewage treatment services, but **permanent approaches** to treating wastewater for release and reuse in the environment”. (USEPA, 1997)

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“Onsite systems are recognized as potentially viable, low-cost, long-term, decentralized approaches to wastewater treatment if they are **planned**, **designed**, **installed**, **operated**, and **maintained properly** ”.
(USEPA, 1997)

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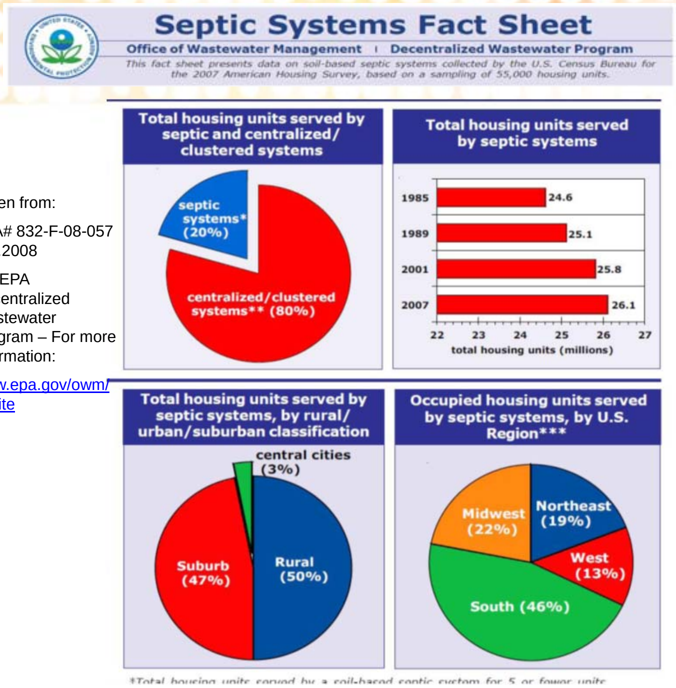

Taken from:

EPA# 832-F-08-057 Oct.2008

US EPA Decentralized Wastewater Program – For more information:

www.epa.gov/owm/onsite

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Florida's Onsite Wastewater Treatment Systems

- **2.67 million** septic systems*
- **8.8 million** housing units**
- > **30%** served by septic systems
- > **465 million gallons per day** of flow (based on 2.51 persons per household and 69.3 gallons per day/person)

*FL Dept of Health, **2008 US Census

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Topics in OSTDS Design

- Wastewater Composition
- Pre-treatment
- Wastewater Disposal

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Body Wastes from the average person

- *1.25 L (0.33 gallons) urine per day*
- *0.25 Kg (0.55 LB.) feces per day*

from Guttormsen, 1978

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Human Body Wastes
(Total volume ~ 1.5 L per day)

DRY SOLIDS 150 g made of

- *Organic material* *118 g*
- *Nitrogen* *16 g*
- *Phosphorus* *2 g*
- *Other* *14 g*

includes salts and trace elements
from Guttormsen, 1978

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Human Body Wastes
organics

- Organic material - anaerobic bacteria
- 10^{12} bacteria **per gram** of feces
- 1,000,000,000,000 or 1 trillion

from Guttormsen, 1978

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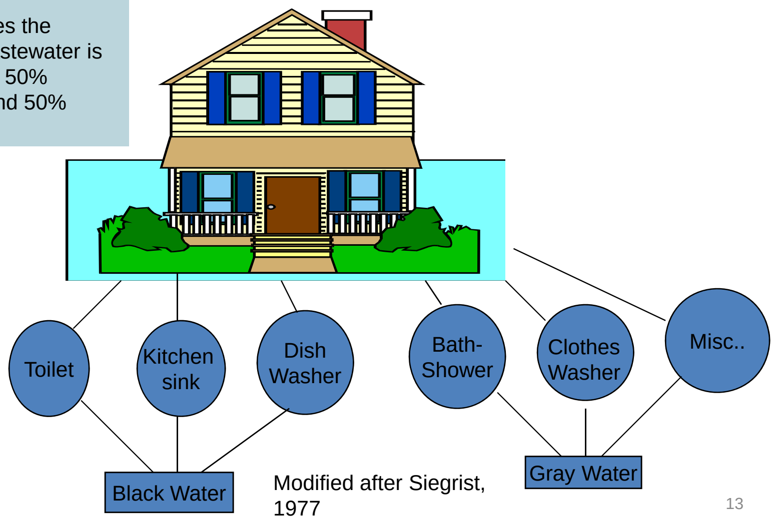
Segregation of Household Wastewater

