REVIEW OF TECHNOLOGIES FOR THE ONSITE TREATMENT OF WASTEWATER IN CALIFORNIA

Prepared for the California State Water Resources Control Board

Center for Environmental and Water Resources Engineering
Department of Civil and Environmental Engineering
University of California, Davis
Davis, California

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NOTICE

Funding for this project has been provided by the State Water Resources Control Board (SWRCB). The contents of this document do not necessarily reflect the views and policies of the SWRCB, nor does mention of trade names or commercial products constitute endorsement or recommendations for use.

CONTENTS

ACRONYMS

Acronym	Meaning
α	Recirculation ratio
ATU	Aerobic treatment unit
BOD	Biochemical oxygen demand
BOD_5	Five day biochemical oxygen demand
$CBOD_5$	Carbonaceous five day biochemical oxygen demand
CFU	Colony forming unit
COD	Chemical oxygen demand
CWC	California Water Code
DF	Dosing frequency
DO	Dissolved oxygen
ES	Effective size
ETV	Environmental technology verification
FC	Fecal coliform
HAR	Hydraulic application rate
HLR	Hydraulic loading rate
LECA	Light expanded clay aggregate
LWA	Light weight aggregate
MPN	Most probable number
NH_3-N	Nitrogen as ammonia
NO_2-N	Nitrogen as nitrite
NO_3-N	Nitrogen as nitrate
NSF	National Sanitation Foundation
NTU	Nephelometric turbidity units
OLR	Organic loading rate
O&M	Operation and maintenance
ON	Organic nitrogen
PBF	Packed bed filter
PFU	Plaque forming unit
pH	Inverse log concentration of hydrogen ions
PLC	Programmable logic controller
PVC	Polyvinyl chloride
RF	Roughing filter
RSF	Recirculating sand filter
SBR	Sequencing batch reactor
SRT	Solids retention time
SWRCB	State Water Resources Control Board
TC	Total coliform

Acronym	Meaning
TF	Trickling filter
TKN	Total kheldahl nitrogen
TN	Total nitrogen
TP	Total phosphorus
TSS	Total suspended solids
UC	Uniformity coefficient
UV	Ultraviolet

TABLES

FIGURES

EXECUTIVE SUMMARY

The State Water Resources Control Board (SWRCB) of California contracted with the Department of Civil and Environmental Engineering to conduct a review of onsite wastewater management systems. The results of the study are contained in this report. The information and findings presented in this report were derived from (1) information supplied by manufacturers, (2) the results of independent testing and reporting, and (3) information reported in conference proceedings and journals. Performance information from the report is summarized in the tables presented below.

The characteristics of typical septic tank effluent are provided in Table ES-1. A system for rating system performance is presented in Table ES-2. Available information on treatment system performance has been summarized in Table ES-3. When data were not available the performance rating was left blank.

Table ES-1
Characteristics of typical residential wastewater[a]

Constituent	Unit	Untreated	Septic tank effluent without effluent filter	Septic tank effluent with effluent filter
BOD_5	mg/L	450	185	135
TSS	mg/L	503	83	42
TN as N	mg/L	70.4	70	70
TP as P	mg/L	17.3	16	16
FC	no./100 mL	10^6	10^6	10^6

[a] Adapted from Crites and Tchobanoglous (1998).

Table ES-2
Classification system for onsite wastewater treatment system performance[a]

Rating	Biochemical oxygen demand (BOD), total suspended solids (TSS), and total nitrogen (TN)	Total phosphorus (TP)	Fecal coliform (FC)
A	< 10 mg/L	< 2 mg/L	< 2
B	< 20 mg/L	< 5 mg/L	< 800
C	< 30 mg/L	< 10 mg/L	< 2000
D	> 30 mg/L	> 10 mg/L	> 2000

[a] Based on values obtained from operational systems, independent certifications, and experimental systems.

Table ES-3
Summary of onsite wastewater treatment system performance

System description	Domain status	Status of technology	Expected performance[a, b] BOD	TSS	TN	TP	FC[c]
Anoxic systems							
5-1.1 AWT Anoxic	Proprietary	In use			A		
5-1.2 Nitrex filter	Proprietary	In use			A		
5-1.3 Rock tank	Public	In-use			A		
5-1.4 RUCK	Proprietary	In use	C	C	B	B	D
Anaerobic systems							
5-2.1 Glendon biofilter	Proprietary	In use	A	A			B
5-2.2 UASB	Public	In-use	D				
Granular media, single-pass trickling biofilter systems							
6-1.1 Activated Carbon	Pubic	Experimental					A
6-1.4 Crushed brick	Public	Experimental	C	C		A	
6-1.7 Expanded Aggregate	Public	In use	B	B	C	A	
6-1.8 Glass (crushed)	Public	In use			C		
6-1.9 Glass (sintered)	Public	Experimental					B
6-1.11 Phosphex	Proprietary	In use				A	
6-1.13 Sand (uniform)	Public	In use	A	A			B
6-1.14 Sand (stratified)	Public	In use	A	A			B
6-1.15 Slag	Public	Experimental	B	B			
6-1.16 Zeolites	Public	Experimental					
Granular media, multi-pass trickling biofilter systems							
6-1.2 AIRR (sand)	Proprietary	In use	A	A			
6-1.3 Ashco-A RSF III	Proprietary	In use					
6-1.5 EnviroFilter	Proprietary	In use	A	A	C		
6-1.6 Eparco	Proprietary	In use					
6-1.7 Expanded Aggregate	Public	In use	B	B	C		
6-1.8 Glass, crushed	Public	In use	B	B	C		
6-1.10 Gravel	Public	In use	A	A	C		D
6-1.12 RIGHT	Proprietary	In use	A	A	C		
Organic media trickling biofilter systems							
6-2.1 Ecoflo	Proprietary	In use	A	A			D
6-2.2 Eco-Pure	Proprietary	In-use	A	A			B
6-2.3 Peat	Public	In use	B	B	B	C	A/B

System description	Domain status	Status of technology	Expected performance[a, b]				
			BOD	TSS	TN	TP	FC[c]
6-2.4 Puraflo	Proprietary	In use	A	A	D	D	C
6-2.5 Woodchip	Public	Experimental					
Synthetic media trickling biofilter systems							
6-3.1 Advantex	Proprietary	In use	A	A	A/B	D	D
6-3.2 Aerocell	Proprietary	In use					
6-3.3 Bioclere	Proprietary	In use	C	C	C	C	D
6-3.4 Rubber, shredded	Public	Experimental					
6-3.5 SCAT	Proprietary	In-use					
6-3.6 SeptiTech	Proprietary	In use					
6-3.7 Waterloo Biofilter	Proprietary	In use	A	A	B/C	C	C/D
Continuous flow suspended growth aerobic treatment systems							
7-1.1 AeroDiffuser	Proprietary	In use	A	B			
7-1.2 AES BESTEP	Proprietary	In use	A	A	B	C	
7-1.3 Alliance	Proprietary	In use	A	B			
7-1.4 BEST 1	Proprietary	In use	C	C			
7-1.5 Bi-A-Robi	Proprietary	In-use					
7-1.6 Brooks	Proprietary	In use	A/B	A/B			
7-1.7 Clearstream	Proprietary	In use	A	A			
7-1.8 Envirocycle	Proprietary	In use	A	A	C	D	
7-1.9 Hydro-action	Proprietary	In use	A	A/B			
7-1.10 JET Commercial	Proprietary	In use	B	B			
7-1.11 Mighty Mac	Proprietary	In use	A	A/B			
7-1.12 Modulair	Proprietary	In use					
7-1.13 Mudbug	Proprietary	In use	B	B			
7-1.14 Multi-flo	Proprietary	In use	A	A			B/C
7-1.15 Navadic	Proprietary	In use	A	A	A		
7-1.16 Singulair	Proprietary	In use	A	A			
7-1.17 Solar Air	Proprietary	In use	B	B			
7-1.18 USBF	Proprietary	In-use	A	A	A	A	
7-1.18 Whitewater	Proprietary	In use	A	A			
Sequencing batch reactor suspended growth aerobic treatment systems							
7-2.1 ABJ ICEAS	Proprietary	In use					
7-2.2 Aquarobic	Proprietary	In use	A	A			
7-2.3 Chromaglass	Proprietary	In use	A	A	A		

System description	Domain status	Status of technology	Expected performance[a, b]				
			BOD	TSS	TN	TP	FC[c]
7-2.4 EnviroSBR	Proprietary	In use					
7-2.5 NitroRaptor	Proprietary	In use	C	C	B		
7-2.6 SYBR AER	Proprietary	In use	A	A			
7-2.7 Thomas TRD	Proprietary	In use	A	A	B	A	B
Membrane bioreactor suspended growth aerobic treatment systems							
7-3.1 Kubota	Proprietary	In use	A/B	A	A	A	A
7-3.2 Zenon	Proprietary	In use	A/B	A	A	A	A
Continuous flow suspended growth with fixed internal packing							
8-1.1 Bio-fosse	Proprietary	In use					
8-1.2 Biomax	Proprietary	In use					
8-1.3 BioSorb	Proprietary	In use					
8-1.4 BTX Biotreater	Proprietary	In use					
8-1.5 EcoKasa	Proprietary	In use					
8-1.6 MicroFast	Proprietary	In use	B	A	B	B/C	D
8-1.7 JET BAT	Proprietary	In use	B/C	B/C	C	B	
8-1.8 Pirana	Proprietary	In use					
Continuous flow suspended growth with suspended internal packing							
8-2.1 Biogreen	Proprietary	In use	A		C	B/C	
8-2.2 Eco-kleen	Proprietary	In use					
8-2.3 Enviroserver	Proprietary	In use	A	A	A/B	A	A/B
8-2.4 Nibbler	Proprietary	In use	C	C	C		
Rotating biological contactors							
8-3.1 Biokreisel	Proprietary	In use	A	A	B/C	D	
8-3.2 Biorotor	Proprietary	In use					
8-3.3 CMS Rotordisk	Proprietary	In use					
8-3.4 Five Star KR505	Proprietary	In use					
8-3.5 Klargester Biodisk	Proprietary	In use	A	A/B	B	C	
8-3.6 Rotofix	Proprietary	In use					
Sequencing batch reactor with attached growth process							
8-4.1 Amphidrome	Proprietary	In use	B	A	B		D
Natural systems							
SF wetlands	Public	In-use	B	B	A	A	
SSF wetlands	Public	In-use	B	B	A	A	
Ecological systems	Proprietary	In-use	A	A	A	A	

System description	Domain status	Status of technology	Expected performance[a, b]				
			BOD	TSS	TN	TP	FC[c]
Evapotranspiration	Public	In-use	A	A	A	A	A
Lagoons	Public	In-use	C/D	C/D			

[a] Based on review of independent data from operational and experimental systems.

[b] Performance rating based on notation outlined in Table ES-2.

[c] Note that any process can eliminate fecal coliform with the addition of an effective disinfection process.

CHAPTER 1
INTRODUCTION

Approximately 3.5 million residents of California use onsite wastewater management systems. Onsite wastewater management systems can adequately provide water quality and environmental protection when properly designed, sited, constructed, maintained, and operated. However, when these conditions are not met, discharges from onsite systems may cause water quality impairments. Such impairment may include degradation of groundwater and surface water by nutrients, pathogenic microorganisms, pharmaceuticals, hormones, and other organic wastewater contaminants.

As development and population densities continue to increase in California, additional measures will be necessary to protect public health and environmental resources for persons living in the urban fringe and in rural areas not served by centralized wastewater collection systems. Recognizing the importance of onsite systems in California, Assembly Bill 885 was passed by the California legislature which added sections 13290 to 13291.5 to the California Water Code (CWC) (September 2000). This legislation requires the State Water Resources Control Board (SWRCB) to set minimum State standards for onsite sewage disposal systems by January 1, 2004. This action by the legislature will require codification of the standards as regulations in the California Administrative Code or implementation as statewide policy as well as completion of the California Environmental Quality Act process.

The purpose of this study is to compile information on onsite system technologies to assist the SWRCB staff in setting minimum standards for onsite wastewater treatment systems by the legislative deadline.

