



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

A – Basic Concepts in Wastewater Treatment

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Objectives

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 System

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Advantages and Importance of Onsite Systems

- Simple and effective wastewater treatment
- Minimal moving parts (for passive system)
- 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

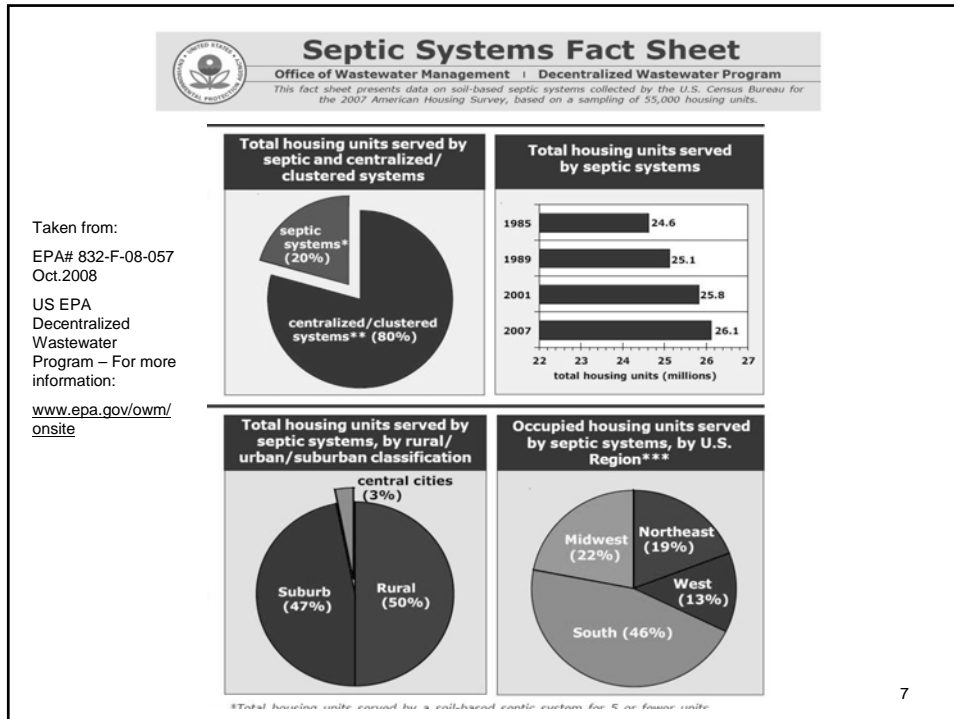
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“Public health and environmental protection officials now acknowledge that onsite systems are not just temporary installations that will be replaced eventually by centralized sewage treatment services, but permanent approaches to treating wastewater 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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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],[***Mayer et al.(1999)]

Onsite Sewage Treatment and Disposal Systems

- 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.

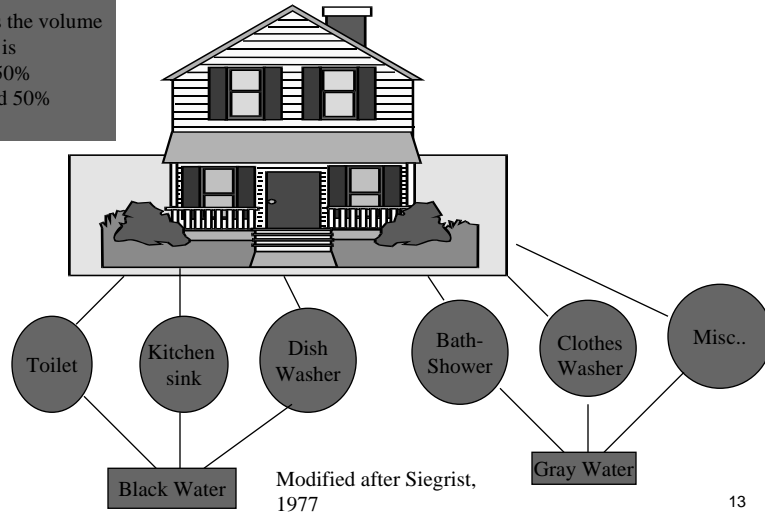


Table 3-3. Residential water use by fixture or appliance^{a,b}

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 ^e 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 ^f —	8.1 ^g 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 served 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.