In Florida

For residences the volume of wastewater is calculated as 50% blackwater and 50% graywater.



Modified after Siegrist, 1977

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Table 3-3. Residential water use by fixture or appliance[a,b]

Fixture/use	Gal/use: Average range	Uses/person/day: Average range	Gal/person/ day: Average range[c]	% Total: Average range
Toilet	3.5 2.9–3.9	5.05 4.5–5.6	18.5 15.7–22.9	26.7 22.6–30.6
Shower	17.2[d] 14.9–18.6	0.75[d] 0.6–0.9	11.6 8.3–15.1	16.8 11.8–20.2
Bath	See shower	See shower	1.2 0.5–1.9	1.7 0.9–2.7
Clothes washer	40.5 —	0.37 0.30–0.42	15.0 12.0–17.1	21.7 17.8–28.0
Dishwasher	10.0 9.3–10.6	0.10 0.06–0.13	1.0 0.6–1.4	1.4 0.9–2.2
Faucets	1.4[e] —	8.1[f] 6.7–9.4	10.9 8.7–12.3	15.7 12.4–18.5
Leaks	NA	NA	9.5 3.4–17.6	13.7 5.3–21.6
Other Domestic	NA	NA	1.6 0.0–6.0	2.3 0.0–8.5
Total	NA	NA	69.3 57.1–83.5	100

[a] Results from AWWARF REUWS at 1,188 homes in 12 metropolitan areas. Homes surveyed were serve by public water supplies, which operate at higher pressures than private water sources. Leakage rates might be lower for homes on private water supplies.
[b] Results are averages over range. Range is the lowest to highest average for 12 metropolitan areas.
[c] Gal/person/day might not equal gal/use multiplied by uses/person/day because of differences in the number of data points used to calculate means.
[d] Includes shower and bath.
[e] Gallons per minute.
[f] Minutes of use per person per day.

Source: Mayer et al., 1999.

Toilet generates the most water use per day

Washing machine generates the most gallons per use

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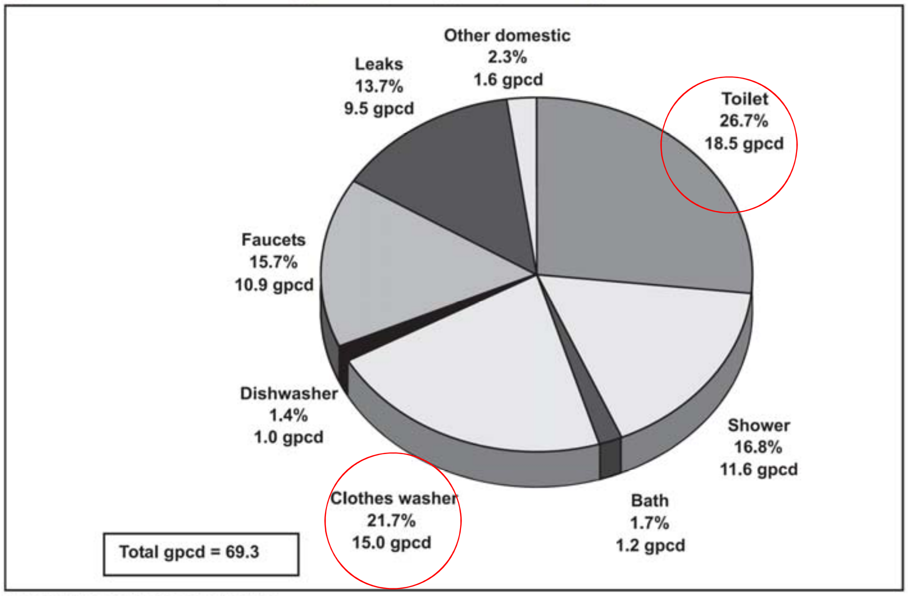
EPA/625/R-00/008, Table 3-3. Source: Mayer et al., 1999.