1-1 Background

For onsite wastewater treatment systems to be effective, they need to meet certain criteria. The factors identified in Table 1-1, presented on the following page, should be considered when selecting an onsite wastewater treatment system. With proper oversight, onsite wastewater treatment systems can provide high levels of treatment, including the removal of organic material, nutrients, and pathogenic organisms. Ongoing management of onsite wastewater treatment systems is necessary to maintain optimum performance and long-term sustainability. Recent developments in web based telemetry monitoring systems will make centralized management of onsite systems a feasible option. The technologies identified in this report represent the state of the art in onsite wastewater management, and reflect the factors identified in Table 1.

1-2 Scope of report

The information and findings contained in this report were obtained from (1) manufacturers and distributors of onsite wastewater treatment products, (2) the results of independent testing and reporting, and (3) information reported in conference proceedings and journals.

1-3 Report organization

To provide the needed information on the available technologies the report has been organized in the following chapters.

1. Introduction
2. Reducing Wastewater Generation
3. Non-Discharging (Containment) Systems
4. Primary Treatment Systems and Appurtenances
5. Anoxic and Anaerobic Systems
6. Trickling Biofilters (Attached Growth Aerobic Treatment Systems)
7. Suspended Growth Aerobic Treatment Systems
8. Combined Suspended and Attached Growth Aerobic Treatment Systems
9. Natural Treatment Systems

10. Disinfection Systems
11. Soil Adsorption Systems and Components
12. Monitoring and Control Systems

Appendixes

Following the introduction, a discussion of methods and technologies that may be used to reduce wastewater generation is presented in Chapter 2. Systems that do not discharge wastewater, and thus do not require a soil adsorption system, are presented in Chapter 3. Septic systems and associated products are presented in Chapter 4. Biological treatment systems that utilize various combinations of anaerobic, anoxic, and aerobic processes are discussed in Chapters 5 through 9. Technologies used for wastewater disinfection are presented in Chapter 10. Soil based adsorption and treatment systems are presented in Chapter 11. Technologies used for monitoring and control of onsite treatment systems are presented in Chapter 12. Useful unit conversions are presented in the Appendix.

A summary of onsite wastewater treatment system performance is also presented in the Executive Summary, contained in the front matter of this report.

Table 1-1
Criteria for selecting an onsite wastewater treatment system

Criteria for selection of onsite systems	Comments
Overall footprint	How much land area will a treatment system occupy? Is there sufficient space available at the site in question?
Capacity in case of system or power failure	If a power outage were to occur, how would the treatment system be affected? How would the duration of the power outage affect the process? What is the storage capacity in the event of a power outage?
Expected treatment performance	What level of treatment is required of the treatment system to ensure that the receiving environment (e.g., groundwater) and human health will not be compromised? What is the fate of dissolved and suspended organic materials, nutrients, pathogenic and non-pathogenic organisms, metals, hormones, pesticides, food additives, pharmaceuticals, and other personal care products?
Electricity usage	What is the electricity demand required to obtain the desired performance? Will changes in the energy market affect the appropriateness of a treatment process?
O & M requirements	What level of service is required to ensure proper operation? Does servicing require a skilled technician? Can the system be monitored remotely and data transferred to a central data management system? What components will wear out and need to be replaced? Will replacement parts be available?
Costs	Does the effectiveness of the treatment system justify the capital and installation costs of the system?
Sludge production	Will sludge or other products of the system require offsite management? Who will perform this service and how much will it cost?

1-4 Acknowledgments

The SWRCB of California contracted with the Department of Civil and Environmental Engineering to conduct a review of onsite wastewater management systems through Todd Thompson, Division of Water Quality. The assistance of the following individuals and organizations is acknowledged gratefully.

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- Cecil Martin
- Chris Chaloupka

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- Olivia Virgadamo
- Erin Onieda

Outside reviewers
- Harold Ball
- Terry Bounds, and

The manufacturers, suppliers, and individuals who provided the information contained in this report.

Using water more effectively reduces both the need for high quality water and the amount of wastewater generated. Reducing the water sent to onsite wastewater treatment systems may improve the overall process performance by reducing the hydraulic loading and, in some cases, providing a more stable wastewater flow. The topics to be considered in this section include: (1) water usage, (2) water conserving fixtures, (3) low water appliances, (4) efficient water heaters, (5) water saving toilets and urinals, and (6) greywater separation.

2-1 Water usage

The choice to use water more efficiently reduces water needs and wastewater generation. An important first step to water conservation is to realize how much water various activities use. A summary of common household water usage is presented in Table 2-1.

Table 2-1
Wastewater generation estimated by water usage for various activities[a]

	Water use, gal/cap·d	
Water usage	Conventional	Conservative
Toilet flushing	17.5	8
Bathing/showering	20	10
Bathroom sink	10	5
Dish washing		
Manual	20	10
Automatic	10	5
Clothes washing	15	7
Total	92.5	45

[a] The use of a water softener will increase water usage. In addition, the brine discharged from water softeners may inhibit the effectiveness of subsequent wastewater treatment processes.

Water saving activities can include
> Using clothes washing machines and dish washers at maximum capacity (newer appliances automatically sense and compensate for partial loads)
> Only using water for wetting and rinsing when showering
> Promptly repairing leaking faucets and toilet valves

Additional information on water usage and conservation can be obtained from the following organizations

2-1.1 WaterWiser

6666 West Quincy Avenue
Denver, CO 80235
Phone (800) 926-7337
Fax (303) 347-0804
E bewiser@waterwiser.org
Web www.waterwiser.org

Description

WaterWiser is a program of the American Water Works Association operated in cooperation with the U.S. Bureau of Reclamation. Website includes manufacturers of water conserving products and educational material database. Online drip calculator at http://www.waterwiser.org/books/wwdripcalc.htm

2-1.2 California Urban Water Council

H2OUSE website
E webmaster@cuwcc.org
Web www.h2ouse.org
Description

An excellent resource on water usage and conservation information.

2-1.3 Federal Energy Management Program

FEMP's Energy Cost Calculator
Web http://www.eren.doe.gov/femp/procurement/calc-index.html
Description

On-line water and energy savings calculator.

2-2 Flow reducers

Water saving fixtures and appliances are easy to install and can reduce the amount of water used for daily household activities. By reducing the amount of wastewater generated, treatment processes will be less likely to fail or have poor performance due to hydraulic overloading. The following is a partial list of organizations, manufacturers, and distributors who provide information and technologies for water conservation. Flow reducers and faucet aerators reduce the flow rate of water during normal faucet or shower usage. Flow control devices include in-line valves that allow the water flow rate to be set manually or in-line flow restrictors that restrict the flowrate.

2-2.1 AM Conservation Group

430 Sand Shore Road, Suite 7
Hackettstown, NJ 07840 USA
Phone (908) 852-6464; (908) 852-6244
Fax (908) 852-6444; (908) 852-7614
E amcg@nac.net
Web www.amconservationgroup.com
Description

AM Conservation distributes various water saving devices including faucet aerators, toilet flush volume reducing components, and accessories for more efficient irrigation.

2-2.2 Jet Blast Incorporated

6800 Fort Smallwood Road
Baltimore, Maryland 21226
Phone (410) 636-0816
Fax (410) 636-0819
E productsales@jetblast.net
Web www.jetblast.net
Description

Manufactures low flow shower heads, models less than 1 gallon per minute.

Figure 2-1

Examples of water saving devices (from left to right): in-line flow control valve, faucet aerator, faucet aerator with on-off control, and low flow showerhead. (Adapted from Niagara Conservation, Inc.)

2-2.3 Niagara Conservation

45 Horsehill Rd.
Cedar Knolls, NJ 07927
Phone (800) 831-8383; (973) 829-0800
Fax (973) 829-1400
E scotth@niagaraconservation.com
Web www.niagaraconservation.com
Description

Niagara is a manufacturer of high efficiency residential conservation products and developer of turnkey conservation solutions. A complete line of showerheads, faucet aerators, ultra-low-flow toilets, and high efficiency lighting products.

2-2.4 Real Goods

13771 S. Highway 101
Hopland CA 95449
Phone (707) 744-2017
Fax (707) 744-1682
Web www.realgoods.com
Description

Products and information on water and energy conservation.

2-3 Low water appliances

Dishwashers and washing machines are both available in low water (and low energy) models. Energy and water efficient dishwashers use between 5 and 8 gal/load. Many current dishwashers do not require pre-rinsing of dirty dishes, further reducing the amount of wastewater generated. Most washing machine manufacturers offer horizontal axis washing machines that reduce the volume of water used for clothes washing. In addition to energy savings, horizontal axis washing machines reduce water usage by an estimated 30 to 50 percent as compared to the vertical axis washing machine. Contact local appliance store for information on specific models. The cost of high-efficiency clothes washing machines is higher than conventional washers; however, state sponsored rebate programs can make the purchase price of water and energy saving appliances more competitive. In addition, the long-term savings can be significant. The magazine *Consumer Reports* (www.consumerreports.org) provides testing services, including water and energy usage for many appliances and may be used as a guide for model selection.

Figure 2-2

Examples of high efficiency washing machines: (left) 17.3 gal/load and 196 kWh/y (based on Energyguide estimate); and (right) 15.8 gal/load and 286 kWh/y (based on Energyguide estimate). Average water usage is 42.4 gal/load for a conventional washing machine. (Adapted from Sears, Inc.)

2-4 Efficient water heaters

Conventional plumbing systems require cold water to be purged from the line, while hot water travels from the hot water heater to the point of use. The cold water that exits the system (typically 3 to 7 gallons) while waiting for hot water, contributes to household wastewater generation. To reduce the amount of water that is discharged, technologies are available that either (1) heat the water at the point-of-use or (2) return cold water to the water heater.

Instant (point-of-use) hot water systems

Hot water heaters that heat water directly before use are known as instant, or point-of-use, hot water heaters. The water heater is located adjacent to the application where hot water is used. These systems can use either gas or electricity to heat water. When there is a hot water demand, the system is activated automatically and hot water is produced, reducing energy losses in the distribution system and cold water loss down the drain. In addition to those listed below, many manufacturers of appliances and plumbing supplies offer instant hot water dispensers.

Figure 2-3

Example of an under the sink point-of-use instant hot water heater. (Adapted from Controlled Energy Co.)

2-4.1 SETS

2500 E Commercial Blvd
Ft. Lauderdale, FL 33308
Phone (877) 666-8265
Fax (954) 772-5651
E sales@tankless-water-heater.com
Web www.tankless-water-heater.com
Description

The SETS Model 110 is an 11 KW two element water heater designed for point of use applications. It can be used in under-sink instant hot water applications in homes and offices in warmer climates.

2-4.2 Controlled Energy Corp.

340 Mad River Park
Waitsfield, VT 05673
Phone (802) 496-4436; (800) 642-3111
Fax (802) 496-6924
E sales@controlledenergy.com
Web www.controlledenergy.com
Description

Two models of instant electric water heaters, Ariston and Powerstream.

2-4.3 In-Sink-Erator®

4700 21st St
Racine, WI 53406-5093
Phone (800) 558-5700
Web www.insinkerator.com
Description

Several models of instant hot water heaters.

2-4.4 KithenAid®

1901 Minnesota Court
Mississauga, ON, Canada L5N 3A7
Phone (800) 461-5681
E appliances@kitchenaid.ca
Web www.kitchenaid.ca
Description

Hot water dispenser delivers water as hot as 190 ^{o}F at the tap, up to 3.75 gal per hour. Water flow stops automatically when knob is released.

Cold water return systems

For applications that use a hot water tank for heating water, cold water return devices can be installed to reduce wastewater. The cold water return concept uses a device that senses the temperature of the water (at the point-of-use) during a hot water demand. If the water temperature is less than a preset level, the water is returned to the hot water tank via the cold water supply line or a separate return line. After the water reaches the correct temperature, a valve is opened to allow hot water flow to the intended use. In addition, cold water return systems generally have a pump to accelerate the flow of hot water to the application.