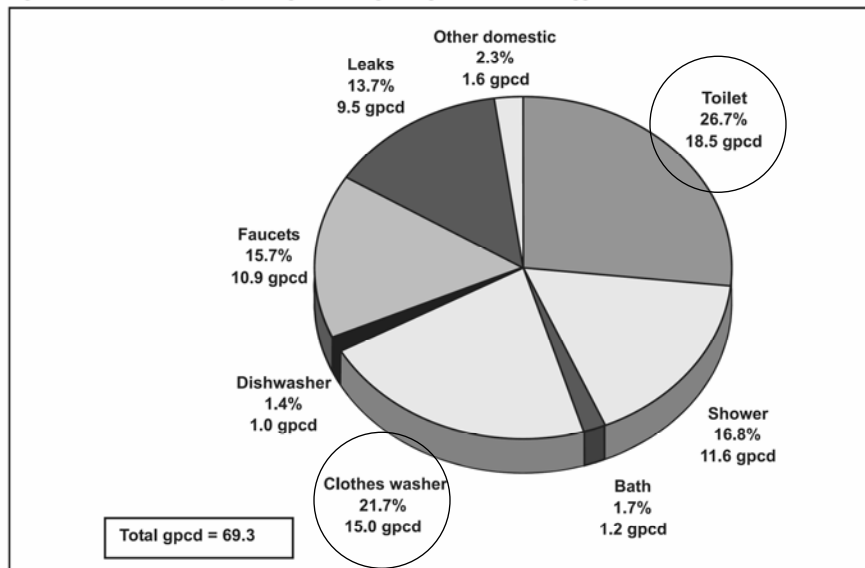
^d Includes shower and bath.

^e Gallons per minute.

^f Minutes of use per person per day.

Source: Mayer et al., 1999.

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.

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 (NH ₄), nitrates (NO ₃) and nitrites (NO ₂). 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.

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%)	
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%)	
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%)	
Total phosphorus ^d	mean	0.1	1.6	1.0	2.7
	range	—	—	—	
	% of total	(4%)	(59%)	(37%)	

^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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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.

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

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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

WERF, 2009

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Residential Influent Wastewater Concentrations (part 2 - nutrients)

<ul style="list-style-type: none"> ▪ Total Nitrogen 	60 mg/l
<ul style="list-style-type: none"> Organic N 	43 mg/l
<ul style="list-style-type: none"> Ammonia (NH₃) 	14 mg/l
<ul style="list-style-type: none"> Nitrate N (NO₃⁻) 	1.9 mg/l
<ul style="list-style-type: none"> ▪ Total Phosphorus 	10.4 mg-P/L

WERF, 2009

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Residential Influent Wastewater Concentrations (part 3 - microbes)

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

•Canter & Knox 1985

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Waterborne Pathogens found in Human Waste and associated Diseases

Type	Organism	Disease
Bacteria	<i>Escherichia coli</i> (enteropathogenic)	Gastroenteritis
	<i>Legionella pneumophila</i>	Legionellosis
	<i>Leptospira</i>	Leptospirosis
	<i>Salmonella typhi</i>	Typhoid Fever
	<i>Salmonella</i>	Salmonellosis
	<i>Shigella</i>	Shigellosis
	<i>Vibrio cholera</i>	Cholera
	<i>Yersinia enterocolitica</i>	Yersinosis

Source: USEPA, 1999

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Waterborne Pathogens found in Human Waste and associated Diseases

Type	Organism	Disease
Protozoans	<i>Balantidium coli</i>	Balantidiasis
	<i>Cryptosporidium</i>	Cryptosporidiosis
	<i>Entamoeba histolytica</i>	Amoebic dysentery
	<i>Giardia lamblia</i>	Giardiasis
	<i>Naegleria fowleri</i>	Amoebic Meningoencephalitis

Source: USEPA, 1999

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Waterborne Pathogens found in Human Waste and associated Diseases

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

Source: USEPA, 1999

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Forms of viral hepatitis - exposure routes

- Hepatitis A
- Hepatitis B
- Hepatitis C
- Delta- Hepatitis
- Hepatitis E
- SewAge (fecal-oral)
- Blood-borne
- Transfusions
- Blood & plasma
- Contaminated water (fecal-oral)

IN: Benenson, 1990

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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

Plews, 1977

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Typical Septic Tank effluent bacterial counts (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 Events

Boyle, Siegrist & Witt, 1976

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.