Figure 3-2. Indoor water use percentage, including leakage, for 1,188 data logged homes[a]



[a] gpcd = gallons per capita (person) per day
Source: Mayer et al. 1999.

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Table 3-8. Residential wastewater pollutant contributions by source[a,b]

Parameter		Garbage disposal (gpcd)[c]	Toilet (gpcd)[c]	Bathing, sinks, appliances (gpcd)[c]	Approximate total (gpcd)[c]
BOD_5	mean	18.0	16.7	28.5	63.2
	range	10.9–30.9	6.9–23.6	24.5–38.8	
	% of total	(28%)	(26%)	(45%)	(100%)
Total suspended solids	mean	26.5	27.0	17.2	70.7
	range	15.8–43.6	12.5–36.5	10.8–22.6	
	% of total	(37%)	(38%)	(24%)	(100%)
Total nitrogen	mean	0.6	8.7	1.9	11.2
	range	0.2–0.9	4.1–16.8	1.1–2.0	
	% of total	(5%)	(78%)	(17%)	(100%)
Total phosphorus[d]	mean	0.1	1.6	1.0	2.7
	range	—	—	—	—
	% of total	(4%)	(59%)	(37%)	(100%)

[a] Adapted from USEPA, 1992.
[b] Means and ranges for BOD, TSS, and TN are results reported in Bennett and Linstedt, 1975; Laak, 1975;Ligman et al., 1974; Olsson et al., 1968; and Siegrist et al., 1976.
[c] Grams per capita (person) per day.
[d] The use of low-phosphate detergents in recent years has lowered the TP concentrations since early literature studies; therefore, Sedlak (1991) was used for TP data.

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Measurement of Wastewater Pollutants/Contaminants

BOD (Biochemical Oxygen Demand)	The test measures the amount of dissolved oxygen organisms need to degrade wastes in wastewater. Also referred to as CBOD5. (Carbonaceous Biochemical Oxygen Demand).
TSS (Total Suspended Solids)	A portion of wastewater that has resisted settling, that is retained when passed through a filter. Also indicates wastewater clarity. Can clog the soil absorption system.
TN (Total Nitrogen)	There are 3 forms of nitrogen that are commonly measured: ammonia (NH4), nitrates (NO3) and nitrites (NO2). Total Nitrogen is the sum of total Kjeldahl nitrogen (organic and reduced nitrogen), ammonia and nitrate-nitrite. (TKN)
TP (Total Phosphorus)	Occurs in wastewater bound to oxygen to form phosphates. Phosphates are classified as orthophosphates, polyphosphates and organic phosphates.
Fecal Coliform	Used as indicator organism for the presence of pathogens and used to determine if wastewater has been adequately treated.
FOG (Fats, Oils and Greases)	The combination of fats, oils, and greases and other related constituents in wastewater. Excessive FOG can clog systems, create odors and increase BOD.

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Table 3-15. Reduction in pollutant loading achieved by eliminating garbage disposals

Parameter	Reduction in pollutant loading (%)
Total suspended solids	25–40
Biochemical oxygen demand	20–28
Total nitrogen	3.6
Total phosphorus	1.7
Fats, oils, and grease	60–70

Source: University of Wisconsin, 1978.