2-4.5 ACT, Inc Metlund® Systems
3176 Pullman Avenue, Suite 119
Costa Mesa, California 92626
Phone (714) 668-1200; (800) 638-5863
Fax (714) 668-1927
E info@gothotwater.com
Web www.metlund.com
Description

The Metlund Hot Water D'MAND® System consists of an electronically controlled pump and valve assembly that allows for the rapid delivery of hot water to plumbing fixtures without the loss of cold water.

2-4.6 Central Plastics
245 Bateman Dr.
Central Point, OR 97502
Phone (800) 914-9887
E sales@chilipepperapp.com
Web www.chilipepperapp.com
Description

The Chilipepper™ recirculates cold water back to the water heater through the cold water line under your sink, shutting off before hot water enters the cold water line.

2-5 Water saving toilets and urinals
Various toilets and urinals are available that reduce or eliminate the amount of water used for flushing activities. Many of the products listed below were originally designed for mobile applications.

Waterless toilets, low flush toilets, and dual flush toilets and urinals
The companies listed below offer products that use much less water for flushing purposes than standard toilets and urinals.

2-5.1 Microphor, Inc.
452 East Hill Rd.
Willits, CA 95490 USA
Phone (707) 459-5563; (800) 358-8280
Fax (707) 459-6617; (707) 459-4365
E info@microphor.com
Web www.microphor.com
Description

Models available that use only 16 ounces, one quart or one half gallon of water per flush. They operate on compressed air, with rear or downward discharge and internal or remote flush activators, depending on the model selected.

2-5.2 Sealand Technology, Inc.
PO Box 38, Fourth St.
Big Prairie, OH 44611
Phone (330) 496-3211; (800) 321-9886
Fax (330) 496-3097
E sealand@sealandtechnology.com
Web www.sealandtechnology.com
Description

Vacuum flush toilets that use as little as one pint of water per flush.

2-5.3 Waterless Co.
1223 Camino Del Mar
Del Mar, CA 92014
Phone (888) 663-5874; (858) 793-5393
Fax (858) 793-5661
Web www.waterless.com
Description

Manufactures waterless urinals. Urinal is designed to allow urine to pass through into wastewater collection system, without the need to flush.

2-5.4 Caroma International
P.O.Box 97; Pascoe Vale South
Victoria 3044 Australia
Phone + 61 3 9926 5477
Fax + 61 3 9354 0017
E export@caroma.com.au
Web www.caroma.com.au
Description

Dual flush toilets in the United States, on average reduces water usage to 1 gallon per flush.

2-5.5 Ecotech
Phone (978) 369-3951
E ecotech@ecological-engineering.com
Web www.ecological-engineering.com/ecotech.html
Description

Distributors of various low flush and waterless toilets including Nepon foam flush toilet, Sealand, dry toilets, and bowl liners (for custom toilets).

2-5.6 Envirovac Inc.
1260 Turret Drive
Rockford, IL 61115-1486
Phone (815) 654-8300
Fax (815) 654-8306
E building@evac.com
Web www.envirovacinc.com
Description

Evak Vacuum-Flush toilet system

Urine separating toilets

Urine separation is often used with composting toilet systems and in dry toilets. Because urine contains a large amount of the nitrogen in household wastewater (up to 90 percent), separation of this fluid may make it possible to treat or reuse the high nitrogen component of the wastewater in a separate process. In other countries source separated urine is being used as a fertilizer in agricultural systems. The urine is stored in large cisterns and periodically pumped out for reclamation. A small nitrifying filter may be used to convert the nitrogen to a non-volatile form, making the urine more valuable for agricultural application. In areas that are sensitive to nitrogen loading, urine diverting toilets offer an interesting alternative to advanced wastewater treatment processes which attempt to denitrify.

Figure 2-4

Typical view of a urine diverting toilet (left) and a cistern for collection of urine located in the basement of a building. (Adapted from EcoTech.)

2-5.7 Servator Separett AB

Skinnebo, SE-330 10
Bredaryd, Sweden
Phone +46-371-71220
Fax +46-371-71260
E info@separett.com
Web www.separett.com
Description
Waterless and urine separating toilet system.

2-5.8 EcoTech

50 Beharrell Street
Concord, MA 01742-2973
Phone (978) 369-3951
Fax (978) 369-2484
E ecotech@ecological-engineering.com
Web www.ecological-engineering.com
Description
Urine diverting, micro-flush and waterless toilets made by Ekologen of Sweden.

2-6 Greywater separation and dual plumbing

Greywater is water from non-toilet sources and accounts for a majority (60 to 80 percent) of the household wastewater. Wastewater from toilets, kitchen sinks, dishwashers, and the laundry of diapers is not included in greywater. Source separation of greywater and blackwater can provide more options for the onsite management of wastewater. In California, the standards for greywater systems are part of the State Plumbing Code. The most common use of greywater is for the irrigation of non-edible landscape plants.

Description of process

A number of possibilities exist for greywater usage, including (1) collection of household washwater in buckets for indoor (toilet flushing) or outdoor usage (irrigation), (2) a hose from indoor greywater source directly draining to outdoor application, and (3) a greywater collection and treatment system followed by subsurface irrigation. The third option is the type of greywater system approved for use in California. In this system, greywater is collected in a separate plumbing system. The treatment generally consists of some type of filtration, a surge tank, and landscape distribution.

Advantages

Greywater systems can significantly reduce the amount of wastewater that needs to be handled with a wastewater treatment system. Using greywater for landscape irrigation can alleviate water demand in areas that are prone to water shortages. Greywater systems are relatively inexpensive when included during building construction.

Disadvantages
Existing buildings may be difficult or impossible to retrofit with a greywater system. Greywater systems may not be appropriate in all areas. If not maintained, greywater systems may create human and environmental health problems.

Performance
Because greywater is not combined with wastewater from toilets and kitchens, it contains less carbon, nutrients, and pathogens. Subsurface application of greywater is considered to be a safe practice.

Operation and maintenance
Standard operation consists of being aware of what materials are being added to the greywater system and cleaning or changing of filtration devices. Simple greywater systems will require much less maintenance than mechanically intensive systems, however, simple systems may not be consistent with local codes.

Power and control
Some greywater systems may use pumps for movement of greywater to filtration systems and/or to irrigation systems.

Cost
Commercial greywater treatment and landscape irrigation systems (approved in California) are available for $2,000 to 3,000, not including shipping and installation. The cost to install a separate plumbing system should also be included and will vary depending on site characteristics.

2-6.1 Center for Ecological Pollution Prevention
P.O. Box 1330
Concord, MA 01742
Phone 978/318-7033
Web www.cepp.cc
Description
WashWater Garden uses an engineered system for evapotranspiration of wastewater.

Fig 2-5
The WashWater Garden™ greywater treatment system. (Adapted from CEPP.)

2-6.2 Oasis Design
5 San Marcos Trout Club
Santa Barbara, CA 93105-9726
Phone (805) 967-9956
Fax (805) 967-3229
Web www.oasisdesign.net
Description
Greywater information including literature, consulting services, and other resources.

2-6.3 Clivus Multrum Inc

15 Union Street
Lawrence, MA 01840
Phone (978) 725-5591
Fax (978) 557-9658
Web www.clivusmultrum.com
Description
A greywater treatment system.

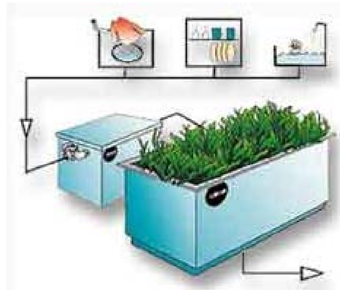


Figure 2-6
Diagram of the Clivus Multrum greywater treatment system. (Adapted from Clivus Multrum, Inc.)

2-6.4 ReWater Systems, Inc.

477 Marina Parkway
Chula Vista, CA 91910
Phone (619) 585-1196
Fax (619) 585-1919
E stevebilson@earthlink.net
Web www.rewater.com
Description
Provides design and installation of approved greywater filtration and subsurface drip irrigation system.

Figure 2-7
The ReWater filtration system and irrigated landscape. (Adapted from ReWater Sys Inc.)

2-6.5 Equaris Corporation

1740 Magnolia Lane North
Plymouth, MN 55441
Phone 763-383-5136
Fax 763-383-5155
E mail@equaris.com
Web www.equaris.com
Description
Equaris supplies complete greywater treatment and recycling systems.

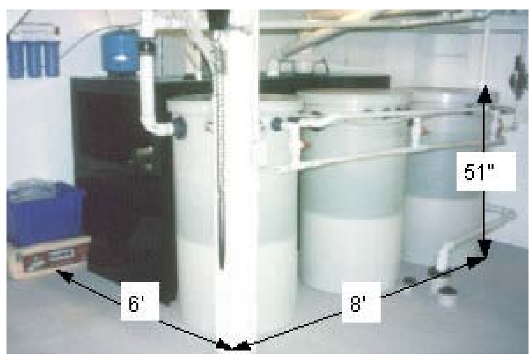


Figure 2-8
The Equaris greywater treatment system. (Adapted from Equaris, Inc.)

References

California Plumbing Code, Title 24, Part 5, California Administrative Code.

Del Porto, D., and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA.

Los Angeles Department of Water Reclamation (1992) Graywater Pilot Project Final Report.

Ludwig, A. (1998) *Create an Oasis with Greywater*, Poor Richards Press, Santa Maria, CA.

CHAPTER 3
NON-DISCHARGING (CONTAINMENT) SYSTEMS

Non-discharging systems may be preferred or the only option in areas where the use of onsite wastewater management systems may not be feasible. Collection and processing of human waste without water can reduce the size of wastewater management systems and produce a material that can be used for landscaping purposes. The amount of maintenance required and the level of sophistication involved should be considered carefully when selecting such systems. Systems considered in this section include: (1) composting toilets, (2) incinerating toilets, and (3) vault toilets and holding tanks.

3-1 Composting toilets

Composting toilets are also known as dry toilets, moldering toilets, waterless toilets, and biological toilets. There are a wide variety of styles and configurations available, ranging from simple bucket-type systems to multi-toilet centralized composting systems. In general, these systems are more common in countries interested in ecological sanitation and in areas that have limited water resources for toilet flushing. In most composting systems, food waste is a natural addition. There are several ways to define composting toilet systems, including (1) by the location of the composting unit relative to the toilet (self-contained vs. centralized), (2) by the method in which the material is composted (continuous vs. batch), and (3) by the level of sophistication (passive vs. intensive). These concepts are discussed below.

Location of the composting unit

Self-contained systems are basically an integrated toilet seat positioned over the composting reactor. These units are generally easy to install because they sit on the floor and require only a vent pipe and leachate effluent tube. Centralized systems are somewhat more complex because the composting unit is located in a separate area, somewhat independent of the toilet. The most common example of this configuration is locating the composting unit in a basement with the toilet on the floor above. Depending on the method of waste transport (i.e., gravity, water, air pressure), the toilet may be directly above, offset above, or on the same level as the composting unit.

Method of composting

Continuous composting systems are based on the principle that new material is added to the top of the composting mass and finished material is removed from the bottom. The concern with this type of system is that the material removed from the bottom, presumably finished, may be contaminated with freshly deposited material. Batch composting systems make it less likely for contamination to occur. Material is collected for a period of time and then set aside for months or years while the composting process occurs.

Level of sophistication

Passive systems use little or no electricity, are manually turned or not turned at all, and collect urine in a separate container for alternate use. Intensive systems utilize electro-mechanical systems for turning and mixing the composting material, leachate evaporation, moisture content regulation, and air circulation.

3-1.1 Aquatron

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Wastewater directly from toilet
Function	Aerobic decomposition; disinfection of liquid
Applications	Individual systems, larger buildings

Background/description of process
The Aquatron composting toilet uses a small amount of water to transport toilet waste through a solid/liquid separation device. The solids are sent to a chamber for composting (with or without worms), and the liquid is passed through a UV disinfection unit. The liquid may then be discharged with household greywater.