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Total Nitrogen in Effluent

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

1993 Florida OSTDS Study

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	Nitrogen Primarily in the form of:
Septic Tank Effluent	Ammonia (NH₃)
Aerobic Treatment Unit Effluent	Nitrate N (NO₃⁻)

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- ## Nitrate
- NOT RETAINED IN SOIL
 - MOVES WITH GROUND WATER
 - CREATED BY UNSATURATED SOILS AND AEROBIC UNITS
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Nitrate 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
- USEPA, 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, 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

EPA, 2002

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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: USEPA 2002

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Volatile Organic Compounds (VOC's)

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

Data from Florida's OSTDS research project

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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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PRETREATMENT

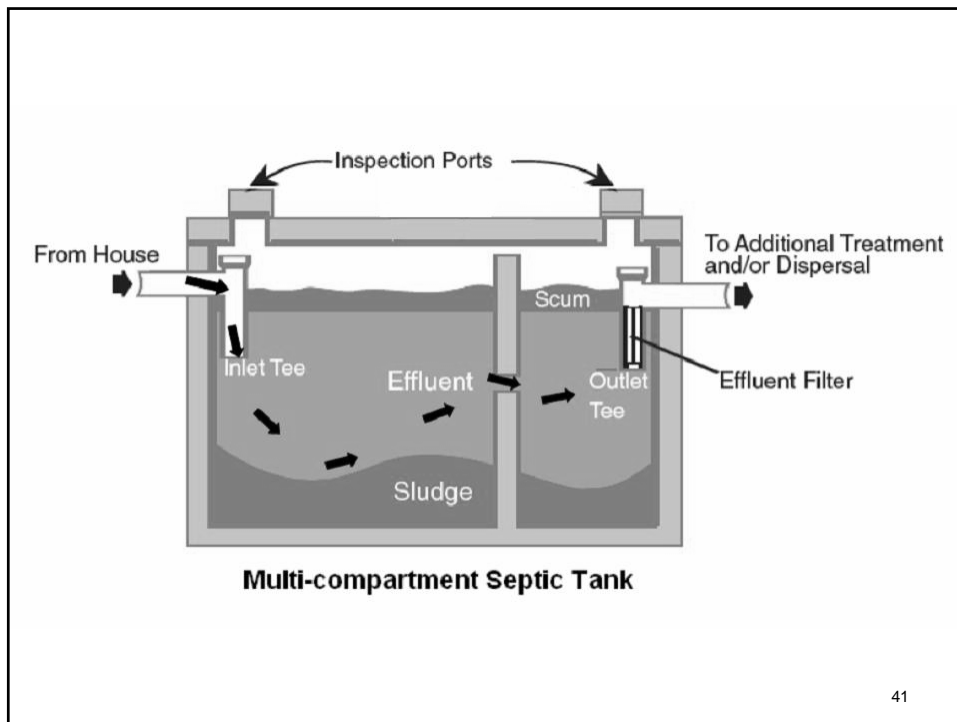
- occurs in treatment tanks
- septic tanks - provide primary treatment
- aerobic units - provide secondary treatment

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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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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

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 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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Septic Tank effluent characteristics

- remove nearly all the settleable solids
- fats, greases & floating debris removed
- soluble BOD₅ strength will increase due to anaerobic digestion

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Septic Tank Effluent

- 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

WERF, 2009

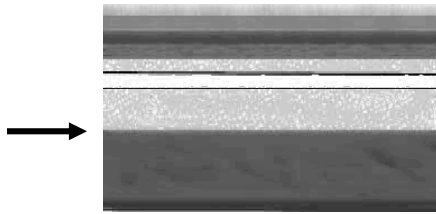
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Closer to the soil surface...

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

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Biomat: 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 .



- Clogging mat, clogging 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

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Table3-17. Examples of soil infiltration system performance

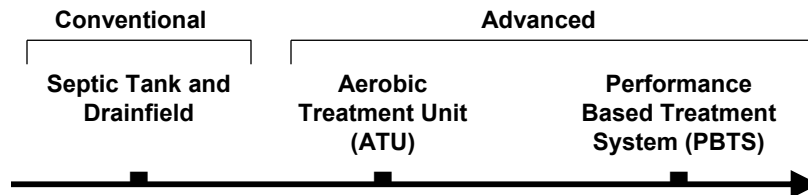
Parameter	Applied concentration in milligrams per liter	Percent removal	References
BOD ₅	130-150	90-98	Siegrist et al., 1986 U. Wisconsin, 1978
Total nitrogen	45-55	10-40	Reneau 1977 Sikora et al., 1976
Total phosphorus	8-12	85-95	Sikora et al., 1976
Fecal coliforms	NA ^a	99-99.99	Gerba, 1975

^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 Onsite



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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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Aerobic Unit effluent meets national secondary standards – NSF Standard 40