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EPA/625/R-00/008, Table 3-15. Source: University of Wisconsin, 1978

Residential Influent Wastewater Concentrations (part 1)

Biochemical Oxygen Demand (BOD)	**420 mg/l**
Total Solids (TS)	1028 mg/l
Total Suspended Solids (TSS)	**232 mg/l**
Total Organic Carbon (TOC)	183 mg/l
Dissolved Organic Carbon (DOC)	110 mg/l

Source: WERF, 2009

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Residential Influent Wastewater Concentrations (*part 2, nutrients*)

Total Nitrogen	**60 mg/l**
Organic N	43 mg/l
Ammonia (NH_3)	14 mg/l
Nitrate N (NO_3^-)	1.9 mg/l
Total Phosphorus	**10.4 mg-P/L**

Source: WERF, 2009

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Residential Influent Wastewater Concentrations (*part 3, microbes*

Total bacteria	1×10^8/100/ml
Total coliform	2×10^6/100/ml
Fecal coliform	3×10^4/100/ml
Fecal streptococci	3×10^4/100/ml
Enteric virus	32-7000 PFU/L

Source: Canter & Knox 1985

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Waterborne Pathogens found in Human Waste and Associated Diseases

Type	Organism	Disease
Bacteria	***Escherichia coli (enteropathogenic)***	**Gastroenteritis**
	Legionella pneumophila	**Legionellosis**
	Leptospira	**Leptospirosis**
	Salmonella typhii	**Typhoid Fever**
	Salmonella	**Salmonellosis**
	Shigella	**Shigellosis**
	Vibrio cholera	**Cholera**
	Yersinia enterolitica	**Yersinosis**

Source: USEPA, 1999

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Waterborne Pathogens found in Human Waste and Associated Diseases

Type	Organism	Disease
Protozoans	*Balantidium coli*	Balantidiasis
	Cryptosporidium	Cryptosporidiosis
	Entamoeba histolytica	Amoebic dysentery
	Giardia lambia	Giardiasis
	Naegleria fowleri	Amoebic Meningoencephalitis

Source: USEPA, 1999

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Waterborne Pathogens found in Human Waste and Associated Diseases

Type	Organism	Disease
Viruses	*Adenovirus (31 types)*	Conjunctivitis
	Enterovirus (67 types)	Gastroenteritis
	Hepatitis A	Infectious hepatitis
	Noroviruses	Gastroenteritis
	Reovirus	Gastroenteritis
	Rotavirus	Gastroenteritis

Source: USEPA, 1999

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Forms of viral hepatitis - exposure routes

- Hepatitis A
- Hepatitis B
- Hepatitis C
- Delta- Hepatitis
- Hepatitis E

IN: Benenson, 1990

- SewAge (fecal-oral)
- Blood-borne
- Transfusions
- Blood & plasma
- Contaminated water (fecal-oral)

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Pathogen Content of Gray water surprisingly high…

Possible sources are:

- sputum & vomitus - bathroom sink
- contaminated garments - clothes washer
- normal skin flora (rectal area) - shower/ bath

Source: Plews, 1977

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Typical Septic Tank effluent bacterial count (mean#/100 ml)

- Total bact. 3.4×10^8
- Total colif. 3.4×10^6
- Fecal colif. 4.2×10^5
- Fecal strep. 4.0×10^4
- *Pseudomonas aeruginosa* 8.6×10^3

Siegrist, 1977
Univ. of Wisconsin, 1978

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Bacterial Characteristics of Gray Water

EVENT	ORGANISM	Mean(#100 ml)
Bath/Shower	Fecal strep.	44
	Fecal colif.	220
	Total colif.	1,100
Clothes Wash	Fecal strep.	210
	Fecal colif.	1,400
	Total colif.	18,000
Clothes Rinse	Fecal strep.	75
	Fecal colif.	320
	Total colif.	5,300

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Nitrogen

- septic tank effluent **27 – 119** mg-N/L (60 mg-N/L median)*
- Very little removal in tank*
- **as much as 10 - 50% removed in drainfield** **(based on soil permeability) ***
- each person generates 9 lbs./year**
- need to determine risks of nitrogen build up in groundwater

* **Water Environment Research Foundation (WERF),** Project Number 04-DEC-1, *Influent Constituent Characteristics of the Modern Waste Stream from Single Sources, 2009*

** **Wekiva Study Florida, Feb 2006** by D. L. Anderson et al, the researchers determined that the average amount of nitrogen in untreated domestic sewage contributed by each person in a home was 11.2 grams per person per day or around 22 pounds per year per each household of 2.5 people.