System footprint
The liquid/solid separation device is located in a basement or lower level. For a household or other small application, the separation and composting unit is about 2 ft in length, 2.3 ft in width, and 4.3 ft in height. A small UV disinfection unit may also be used. Toilets are located above the separation/composting unit and drain by gravity.

Advantages
The Aquatron composting toilet systems utilize standard 1 to 1.5 gal/flush toilets. Solids are separated in-line and composted. A septic tank is not required.

Disadvantages
System may require more maintenance than a standard septic system. Need for effluent and greywater management still exists. Odors and clogging issues will need to be addressed if they develop.

Performance
Efficient process for solids separation and composting. System effluent is disinfected and amenable to greywater usage. Composted material may be used in garden or further composted before use in garden (depending on Aquatron model).

Operation and maintenance
System contents (composted solids) will need to be emptied occasionally, depending on use, typically once every year or two. If needed, worms will need to be added during system start-up. UV lamps will need to be changed periodically (every 4 or 5 years). System should be periodically inspected for clogging, insufficient liquid separation, or other malfunctions.

Power and control
The only power requirement is for UV disinfection system (2 bulb system). If unit is located below greywater system, a pump will be needed to move the liquid.

Contact
Aquatron International AB
Box 2086, SE-194 02
Uplands Vasby, Sweden
Phone +468 590 304 50
Fax +468 590 304 94
E info@aquatron.se
Web www.aquatron.se
Model description
- Aquatron 90, suitable for vacation/leisure homes or small households
- Aquatron 4x100, full composting, suitable for vacation/leisure homes or small households
- Aquatron 400, suitable for year-round households (or vacation homes)
- Aquatron 4x200, full composting, suitable for year-round households
- Aquatron 4x300, full composting for schools, day-care centers etc
- Aquatron 1200, suitable for schools, day-care centers, small office buildings etc
- Aquatron 3000, suitable for installations in particularly sensitive environments
- Aquatron ALE, toilet and organic waste composting for large residential buildings

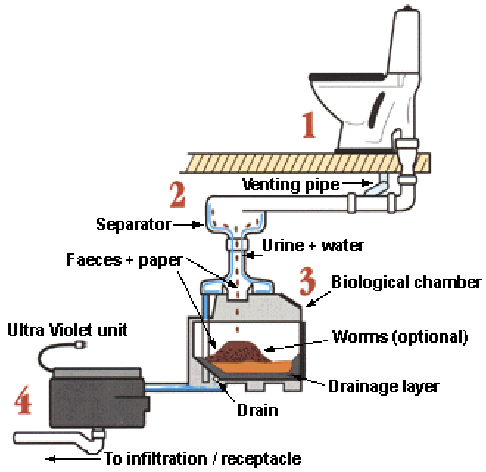


Figure 3-1

The Aquatron system for liquid/solid separation of human waste and biological composting. (Adapted from Aquatron International AB.)

References and other resources

Del Porto, D., and C. Steinfeld (1999) The Composting Toilet System Book, the Center for Ecological Pollution Prevention, Concord MA

3-1.2 Biolet

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Excrement and toilet paper
Function	Aerobic decomposition; liquid evaporation
Applications	Single home and small community residential systems

Background

BioLet composting toilets are on-site, self-contained, biological toilets, where human waste (feces, urine, and toilet paper) are collected, excess liquid is evaporated, and solid material is composted.

Description of process

Material is deposited directly into the composting chamber. A mixing arm turns the material to enhance the composting process. Finished compost falls through a screen and collects in a removable tray, and the leachate is evaporated by a small heater. A small fan is used to pull air through the unit and exhaust odors out a vent pipe. A view guard in the bottom of the toilet bowl hides the composting contents and opens automatically upon seat pressure.

System footprint

A small, self-contained unit. Typical dimensions are about 2.75 ft in length, 2.2 ft in width, and 2.25 ft in height. Additional space is needed for removing the drawer.

Advantages

It is a small unit, and is relatively inexpensive and easy to install. Toilet waste does not require any other management because all contents are composted or evaporated in the unit. The view guard improves aesthetics of the toilet. An exhaust fan helps to prevent odors. Previously NSF approved. Some units are available that do not use electricity.

Disadvantages
Contents will not be completely composted if overloaded. Electrical and moving components may fail and will eventually need to be replaced.

Performance
Material discharged includes finished compost and exhaust air. If overloaded, excess leachate and uncomposted materials will also need management. Finished compost less that 200 FC/g (per NSF standards).

Operation and maintenance
Composted material will need to be emptied several times a year under normal operating conditions. An amendment material is added to the unit at start-up and after each use. System should be inspected regularly for component failure or other operation problems. Incompletely composted material and leachate will need to be handled properly in case of overloading or improper operation.

Power and control
Electric units may have a 25 W exhaust and air circulation fan, a 40 W mixer motor, and 305 W heaters. Annual electrical usage expected to be 500 to 600 kWh. Non-electric units are manually operated and have no electricity usage.

Cost
Retail cost from $1000 to 1600, not including delivery and installation.

Figure 3-2
BioLet XL (electric) and the Biolet NE (non-electric). (Adapted from Biolet USA.)

Contact

Biolet USA, Inc.
150 East State St.; PO Box 548
Newcomerstown, OH 43832
Phone   (800) 524-6538
Fax   (740) 498-4073
E   info@biolet.com
Web   www.biolet.com

Real Goods
13771 South Hwy 101
Hopland, CA 95449
Phone   (707) 744-2100

Model description

Toilet	Full-Time	Part-Time	Type	Cost
BioLet XL	4 People	6 People	Electric	$1599
BioLet Deluxe	3 People	4 People	Electric	$1499
BioLet Standard	3 People	4 People	Electric	$1399
BioLet Basic	2 People	3 People	Non-Electric	$999
BioLet NE	4 - 6 People	4 - 6 People	Non-Electric	$999

Manufacturer support

Three year limited warranty and phone customer support.

References and other resources

BioLet product brochure; available from www.biolet.com.

Del Porto, D., and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

3-1.3 Bio-Recycler

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Excrement, toilet paper
Function	Aerobic decomposition; liquid evaporation; worm composting optional
Applications	Residential, sensitive areas

Background/description of process

System features a vacuum collection system, allowing the composting chamber to be located away from the building.

Advantages

Remote placement of composting chamber may reduce aesthetic concerns.

Disadvantages

Uses a compressor to power vacuum system

Contact

Bio-Recycler Co.
5308 Emerald Dr.
Sykesville, MD 21784
Phone (410) 795-2607

3.1-4 Bio-Sun®

Category	Non-discharging
Technology	Continuous feed composting toilet system
Input	Excrement, toilet paper, food waste
Function	Aerobic decomposition; liquid evaporation
Applications	Residential, institutional, commercial system, custom designed

Background/description of process

Materials to be composted are deposited into the compost chamber located below, generally in a basement. An air blower is used to provide positive aeration and accelerate the composting process.

System footprint
Custom made systems convert a portion of a concrete basement into an aerobic composting chamber. Systems are adapted to needs and space available.

Advantages
Aeration potentially results in faster composting process.

Disadvantages
Blower may be expensive if used continuously.

Operation and maintenance
Composting material must be raked to obtain even distribution in the composting chamber. Composted material will need to be removed occasionally.

Power and control
Blower used to provide positive aeration, no heating required.

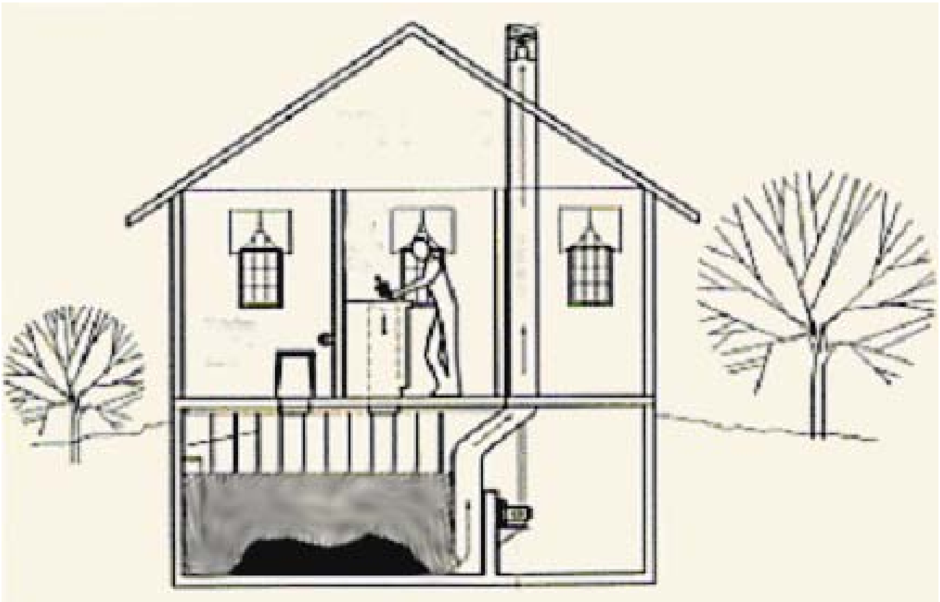


Figure 3-3

Diagram of the residential Bio-Sun composting toilet system. (Adapted from Bio-Sun Systems, Inc.)

Contact
Bio-Sun Systems, Inc.
Box 134A, Rd #2
Millerton, PA 16936
Phone   (800) 847-8840; (570) 537-2200
Fax   (570) 537-6200
E   bio-sun@ix.netcom.com
Web   www.bio-sun.com

References and other resources
Del Porto, D., and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

3-1.5 Clivus Multrum

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Excrement, toilet paper, food waste
Function	Aerobic decomposition; worm composting
Applications	Residential, institutional, sensitive areas

Background/description of process
One of the oldest and best known composting toilet systems. The composting chamber has a sloped floor, allowing material to compost as it moves down the reactor over time. The composting chamber is large, promoting long retention times for thorough composting. Finished material is removed by opening a door at the bottom end of the composter and removing the contents. Leachate drains and is collected form the bottom of the unit.

System footprint
System size varies depending on the unit selected (see model description below). Basic residential system is configured with composting reactor located in basement with toilet located directly above, with material falling directly into the composting system.

Advantages
The large composting chamber allows for longer composting times. Company is well established and NSF approved, possibly being easier to permit in some areas. Flushing system uses no or very little water.

Disadvantages
Continuous flow design could result in insufficient composting due to premature mixing. Toilet must be located directly above with composting unit. Excess leachate must be managed.

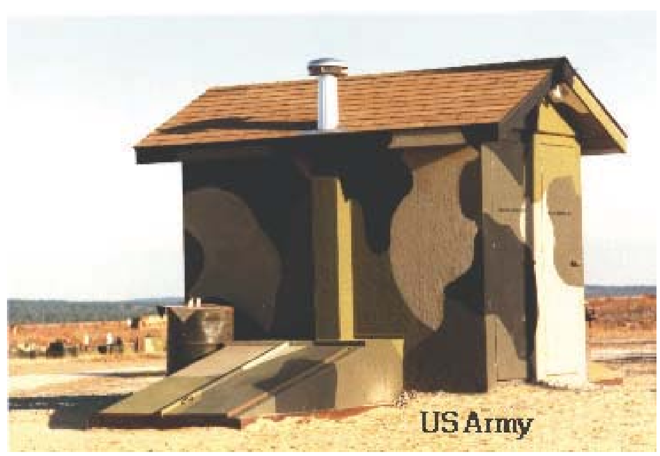


Figure 3-4

Clivus Multrum composting units, in-home residential system and system housed in separate building. (Adapted from Clivus Multrum, Inc.)

Performance
NSF approved system.

Operation and maintenance
Periodic compost removal, inspection, and cleaning.

Power and control
Process control devices include a fan to exhaust the composting chamber, water application to maintain correct composting moisture content, and a pump to remove accumulated leachate.

Cost
Residential systems range from about $2,500 to 5,000 (not including shipping and installation).