- 25 mg/L BOD₅ (versus 140 mg/L septic)
- 30 mg/L TSS (versus 75 mg/L septic)
- 99.9% microbial reduction
However, this is not disinfection

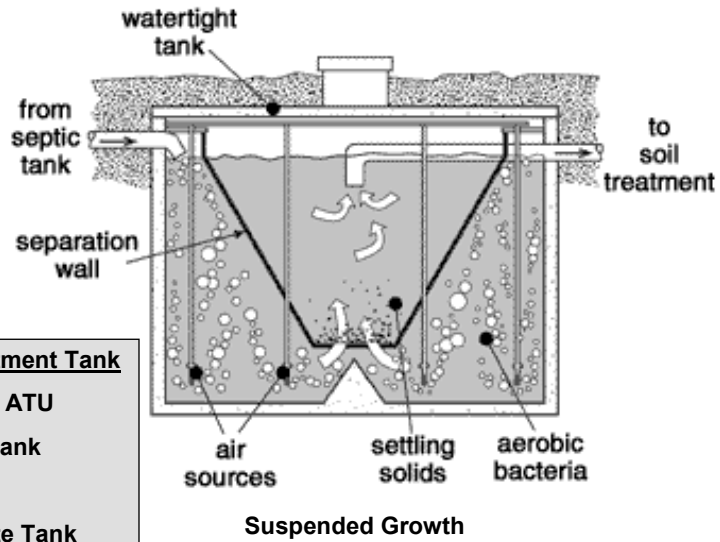
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Steps in Aerobic Treatment

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

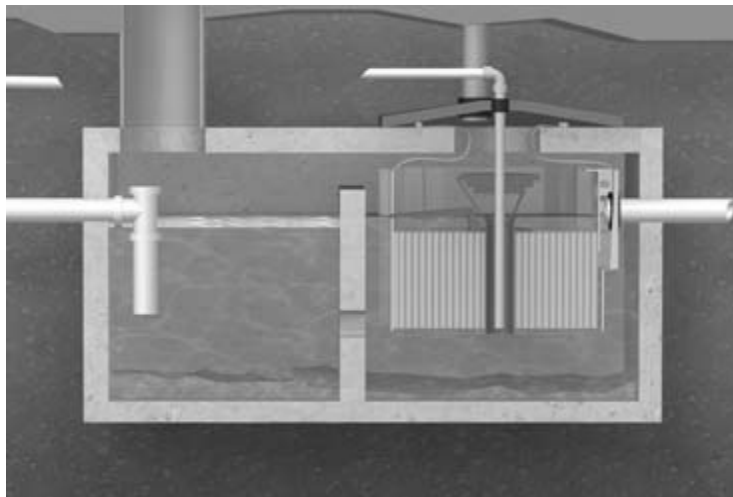
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Aerobic Treatment Unit (ATU)



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Aerobic Treatment Unit (ATU)



Attached Growth

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Aerobic Treatment Units

Incentives/ Advantages	Disincentives/ Addn. requirements
<ul style="list-style-type: none"> ▪ Much higher treatment (greater reduction in BOD and TSS) ▪ Can extend drainfield life ▪ Reduced drainfield ▪ Replacement system in areas with chronic failing septic tanks 	<ul style="list-style-type: none"> ▪ 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.

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Performance Based Treatment Systems (PBTS)

- a specialized onsite sewage treatment and disposal system designed by a professional engineer with a background in wastewater engineering, licensed in the state of Florida, using appropriate application of sound engineering principles to achieve specified levels 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 measurable established performance standard. This term also includes innovative systems.
Chapter 64E-6.025(10)

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Performance Based Treatment Systems (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

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PERFORMANCE STANDARDS						
POLLUTANT	BASELINE SYSTEM STANDARDS	BASELINE SYSTEM STANDARDS	AEROBIC TREATMENT UNIT	SECONDARY TREATMENT STANDARDS	ADVANCED SECONDARY TREATMENT STANDARDS	ADVANCED WASTEWATER TREATMENT STANDARDS
	Septic tank effluent	@ base of 24 inch unsaturated zone	(effluent)	(effluent)	(effluent)	(effluent)
CBOD₅ (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 groundwater drains dry retention & swales	no change no change no change	no change no change no change	no change no change no change	65 ft no change no change	50 ft 10 ft 10 ft	25 ft 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 CBOD₅ and TSS. TN, TP and fecal coliform do not apply. (2/25/2011 – revised BH)

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, Bureau of 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/>