Total Nitrogen in Effluent

- ~ 45 mg-N/L SEPTIC TANK
- ~ 40 mg-N/L AEROBIC UNIT

Source: 1993 Florida OSTDS Study

Nitrogen

	Nitrogen Primarily in the form of:
Septic Tank Effluent	**Ammonia (NH_3)**
Aerobic Treatment Unit Effluent	**Nitrate N (NO_3^-)**

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Nitrate

- Not Retained In Soil
- Moves With Groundwater
- Created By Unsaturated Soils and Aerobic Treatment Units

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Nitrogen Contamination Public Health Concerns

- High concentrations of nitrate (greater than 10 mg/L) can cause **METHEMOGLOBINEMIA** or **"Blue Baby Syndrome"** a disease in infants that reduces the blood's ability to carry oxygen
- **MCL for N is 10 mg/l** – EPA Groundwater Standard
- Septic tanks are ineffective in removing nitrogen
- Nitrogen contamination of ground water below infiltrative fields has been documented by many investigators

Source: EPA, 2002

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Limiting Nitrate Effects

- **Control System Density**
- Maximum Sewage Flow Applied Per Acre
- Reduce Amount Of Nitrogen In Effluent

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Phosphorus

- Sources: soaps & detergents (lowered), feces
- Average person generates 3 lb./yr
- 5-20% retention in tank
- Plant uptake in root zone
- Soils with organic content will absorb P
- 85 – 95% removed as measured in the vadose zone (aerated or unsaturated zone below the drainfield)
- Chemical precipitation, ion exchange canisters
- Fate: lake and tropical marine degradation

Source: EPA, 2002

Volatile Organic Compounds (VOCs)

- Sources: cleansers, dyes, solvents used in home, pesticides, organic chemicals
- Removal efficiency: high in coarse aggregate drainfield material (presumably vaporize into air voids)
- Most prevalent toxic organics in wastewater: toluene, xylenes, acetone.

Source: EPA, 2002

Volatile Organic Compounds (VOCs)

- Concentrations in septic tank effluent 9-75 micrograms/L
- toluene found in all effluent samples
- chloroform & methylene chloride found in some effluent samples
- <u>no positive samples immediately beneath drain fields</u>

Source: Florida's OSTDS Research Project

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Pretreatment

- occurs in treatment tanks
- septic tanks - provide <u>*primary*</u> treatment
- aerobic units - provide <u>*secondary*</u> treatment

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Functions of a Septic Tank

- Sedimentation in scum & sludge layers
- Storage of layers
- Digestion of solids without oxygen

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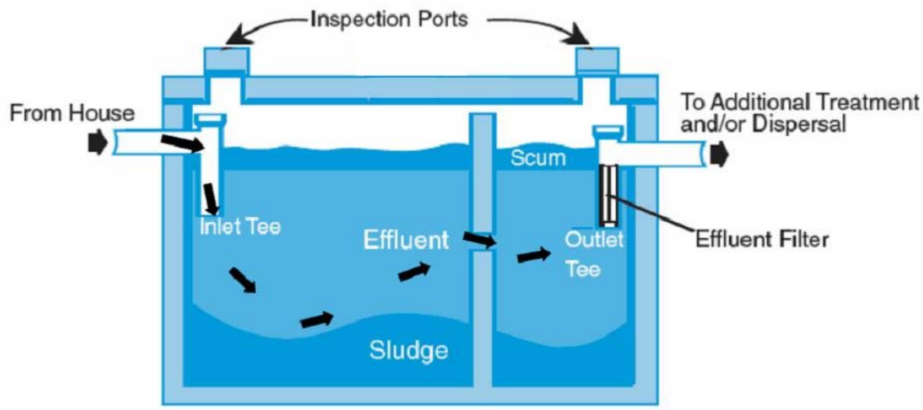
Septic Tank



Multi-compartment Septic Tank

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Sedimentation Function

- quiescent conditions
- settleable solids sink to bottom - sludge
- floatables rise to form scum layer
- remove / reduce particles suspended in wastewater
- partition tanks (baffled) or tanks in series prevent short circuiting