Contact
Clivus Multrum Inc.
15 Union Street
Lawrence, MA 01840
Phone (978) 725-5591
Fax (978) 557-9658
Web www.clivusmultrum.com
Model description (NSF certified models)

Model	Uses/day	Dimensions
Model M-1	10	height = 56 in; width = 33 in; length = 65 in
Model M-2	15	height = 66 in; width = 33 in; length = 65 in
Model M-12	80	height = 58.5 in; width = 62 in; length = 105 in
Model M-15	100	height = 99.5 in; width = 41 in; length = 119.5 in
Model M-18	120	height = 83 in; width = 62 in; length = 105 in
Model M-22	80	height = 64 in; width = 62 in; length = 115 in
Model M-25	100	height = 98.5 in; width = 41 in; length = 122 in
Model M-28	120	height = 89.5 in; width = 62 in; length = 115 in
Model M-32	110	height = 67 in; width = 70.5 in; length = 103 in
Model M-35	180	height = 89 in; width = 70.5 in; length = 103 in
Model M54ADA	60	composting toilet system inside of a building

References and other resources
Del Porto, D., and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

3-1.6 Composting toilet (site built)

Category	Non-discharging
Technology	Site-built composting toilet
Input	Excrement, toilet paper, food waste
Function	Aerobic decomposition; liquid evaporation
Applications	Residential, sensitive areas

Background/description of process
Plans are available for many types of composting toilet systems that can be built onsite. Systems are generally simple batch or continuous composting systems, requiring little or no electrical input. Common systems utilize 55 gallon drums or other large containers for collection and composting of material.

System footprint
Typical systems are composed of a toilet stool located above the compost reactor. The composting unit may be located outside of the building or in the basement. The reactor can be as simple as a 55 gal drum or wheeled container housed inside of a wood structure.

Advantages
Simple and inexpensive system to construct, many popular designs available. Can be constructed in part from salvaged materials.

Disadvantages
Requires regular operation and maintenance, depending on the specific type of system and usage. Not approved through NSF type certification. May be difficult to get approved by regulatory agencies. Design and construction not uniform.

Performance
Will vary depending on system type and usage.

Operation and maintenance
Typical operation and maintenance may include the exchange and emptying of receptacles upon filling, inspection for proper operation, and the addition of an amendment material to enhance the composting process.

Power and control
A small exhaust fan in generally used to disperse odors, if used intermittently, energy usage is minimal.

Cost
Depends on cost of plans and materials used, but typically $500 to1,000, not including labor.

Figure 3-5

Site built batch drum composting toilet system.
(Adapted from the Lama Foundation)

Contacts

Center for Ecological Pollution Prevention
P.O. Box 1330
Concord, MA 01742 USA
Phone (978) 318-7033
Web www.cepp.cc

National Water Center
5473 Hwy 23N
Eureka Springs, AR 72631
Phone (501) 253-9431
E peace@ipa.net
Web www.nationalwatercenter.org

The Center for Innovation in Alternative Technologies
Ave. San Diego No. 501
Col. Vista Hermosa, C.P. 62290 MEXICO
Phone (52-7) 322-8638
E cita@central.edsa.net.mx
Web www.laneta.apc.org/esac/citaing.htm

References and other resources

Del Porto, D., and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

Oasis Design (http://www.oasisdesign.net)

Van der Ryn, S. (1995) *The Toilet Papers: Recycling Waste and Conserving Water*, Ecological Design Press.

3-1.7 CTS

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Excrement, toilet paper, food waste
Function	Aerobic decomposition
Applications	Sensitive and remote areas

Background/description of process

The CTS composting system is similar in operation to the Clivus Multrum composting toilet. A waterless toilet is located directly above composting chamber. As material is deposited into the composting unit, it gradually moves down an incline while composting. Finished compost is removed from the bottom of the unit.

System footprint

Toilet must be located directly above the composting unit, for dimensions see model descriptions below.

Advantages

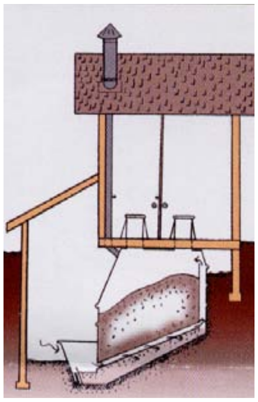
Relatively simple composting process with very few moving parts. Flushing system does not use water. Design adapted to remote areas and minimal maintenance.

Disadvantages

Continuous composting system is susceptible to contamination of finished compost with freshly deposited material.

Performance

Previously NSF approved.



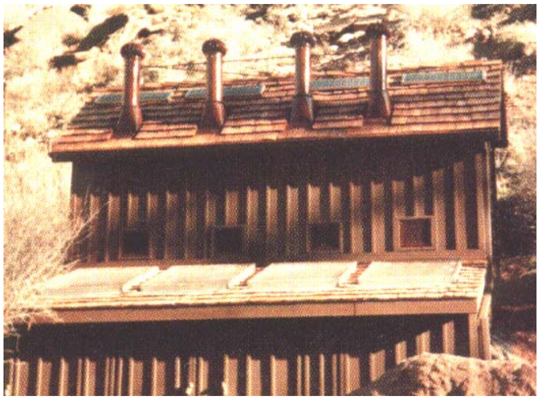


Figure 3-6

A diagram of the CTS composting toilet system (left) and a system installed in a remote area. (Adapted from CTS, Inc.).

Operation and maintenance
Finished compost will need to be removed from the unit periodically, system components should be inspected regularly for proper operation.

Power and control
An AC or DC/solar fan is used to promote air flow and exhaust odors. Fire suppression kits are also available for controlling temperature and moisture content.

Cost
Basic system (CTS 410) costs around $4,500 for the complete system.

Contact
Composting Toilet Systems, Inc.
PO Box 1928
Newport WA 99156-1928
Phone (509) 447-3708; (888) 786-4538
Fax (509) 447-3708
E cts@povn.com

Model description

Model	Uses/day	Dimensions
CTS 410	18	width = 4 ft; length = 9 ft; height = 6 ft;
CTS 710	40	width = 4 ft; length = 9 ft; height = 7 ft;
CTS 1010	75	width = 4 ft; length = 9 ft; height = 8 ft;
CTS 904	80	width = 5 ft; length = 9 ft; height = 5 ft;
CTS 914	120	width = 5 ft; length = 9 ft; height = 7 ft;

Manufacturer support
Five year limited warranty.

References and other resources
CTS product brochure

3-1.8 EcoTech Carousel

Category	Non-discharging system
Technology	Batch composting toilet
Input	Excrement, toilet paper, food waste
Function	Composting solids, liquid evaporation
Applications	Residential, sensitive areas

Background/description of process
Material is deposited directly into one chamber of a multi-sectioned composting chamber. Liquid passes through the perforated bottom into an evaporation chamber. After one section of the composter fills, the carousel is rotated so that an empty chamber may begin collecting waste.

System footprint
Small, medium, and large composting carousel sizes are available, depending on needs. Medium sized unit is approximately 25 in high with a diameter of 52 in, while the larger unit is 52 in tall with a diameter of 52 in.

Advantages
Batch style composting does not mix fresh material with finished compost material. The large composting chamber can accept material for long period of time before needing to be emptied.

Disadvantages
Composted material must be periodically removed from the composting chamber.

Performance
Large model previously NSF approved under standard 41.

Operation and maintenance
After two years of accumulation, composting chambers will need to be emptied every three months to one year. System will need to be checked to ensure proper operation of exhaust fans and heaters.

Power and control
Electrical components can include exhaust fans and heater. The carousel is rotated manually. Estimated 200 to 400 kWh annual power requirement.

Cost
Estimated cost for the composting system range from $2,100 to 3,500 (does not include toilet stool, installation, or delivery).

Figure 3-7

Diagrams of the EcoTech Carousel composting toilet. (Adapted from EcoTech.)

Contact
Ecotech
PO Box 1313
Concord, MA 01742-2968
Phone (978) 369-3951
E ecotech@ecological-engineering.com
Web www.ecological-engineering.com/ecotech/carousel.html

Model description

Small	2 people year round, 12 people weekend/vacation use
Medium	3 people year round, 15 people weekend/vacation use
Large	5+ people year round, 32 people weekend/vacation use

References and other resources

Del Porto, D., and C. Steinfeld (1999) The Composting Toilet System Book, the Center for Ecological Pollution Prevention, Concord MA

3-1.9 Envirolet™

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Excrement and toilet paper
Function	Aerobic decomposition; liquid evaporation
Applications	Residential, mobile applications

Background/description of process

The Envirolet composting toilet system is available in two basic configurations: self-contained and remote composting. The self-contained models sit directly on the floor and the material is composted in the unit. For the remote system, the composter is located in a separate area (e.g., outside or in a basement) and waste material is transported using a small amount of water. Features include a manual mixer and raking bar to enhance the composting process and heaters and fans to circulate warm air and exhaust odors.

System footprint

Self contained systems are relatively small, see model description details below.

Advantages

Manually operated door in toilet bowl allows for easy stand-up use. System is relatively small and inexpensive. Electrical and non-electrical units available. CSA (NSF 41) approved.

Disadvantages

Continuous composting system may result in contamination. Heater and fan system may dry out material, inhibiting composting process. Accumulated leachate will need to be managed.

Performance

CSA certified (NSF 41).

Operation and maintenance

Operation consists of adding peat moss or other amendment to process daily, periodic cleaning, and removal of composted contents. Regular monitoring and maintenance is also recommended, including inspection of electrical components.

Power and control

For electric models, fan (40 W) and heater (540 W) are both used. Electricity usage depends on length of operation. Non-electric models do not require electricity.

Cost

Self-contained units range in cost from about $1,000 to 1,300, while remote composting units range from $1,400 to 1,600 (includes composting unit, toilet, and accessories).

References and other resources

Del Porto, D., and C, Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

Contact
Sancor Industries Ltd.
140-30 Milner Ave.
Scarborough, Ontario, Canada, M1S 3R3
Phone 800.387.5126
Web www.envirolet.com
Model description

Model	Uses/day	Dimensions
Self-contained; waterless		
Basic Plus (non-electric)	6	All self-contained units:
DC12 (battery or solar power)	12	Width = 25 in; Length = 33 in;
MS10 (120 VAC electric power)	18	Height = 25 in
SC Hybrid (120 VAC or 12 VDC)	12	
Remote composting systems; waterless		
W/RS/NE (non-electric)	12	All remote units: Width = 25 in;
W/RS/12VDC	18	Length = 33 in; Height = 28.5 in
W/RS/120VAC	24	Waterless toilet: Width = 16.5
W/RS/12VDC/120VAC	21	in; Length = 22.5 in; Height =
		20.5 in
Remote composting systems; low-water		
LW/RS/NE (non-electric)	12	All remote units: Width = 25 in;
LW/RS/12VDC	18	Length = 33 in; Height = 28.5 in
LW/RS/120VAC	24	Waterless toilet: Width = 15.25 in; Length = 20.5 in; Height =
LW/RS/12VDC/120VAC	21	18.75 in

Manufacturer support
There is a lifetime warranty on the the body of Envirolet systems and a 4 year warranty on the internal components (including fans, heater, thermostats, etc.).

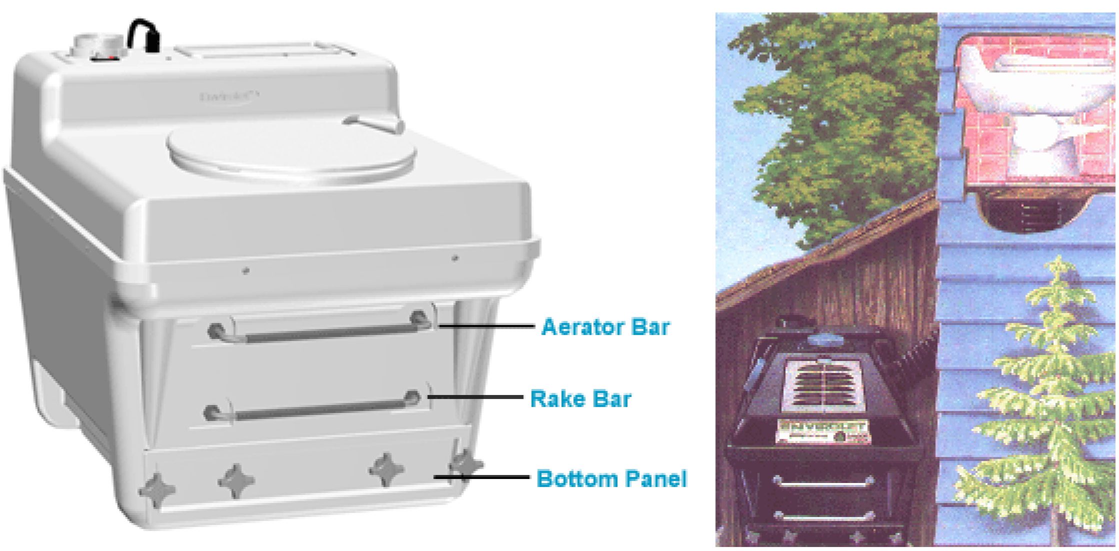


Figure 3-8
The self-contained and remote Envirolet composting toilet systems. (Adapted from Sancor Industries, LTD.)

3-1.10 Equaris Separation/Composting System

Category	Non-discharging
Technology	Continuous composting toilet system;
Input	Excrement, toilet paper, and food waste
Function	Aerobic decomposition; greywater treatment and water recycling optional
Applications	Residential, sensitive areas

Background/description of process
The Equaris system was formerly known as AlasCan of Minnesota. The system is based on separation of household greywater from toilet and food waste. The organic waste is composted in an aerobic reactor and the greywater is treated in an aerobic treatment system. After treatment, the water may be passed through a water treatment system for production of potable water.

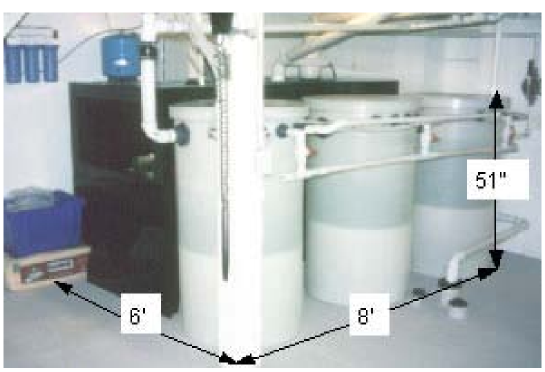
System footprint
The composting reactor and greywater treatment systems are about 8 ft long, 6 ft wide, and 4.5 ft tall; the drinking water treatment system (water recycling) is 24 in wide x 40 in long x 72 in tall.

Advantages
A complete onsite waste treatment system that reduces the amount of water discharged to soil systems and reduces the constituent concentrations in the effluent. Remote monitoring equipment and automated controls can improve process reliability.

Disadvantages
A highly mechanized process that needs more maintenance than other simple composting toilets.

Performance
Manufacturer claims 90 percent reduction in nitrogen, BOD, and TSS in the process effluent (to soil system) and overall wastewater flow reduced by 40 percent.

Operation and maintenance
Maintenance includes adding amendment material to the composting process and periodic removal of finished compost. Greywater treatment and water recycling systems require additional maintenance.



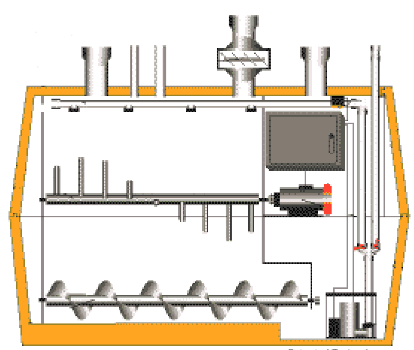


Figure 3-9

The Equaris composting and greywater treatment system (left), and a diagram of the composting reactor (right). (Adapted from Equaris Inc.)

Power and control
Electricity required to operate the fan (27 W) and process pumps. The greywater treatment

system also uses a 67 W air compressor to maintain aerobic conditions. Disinfection and water recycling system require additional electricity. Maintenance costs expected to range from $100 to $300 depending on complexity of system. Estimated electricity usage ranges from 400 to 450 kWh, also depending on system components.

Cost
System cost ranges from $7,500 to 22,000 for basic composting toilet and complete waste treatment/water recycling system, respectively (not including installation costs, which range from $1,000 to 2,000).

Contact
Equaris Corporation
1740 Magnolia Lane North
Plymouth, MN 55441
Phone (763) 383-5136
Fax (763) 383-5155
E mail@equaris.com
Web www.equaris.com
Model description

Model I	Equaris Toilet Wastes BioMatter Resequencing Converter (BMRC)
Model II	Equaris Toilet and Organic Kitchen Wastes BMRC
Model III	Equaris Toilet and Organic Kitchen Wastes BMRC and Greywater System
Model IV	Equaris Toilet and Organic Kitchen Wastes BMRC and Greywater System and and Filtration and Disinfection Potable Water Discharging System
Model V	Equaris Toilet and Organic Kitchen Wastes BMRC and Greywater System and Total Household Water/Wastewater Treatment and Recycling System

Manufacturer support
Complete remote monitoring and maintenance service available.

References and other resources
Equaris literature package (2002).

3-1.11 Phoenix Composting Toilet

Category	Non-discharging
Technology	Continuous composting toilet system
Input	Excrement and toilet paper
Function	Aerobic decomposition; liquid evaporation
Applications	Residential, remote and sensitive areas

Background/description of process
The Phoenix composting system is a remote composting system with an internal mixing mechanism. This system can be operated with waterless, gravity toilets located directly above the unit, low-flush toilets located above but with vertical offset, or vacuum flush toilets located on the same level as the composting unit. Leachate is recirculated through the system and evaporated or discharged through a drain.

System footprint
The composting unit is typically located in the basement or lower level. Dimensions are provided in the model description section.

Advantages
A large composting volume does not have to be emptied as frequently. Low power usage and compatible with waterless toilets. Suitable for off-grid applications.

Disadvantages
Continuous flow design may result in mixing of finished compost with unprocessed material.

Operation and maintenance
Occasional addition of amendment material and removal of composted material. Inspection of moving parts and operation. Discharge or evaporation of leachate. Periodically turning the crank for manual mixing.

Power and control
Typical electricity required to power exhaust fan ranges from 5 to 25 W. An optional evaporation system may be used to eliminate liquid discharge.

Cost
Estimated cost range from $3,500 to 5,000 (does not include shipping or installation costs). Evaporation system costs around $1,000. Custom made public systems housed in a building are also available.

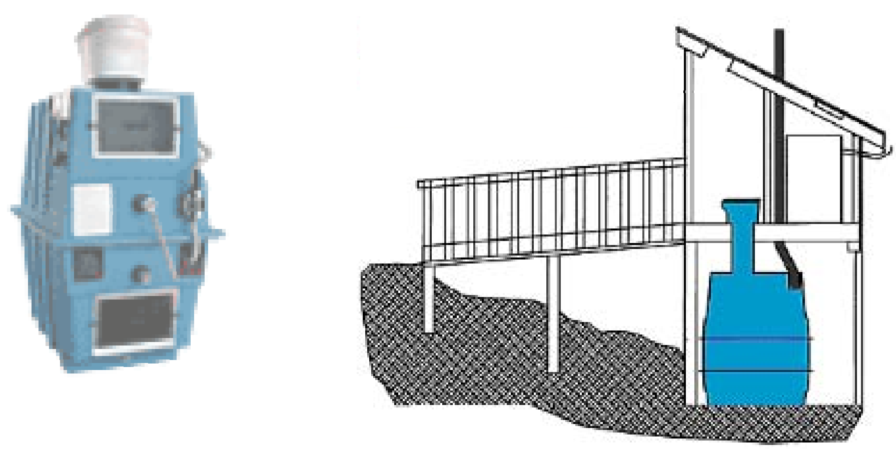


Figure 3-10

Phoenix composting toilet system and standard configuration. (Adapted from Advanced Composting Systems.)

Contact
Advanced Composting Systems
195 Meadows Rd.
Whitefish, MT 59937
Phone (905) 332-1314
Fax (905) 332-1315
E phoenix@compostingtoilet.com
Web www.compostingtoilet.com
Model description

Model	Capacity	Dimensions
R199	2 people	height = 53 in; width = 40 in; length = 61.5 in
R200	4 people (30 uses/d)	height = 68 in; width = 40 in; length = 61.5 in
R201	8 people (50 uses/d)	height = 84 in; width = 40 in; length = 61.5 in

References and other resources
Del Porto, D,. and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

3-1.12 Sun-Mar

Category	Non-discharging
Technology	Composting toilet system
Input	Human and food waste
Function	oxidation, stabilization
Applications	Cottage, residential, boat, RV

Background
Sun-Mar corporation produces electric and non-electric, self-contained and central composting systems. The unique design features of Sun-Mar composting toilets are an internal rotating drum composter and three separate chambers for material handling.

Description of process
Human and vegetable waste is deposited in the composting drum chamber. One cup of peat moss per person per day is added to the material to be composted. Every third day the composting drum is rotated to maintain aerobic composting conditions. Gases are vented from the composting unit with a small fan or chimney. Finished compost material must be removed periodically, depending on use.

System Footprint
Sun-Mar composting toilets are available in self-contained and central systems. A drain line should be hooked up (optional for electric models). A vent pipe is used to exhaust gases to the atmosphere. Remote composting systems are typically utilize ultra low-flush toilets connected to a composting unit located below (e.g., in a basement). Dimensions for the self-contained and remote composting systems are provided below in the model description section.

Advantages
Well established company certified by NSF 41. Drum composting system effective for mixing and aeration of composting material.

Disadvantages
The continuous composting system may allow contamination of finished compost with newly deposited material.

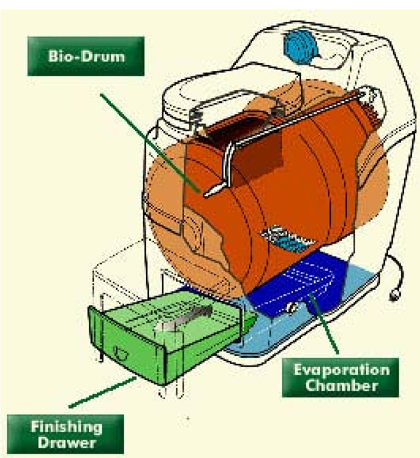


Figure 3-11
Sun-mar self-contained and remote composting system. (Adapted from Sun-Mar Co.)

Performance
Certified by NSF under standard 41.

Operation and maintenance
Operation consists of periodic addition of amendment material and rotation of composting drum for mixing and aeration. Inspection of mechanical components.

Power and control
Electrical components include an exhaust fan (30 W) and heater (250 W). The estimated annual power usage is 1300 kWh.

Cost
Self-contained systems range from $1,000 to 1,200. Remote composting systems from $1,200 to 1,600 (not including shipping and installation).

Contact
Sun-Mar Corporation
600 Main St
Tonawanda, NY 14150
Phone 800-461-2461
E compost@sun-mar.com
Web www.sun-mar.com
Model description

Model	Capacity	Dimensions
Self-contained composting system		
Compact	3 to 4 people	height = 27.5 in; width = 22 in; length = 33 in
Ecolet family	3 to 4 people	height = 28 in; width = 21 in; length = 19 in
Excel AC/DC	AC 3 to 5; DC 2 to 3	height = 32 in; width = 22.5 in; length = 33 in
Excel-NE	2 to 3 people	height = 31 in; width = 22.5 in; length = 33 in
Excel	3 to 5 people	height = 31 in; width = 22.5 in; length = 33 in
Spacesaver	3 to 4 people	height = 28 in; width = 21in; length = 19 in
Remote composting system		
1000 Series	Seasonal light/medium use by 5 to 7 people	Most units available in various styles including non-electric dry toilet, electric dry toilet, DC electric dry toilet, low-flush non-electric, low-flush electric, and DC electric low-flush
2000 Series	Seasonal medium/heavy use by 6 to 9 people; light residential use by 3 to 6 people	
3000 Series	Heavy seasonal use by 7 to 11 people; residential use by 5 to 8 people	Typical size is height = 27.5 in; width = 32in; length = 27 in

Manufacturer support

The fiberglass body is warranted for 25 years, and the parts are warranted for 3 years.