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Storage Function

- Adequate volume
- Scum and sludge stored without disturbing other functions
- Protects drainfield absorption area

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Digestion Function

- Without oxygen (anaerobic)
- Reduce organic molecules to soluble compounds and gases
- Gas bubbles produced in sludge rise to surface and seed the clear zone
- Can interfere with sedimentation
- Reason for compartmentalized tanks and outlet and filter devices

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Anaerobic Digestion

The purpose of the anaerobic process is to convert sludge to end products of liquids and gases while producing as little biomass as possible

- ***Hydrolysis*** – large polymers broken down by enzymes
- ***Fermentation*** – Volatile fatty acids are also produced along with carbon dioxide and hydrogen
- ***Acetogenesis*** – breakdown of volatile acids to acetate and hydrogen
- ***Methanogenesis*** – Acetate, formaldehyde, hydrogen and carbon dioxide are converted to methane and water

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Indigestible materials to avoid:

- coffee grounds
- cooking fats & grease
- wet strength towels
- disposable diapers
- cigarette butts
- plastics
- kitty litter

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What is in Septic Tank Effluent?

- oxygen-demanding substances
- disease-causing agents
- small suspended particles
- nutrients and other dissolved substances
- 99.9% ***water***

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Septic Tank Effluent Characteristics

- Remove nearly all the settleable solids
- Fats, greases & floating debris removed
- Can vary widely in characteristics
- Can vary from day to day in same tank, depending on usage, season and climate

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Septic Tank Effluent

	Influent RAW (mg/l)	Effluent (STE) (mg/l)	% Reduction
$CBOD_5$	420	216	50%
TSS	232	61	60-80%
Total Nitrogen	60	60	NR
Total Phosphorus	10.4	9.8	little

Source: WERF, 2009

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Closer to the Soil Surface…

- more biological activity
- stimulation natural microbes & macro-organisms
- greater oxygen concentration
- shorter distance for oxygen to diffuse to biomat

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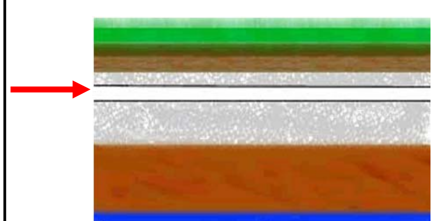
Biomat



- Clogging mat, zone, or bio-crust
- Highly effective in removing bacteria and pathogens
- Acts as an active biological site for treatment
- Large portion of BOD removed
- Adsorption, filtration and purification
- Predation of sewage microbes by naturally-occurring soil microbes

Biomat: The layer of biological growth and inorganic residue that develops at the wastewater-soil interface and extends up to about **1 inch into the soil matrix.** The biomat controls the rate at which pretreated wastewater moves through the infiltrative surface/zone .

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Table3-17. Examples of soil infiltration system performance

Parameter	Applied concentration in milligrams per liter	Percent removal	References
BOD_5	130–150	90–98	Siegrist et al., 1986 U. Wisconsin,1978
Total nitrogen	45–55	10–40	Reneau 1977 Sikora et al., 1976
Total phosphorus	8–12	85–95	Sikora et al., 1976
Fecal coliforms	NA[a]	99–99.99	Gerba, 1975

[a] Fecal coliforms are typically measured in other units, e.g., colony-forming units per 100 milliliters.

Source: Adapted from USEPA, 1992.