References and other resources

Del Porto, D,. and C. Steinfeld (1999) *The Composting Toilet System Book*, the Center for Ecological Pollution Prevention, Concord MA

3.1-13 Other Systems

Below is a list of additional composting toilet systems that are not as readily available in the United States as some of the systems described above.

Contacts

Enviro Loo
PO Box 219; 23 Gooraway Place
Berowra Heights, NSW 2082 Australia
Phone 02 9456 0172
Fax 02 9456 0173
E allan@enviro-options.com.au
Web http://www.enviro-options.com.au/
Description
An evaporation /dehydration system.

Nature Loo
P.O. Box 150 Bulimba
Queensland, Australia 4171
Phone 07 3395-6800
Fax 07 3395-5322
E info@nature-loo.com.au
Web www.nature-loo.com.au
Description
Batch-type composting toilets.

Rota-Loo
2/32 Jarrah Drive
Braeside, VIC.3195 Australia
Phone 03 587-2447
Fax 03 587-5622
E enquiries@rotaloo.com
Web www.rotaloo.com
Description
Batch type carousel composters.

Vera Miljø A/S
Postboks 2036
3239 Sandefjord
Phone 33 42 01 00
Fax 33 47 46 80
E mail@vera.no
Web www.vera.no/
Description
Several models available.

Dowmus
P.O. Box 323 Cooroy
Queensland, Australia 4563
Phone 61 074 476 342
Fax 61 074 425 228
E djrcamp@peg.apc.org
Web http://www.dowmus.com/

Ekosanic Scandinavia
Box 620, S-135 26
Tyresö, Sweden
Phone 468-745 06 30
Fax 468-777 45 07
E m-20071@mailbox.swipnet.se
Web www.ekosanic.a.se

Naturum
Luonto-Laite Oy
FIN-17740 Kasiniemi FINLAND
Phone 358 3 556 8132
Fax 358 3 556 8133
E luontola@sci.fi
Web www.naturum.fi/english

Contuit Dry Toilet
E conradg@cape.com
Web www.cape.com/cdt/

EKOLET Composting Toilets
Estetie 3, 00430
HELSINKI, FINLAND
Phone 358 40 5464775
Fax 358 9 5635056
E ekolet@ekolet.com
Web www.ekolet.com/

3-2 Incinerating toilets

Incinerating toilets are self-contained systems for the combustion of human waste, using gas or electricity, and resulting in a sterile ash material. Incinerating toilets may be considered in areas where biological wastewater treatment is not feasible. There are two basic types: one system combusts waste material after each use and the other system stores waste material for some period of time before batch combustion.

While these systems use no water, they do require energy (either gas or electricity) for operation. In addition, the air emissions from waste combustion systems are not known. Maintenance includes manufacturer recommended upkeep and removal of the residual ash.

3-2.1 Incinolet Electric Toilet System

Category	Non-discharging
Technology	Incinerating toilet
Input	Excrement, toilet paper
Function	Combustion of human waste
Applications	Sensitive and remote areas

Background/description of process
The Incinolet toilet is an NSF approved system for the combustion of human waste. A bowl liner is used with each use to capture human waste. The liner and waste material are then dropped into the combustion chamber by depressing a foot pedal; the combustion system is then manually activated. The waste material is reduced to a pile of ash, which is then disposed of in the trash. The combustion cycle takes about 1.5 h, but the unit can continue to be used during the combustion cycle.

System footprint
The standard unit is 15 in wide, 20 in high, and 24 in long. Additional space is required in front of the unit for removal of the ash. A vent pipe also needs to be connected to control odors and exhaust.

Advantages
Ash material can be disposed of without odor. Unit is small and easy to install. Process does not use any water, and a catalyst is used to control emissions. Waste is processed immediately, so only ash is left to dispose of.

Disadvantages
Needs electricity to operate, system will not operate during a power outage. Bowl liners must be used during each use. If incomplete combustion of the waste occurs, the uncombusted material will need to be removed from the chamber.

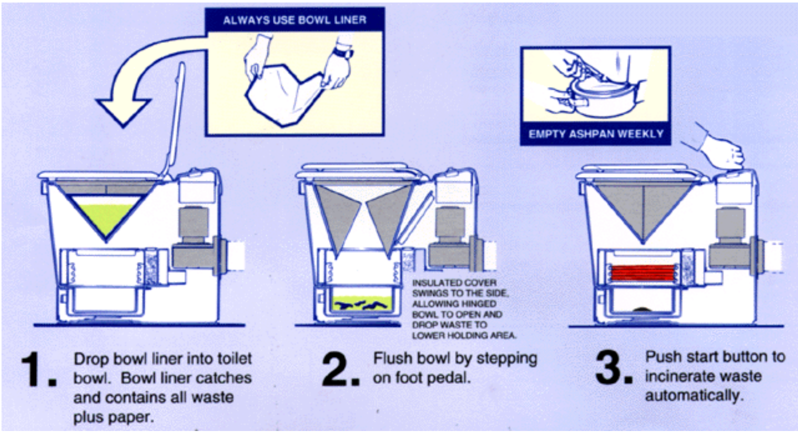


Figure 3-12

The Incinolet electric toilet system (left) and typical system operation (right). (Adapted from Research Prosucts/Incinolet, Inc.)

Operation and maintenance
A bowl liner needs to be installed for each use. Ash must be emptied periodically, depending on usage (typically once per week). Blower must be cleaned every 90 days. Other components, such as the heater, catalyst, and switches, will need to be replaced as necessary.

Power and control
System uses approximately 0.5 to 1 kWh per usage.

Cost
Cost for Incinolet ranges from $1600 to 2000, depending on specific model. Bowl liners are about $0.10 each. Annual operation and maintenance costs can be expected to be several hundred dollars.

Contact
Research Products/Blankenship
26 Andjon
Dallas, TX 75220
Phone (214) 356-4238; (800) 527-5551
Fax (214) 350-7919
Web www.incinolet.com

Model description

Model	Application	Electrical needs	People
CF	Cottages/light use	120 V/1800 W	4
RV	Mobile	120 V/1800 W	4
TR	Homes/heavy use	240 V/3600 W	8
WB	Marine	120 V/1800 W; 240 V/3600 W	4 or 8

Manufacturer support

One and two year warranties, depending on the model. Phone support and sales assistance available during business hours.

References and other resources

Incinolet electric toilet system brochure (2002)

U.S. EPA (1999) Water Efficiency Technology Fact Sheet: Incinerating Toilets, EPA 832-F-99-072, Office of Water, U.S. Environmental Protection Agency, Washington DC.

3-1.2 Storburn Gas Fired Incinerator Toilet

Category	Non-discharging
Technology	Incinerating toilet
Input	Excrement, toilet paper
Function	Combustion of human waste
Applications	Sensitive and remote areas

Background/description of process
The Storburn incinerating toilet system uses propane or natural gas to combust human waste. Excrement is stored in a reservoir (3 gal), which fills after 40 to 60 uses; the waste material is then combusted as a batch. An anti-foaming agent is also added to the process before combustion. The combustion process requires about 4.5 h, during this time the toilet can not be used.

System footprint
Unit is 17.75 in wide, 31.25 in long, and 53 in tall, however 43 in of space is required above the unit. A vent pipe is also needed.

Advantages
May be convenient in remote locations or where waste discharge is not acceptable. Does not use water or electricity. Few moving parts reduce maintenance needs.

Disadvantages
Requires natural gas or propane to operate. Can not be used during incineration cycle.

Operation and maintenance
Anti-foam agent is added before the combustion cycle and ash is emptied after the combustion cycle. Periodic cleaning of the burner is needed.

Power and control
About 10 to 16 complete burn cycles (40 to 60 uses per cycle) can be accomplished with a full 100 lb propane cylinder. Conducting the combustion cycle after the chamber is full is more fuel efficient than combusting partial loads.

Cost
Propane and natural gas fired toilets cost about $3,000 (not including shipping and installation). The vent kit is around $300 and the anti-foam agent is $25 for 24 packets.

Figure 3-13
The Storburn incinerating toilet. (Adapted from Storburn International Inc.)

Contact
Stroburn International Inc.
47 Copernicus Blvd., Unit 3
Brantford Ontario, N3P 1NA, Canada
Phone (519) 752-8521
Fax (519) 752-5872
Web www3.sympatico.ca/storburn/products.htm
Model description
Propane and natural gas operated toilets available.
Manufacturer support
One year warranty.

References and other resources

U.S. EPA (1999) Water Efficiency Technology Fact Sheet: Incinerating Toilets, EPA 832-F-99-072, Office of Water, U.S. Environmental Protection Agency, Washington DC.

3-3 Vault Toilets and Holding Tanks

Vault toilets are facilities where human waste is deposited directly into a watertight tank without flushing. The tank (i.e., vault) is typically stored below ground and may be dry or contain a sanitizing chemical. Vault toilets are commonly used by the forest service in remote, but high traffic areas. Waste material must be pumped out and hauled away periodically.

A holding tank is an underground tank that is used to collect and store wastewater. Holding tanks are used at residential and commercial locations where wastewater collection or onsite treatment is not available, such as remote areas, summer cottages, areas that are environmentally sensitive, and/or in areas that have conditions which would not permit the use of a soil adsorption system. The tanks are watertight and generally have several thousand gallons of capacity. A high water alarm or other monitoring device is used to alert the users when the tank needs to be emptied. These systems have a relatively low capital cost (about the same as a septic tank), and minimal operation cost.

Maintenance needs for vault toilets and holding tanks includes periodic emptying of the tank contents. For remote areas or in areas where pumping and hauling septage is expensive, these systems may become cost prohibitive. A rough water balance should be used to confirm that the tank is not leaking.

3-3.1 CXT Inc.

Category	Non-discharging
Technology	Vault toilet
Input	Excrement, toilet paper
Function	Storage
Applications	Remote and sensitive areas

Background/description of process

Precast concrete restroom facilities for remote areas. Toilet seat is mounted directly above concrete storage tank. Waste material must be periodically removed from the tank.

Figure 3-14

Vault toilet facilities by CXT, Inc. (Adapted From CXT, Inc.)

Contact
CXT, Inc.
3808 North Sullivan Rd., Bldg. 7
Spokane, WA 99216
Phone (509) 921-8766
Fax (509) 928-8270
Web www.cxtinc.com
Model descriptions

Aspen Mark 11	1000 gal
Gunnison	1000 gal
Sierra	1000 gal
Tioga	2000 gal
Tioga Special	2000 gal
Vail	1000 gal

3-3.2 Romtec

Category	Non-discharging
Technology	Vault toilet
Input	Excrement, toilet paper
Function	Storage
Applications	Remote and sensitive areas

Background/description of process
Romtec designs and builds pre-engineered restroom facilities. Many models and styles are available, including both plumbed and waterless options.

Cost
Prices range from $8,000 to 30,000 for complete facility.

Figure 3-15
Vault toilet facilities by Romtec, Inc. (Adapted from Romtec, Inc.)

Contact
Romtec, Inc.
18240 North Bank Rd.
Roseburg, OR 97470
Phone (541) 496-3541
Fax (541) 496-0803
Web www.romtec.com
Model description

A wide variety of plumbed and waterless facilities.

CHAPTER 4
PRIMARY TREATMENT SYSTEMS AND APPURTENANCES

Technologies are available that can be used to modify the characteristics of wastewater discharged to a septic tank. Pretreatment can reduce the amount of lint and grease discharged in the wastewater, which can influence the maintenance requirements and/or performance of subsequent treatment processes. Lint filters and grease traps are considered in this section.

Items to improve the operation of septic tanks can include liners and effluent filters. Liners and sealants are used to improve the water tightness of existing and some new tanks. Effluent filters are used to limit the discharge of particulate solids to the soil adsorption system and improve the performance of subsequent treatment processes, particularly biological treatment processes.

Technologies discussed in this chapter include: (1) lint filters, (2) grease traps, (3) septic tanks, (4) septic tank additives, (5) septic tank outlet filters, and (6) septic tank liners.