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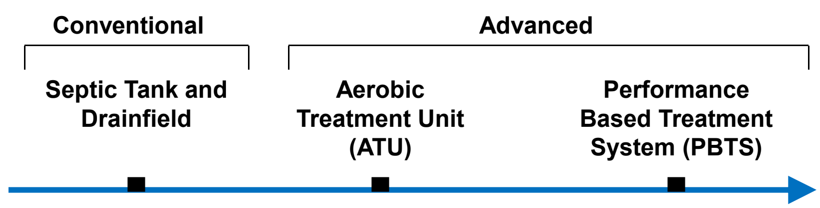
Conventional vs. Advanced OSTDS



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Aerobic Treatment Unit (ATU)

- A sewage treatment unit which introduces air into sewage
- Treatment provided by bacteria adapted to presence of dissolved oxygen

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Aerobic vs. Anaerobic Bacteria

- Get more energy out of same amount of food
- Reproduce faster when conditions favorable
- Greater proportion of food consumed goes into cell mass

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Aerobic Unit Effluent Meets National Secondary Standards – NSF Standard 40

	Conventional STE	ATU NSF 40 STE Standard
BOD_5	216 mg/L	25 mg/L
TSS	61 mg/L	30 mg/L
Microbe Reduction	loaded	99.9% (not disinfection)

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Steps in Aerobic Treatment

- Pretreatment - using septic tank, trash trap or primary settling compartment *(manufacturer specifications/NSF certification)*
- Aeration - two types
  - suspended growth - floating in liquid
  - attached growth - attach to surface trickling filter or rotating disks examples

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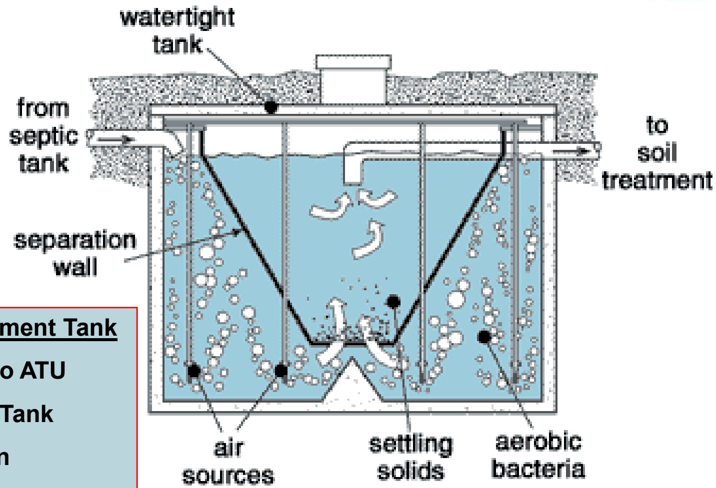
Aerobic Treatment Unit



Pretreatment Tank

- Prior to ATU
- Trash Tank
- Built in
- Separate Tank

Suspended Growth

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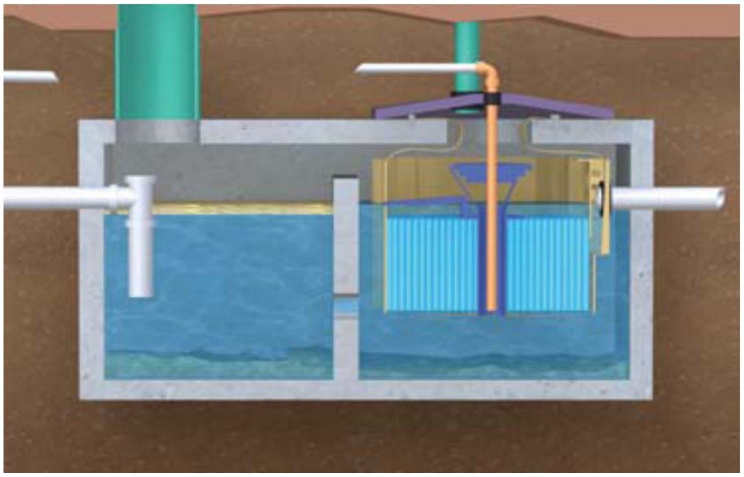
Aerobic Treatment Unit



Attached Growth

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Aerobic Treatment Unit

Incentives/ Advantages	Disincentives/ Addn. requirements
▪ Much higher treatment (greater reduction in BOD and TSS) ▪ Can extend drainfield life ▪ Reduced drainfield ▪ Replacement system in areas with chronic failing septic tanks	▪ Operating expense ▪ Requires electricity ▪ More frequent routine maintenance ▪ Subject to upsets under heavy loads ▪ Less resilient to long periods of no use (starvation)

In addition, an operating permit and annual inspection by CHD required.

Performance Based Treatment System (PBTS)

- Engineer Design
- Comparison/Differences to ATU's
- Reduction in Sewage Strength and Nutrients
- Increased Lot Flows
- Reduction in Set backs
- Greater Reduction in Drainfield size than ATU
- Operating Permits
- Maintenance
- Monitoring and Sampling
- CHD Inspection - Annually

Performance Based Treatment System (PBTS)

- a <u>specialized onsite sewage treatment and disposal system</u> designed by a professional engineer with a background in wastewater engineering, licensed in the state of Florida, using appropriate application of sound engineering principles <u>to achieve specified levels</u> of **CBOD5** (carbonaceous biochemical oxygen demand), **TSS** (total suspended solids), **TN** (total nitrogen), **TP** (total phosphorus), and **fecal coliform** found in domestic sewage waste, to a specific and <u>measurable established performance standard</u>. This term also includes innovative systems.
Chapter 64E-6.025(10), Florida Adminstrative Code

PERFORMANCE STANDARDS

Performance Based Treatment Systems (PBTS)

POLLUTANT	BASELINE SYSTEM STANDARDS (Septic tank effluent)	BASELINE SYSTEM STANDARDS (@ base of 24 inch unsaturated zone)	AEROBIC TREATMENT UNIT (effluent)	SECONDARY TREATMENT STANDARDS (effluent)	ADVANCED SECONDARY TREATMENT STANDARDS (effluent)	ADVANCED WASTEWATER TREATMENT STANDARDS (effluent)
$CBOD_5$ (Carbonaceous Biochemical Oxygen Demand)	120-240 mg/l	< 5 mg/l	=or< 20 mg/l	=or< 20 mg/l	=or< 10 mg/l	=or< 5 mg/l
TSS (Total Suspended Solids)	65-176 mg/l	< 5 mg/l	=or< 30 mg/l	=or< 20 mg/l	=or< 10 mg/l	=or< 5 mg/l
TN (Total Nitrogen)	36-45 mg/l	15-25 mg/l	not applicable	not applicable	=or< 20 mg/l	=or< 3 mg/l
TP (Total Phosphorus)	6-10 mg/l	< 5 mg/l	not applicable	not applicable	=or< 10 mg/l	=or< 1 mg/l
Fecal coliform		undetected	not applicable	=or< 200 fc col/100 ml	=or<200 fc col/100 ml	BDL for 100 ml
DRAINFIELD REDUCTIONS	not applicable	not applicable	25% in slightly limited soil	25%	40%	40%
REDUCE: SETBACKS surface water	no change	no change	no change	65 ft	50 ft	25 ft
groundwater drains	no change	no change	no change	no change	10 ft	10 ft
dry retention & swales	no change	no change	no change	no change	10 ft	10 ft
SEPARATIONS to SHWT	no change	no change	no change	no change	no change	12 in
INCREASE AUTHORIZED FLOWS	no change	no change	no change	25%	50%	100%

NOTES:
1. Drainfield size reductions depend on achieving the results above for $CBOD_5$ and TSS. TN, TP and fecal coliform do not apply. (2/25/2011 – revised BH)

2/25/2011 01-15-2002

Additional Reference Materials

- EPA Design Manual – Onsite Wastewater Treatment and Disposal Systems, October 1980
  EPA/625/1-80-012
  http://www.epa.gov/nrmrl/pubs/625180012/625180012total.pdf

- EPA – Onsite Wastewater Treatment Systems Manual, February 2002
  EPA/625/R-00/008
  http://www.epa.gov/nrmrl/pubs/625r00008/html/625R00008.htm

- Florida Department of Health, Onsite Sewage Programs
  http://www.myfloridaeh.com/ostds/index.html

- Water Environment Research Foundation (WERF), Project Number 04-DEC-1, *Influent Constituent Characteristics of the Modern Waste Stream from Single Sources, 2009*
  http://www.werf.org/