4-1 Lint filters
Filtration of water discharged from greywater sources (i.e., washing machines, bathroom sinks, and bathing facilities) is a form of wastewater pre-treatment. Filtration of wastewater before release to the wastewater management system can eliminate non-biodegradable particulates (i.e., plastic clothes fibers, hair, and other particulate and fibrous materials) that can reduce the rate of sludge accumulation in septic tanks and can reduce the performance of soil adsorption systems due to soil clogging.

Operation and maintenance
Periodic removal and cleaning of the filter cartridge is needed, depending on frequency of clothes washing or alternate use. Filters need replacement every 1 to 3 years.

Cost
Basic unit cost between $150 and 200, and replacement filters are about $20.

4-1.1 Septic Protector™
14622 268th Ave.
Zimmerman, MN 55398
Phone (612) 856-3800
Fax (612) 856-3888
E jvonmeier@sherbtel.net
Web www.septicprotector.com
Model description
Mesh sizes of 160 μm (30 μm optional).

Figure 4-1
The Septic Protector connected to the outlet of a washing machine. (Adapted from Septic Protector, Inc.)

4.2 Grease traps (oil and grease interceptors)
Separation of oil and grease from wastewater can improve the performance of downstream treatment systems, such as a septic tank, aerobic treatment processes, and soil adsorption systems. Grease traps are typically installed in-line before a septic tank and are designed to temporarily retain and cool water, allowing time for grease and oil to separate from water. Baffles located inside the grease trap, retain the grease and oil that floats to the surface. The clarified wastewater is discharged to subsequent treatment processes.

Advantages
Grease traps can prevent the premature failure of onsite wastewater treatment systems. Best used for applications with high concentrations of oil and grease in wastewater, such as restaurants, bakeries, laundromats, and service stations.

Disadvantages
Grease traps need to be emptied or pumped out periodically. The use of emulsifiers or oils with high solubility may be difficult and costly to remove. Emulsifiers are often used with under-the-sink or in-kitchen type grease traps to minimize kitchen clean-up time and effort; however, emulsifiers may reduce the performance of downstream treatment systems and/or impair soil adsorption systems. During peak wastewater discharge, flow rate may exceed rated capacity and result in insufficient oil and grease removal. Inefficient grease traps should be emptied more often (i.e., 50 percent capacity) to avoid oil and grease carryover to subsequent wastewater management systems. Oil and grease should be separated from the wastewater stream before mixing with blackwater sources to improve downstream treatment processes. Regulations imposed on treatment sites capable of processing septage with high concentrations of grease and oil will increase the transportation and disposal costs.

Operation and maintenance
Periodic monitoring to check level of grease and oil accumulated in tank. Removal and management of accumulated grease and oil will be required periodically, typically, every 3 to 6 months, depending on the effectiveness of the grease trap and the amount of oil and grease in the wastewater. Cleaning of internal components may be needed for automated grease and oil removal systems.

Cost
The cost is a dependent on the level of sophistication. Some systems include automated grease and oil removal from the separation chamber and/or grease and oil level monitoring equipment. Systems may be installed below ground or near the wastewater source, such as under a sink. Cost range is typically between $2,000 and 7,000. Many manufacturers of septic tanks also manufacture grease and oil interception tanks. Effluent (outlet) filters have also been used to improve the performance of grease traps.

4-2.1 Atlas Systems Inc.
PO Box 747
Rockland, MA 02370
Phone (617) 878-0334

4-2.2 Big Dipper-Thermaco®
646 Greensboro St
Asheboro, NC 27203
Phone (336) 629-4651; (800) 633-4204
Fax (363) 626-5739
E info@thermaco.com
Web www.big-dipper.com
Model descriptions
In-kitchen type systems for grease and oil removal for flow rates from 20 to 150 gpm.

Figure 4-2
The Big Dipper grease and oil removal system from Thermaco. (Adapted from Thermaco.)

4-2.3 NCS

16207 Meridian East; PO Box 73399
Puyallup, WA 98373
Phone (253) 848-2371; (800) 444-2371
Fax (363) 626-5739
E paulm@nwscascade.com
Web www.nwcascade.com

Model descriptions

A typical NIBBLER system has a grease trap, surge tank, NIBBLER unit, and clarifier. NIBBLER grease tanks may be located in a remote area (not in-kitchen) and typically have an HRT of several days.

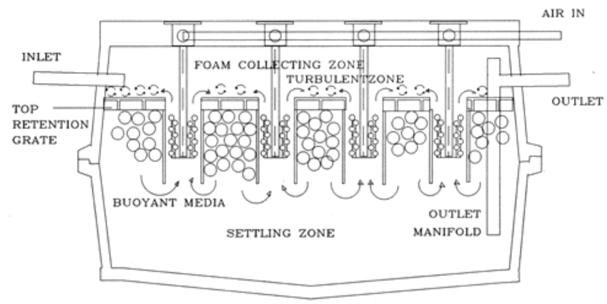


Figure 4-3

Side view of the NIBBLER system. (Adapted from NCS.)

4.3 Septic tanks

Settleable and floatable particulate materials need to be removed before release to a soil treatment system or secondary treatment process. Primary treatment efficiency is dependent on the primary treatment tank specifications and installation. The Imhoff tank is an alternative to the conventional septic tank, in which the sludge digestion and effluent clarification processes occur in separate regions. Septic tanks are available in concrete, plastic, and fiberglass. Plastic and fiberglass septic tanks lighter than concrete tanks and may require anti-floatation devices in high groundwater areas. Regardless of the material used for construction, all septic tanks should be evaluated to ensure that they are both **watertight** and **structurally sound**.

Operation and maintenance

The solids that accumulate in the septic tank need to be removed periodically, depending on the specific application (e.g., commercial or residential) and wastewater characteristics. Solids removal is conducted with a septic pumping and hauling truck and consists of removal of the settled sludge, liquid contents, and scum layer. The liquid and solid contents from the septic tank are typically hauled to a wastewater treatment facility for treatment.

Septic tanks that are regularly serviced and maintained can have the solids removed on an as needed basis (estimated 15 to 20 years), whereas septic tanks that are not regularly serviced may require more frequent solids removal (estimated 3 to 5 years). In addition, managed systems (i.e., on a regular monitoring schedule) may be eligible for other benefits including reduced drainfield size and less restrictive sizing and setback criteria due to the reduced possibility that the system will fail. Technologies that are being developed for measuring water level and solids depth will make remote monitoring more feasible.

Cost

Septic tanks cost about $1 per gallon of capacity for residential sized tanks. Solids removal is usually $150 to 400 per 1000 gallons. Complete septic systems, installed with a standard soil adsorption system, are typically in the range of $5,000 to 15,000 (cost may be considerably more in areas with poor soils).

Suppliers

Manufacturers of concrete septic tanks are available in most areas. Plastic and fiberglass septic tanks are lightweight and may be easier to install in some areas. Because of past failures, it is recommended that plastic tanks be water tested and inspected carefully for structural integrity.

4-3.1 Fiber Enterprises, Inc.

PO Box 8386
Red Bluff, CA 96080
Phone (530) 527-2196
Web www.fiber-enterprises.com

4-3.2 Mid-State Concrete Products

1625 East Donovan
Santa Maria, CA 93454
Phone (805) 928-2855
Fax (805) 928-2114
E midstate@midstateconcrete.com
Web www.midstateconcrete.com
Model description
800 to 1500 gallon precast septic tanks and grease traps, standard and traffic bearing models.

Figure 4-4

A precast concrete septic tank. (Adapted from Mid-State Concrete Products.)

4-3.3 Orenco Systems, Inc

814 Airway Ave.
Sutherlin, CA 97479
Phone (541) 459-4449
Fax (541) 459-2884
Web www.orenco.com
Model description
Assorted fiberglass tanks

Figure 4-5

Illustration of a fiberglass septic tank showing baffle and flow through ports. (Adapted from Orenco Systems, Inc.)

4-3.2 Jensen Precast

5400 Raley Blvd
Sacramento, CA 95838
Phone (916) 991-8800;
(800) 843-9569
Fax (916) 991-8810
Web www.jensenprecast.com
Model description
Precast septic tanks and grease interceptors from 750 to 25,000 gal, also supply dosing tanks, pump vaults, and dosing siphons.

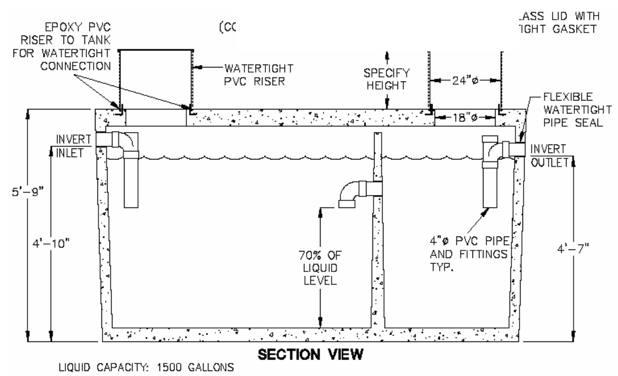


Figure 4-6

Diagram of typical precast concrete residential septic tank. (Adapted from Jensen Precast.)

4-3.3 Premier Tech Environment

7051 Meadow Lark Dr, Building 200, Suite 208
Birmingham, Al 35242
Phone (877) 295-5763
Fax (205) 408-8783
Web www.premiertech.com
Model description

PST-280	750 gal
PST-340	900 gal
PST-390	1030 gal
PST-500	1320 gal
PST-660	1745 gal

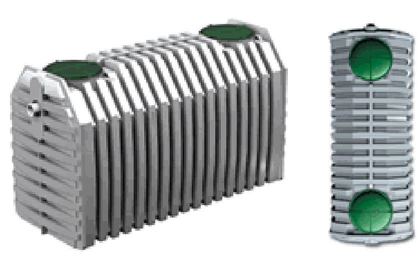


Figure 4-7

Views of the Premier Tech polyethelene septic tank. (Adapted from Premier Tech.)

4-3.4 Loomis Tank and Trough

44 N Canyon Way
Colfax, CA 95713
Phone (530) 346-7391
E info@loomistank.com
Web www.loomistank.com
Model description
Fiberglass and polyethylene septic tanks with sizes ranging from 300 gallons to 1,500 gallons.

Figure 4-8
Fiberglass and polyethylene septic tanks. (Adapted from Loomis Tank and Trough.)

4-3.5 Water Tanks.com

200 American Way; PO Box 340
Windsor, CA 95492
Phone (707) 535-1400; (877) 655-1100
Fax (707) 535-1450
E sales@watertanks.com
Web www.watertanks.com
Model description
300 to 1000 gallon polyethylene or fiberglass reinforced septic tanks.

4-4 Septic system additives

Approximately 1200 septic tank additives are currently available (National Small Flows Clearinghouse, 2002) and advertised as (1) removing deposits in household drains, (2) improving the operation of septic tanks, (3) reducing odors associated with septic systems, or (4) unclogging soil adsorption systems. Products fall into two broad categories (1) chemical (inorganic and organic) and (2) biological (bacteria or enzymes) supplements. Use of these products have advantages and disadvantages, although most studies have concluded that these products are not effective, and, in some cases, can be detrimental to septic systems.

Advantages
Products that are effective can provide a cost effective solution for improving the performance of onsite treatment systems. Products that are not effective for improving the operation of the septic system may increase homeowner’s awareness of the septic system.

Disadvantages
Septic system additives may have a negative effect on the septic system, resulting in bacterial die off and/or reduced effluent quality. Caustic chemicals and organic solvents should never be added to septic systems. Controlled studies are needed to test manufacturer performance claims.

Operation and maintenance
Most manufacturers recommend adding products on a regular basis, for example, every other week, month, or year. In many cases, these products are used in an attempt to remedy a failing system and may be used as an indicator that the septic tank needs to be pumped or that the soil adsorption field is clogging.

Cost
The cost of septic tank additives depends on the manufacturer and the recommended usage. Typical costs range from ten to several hundred dollars per year.

References

National Small Flows Clearinghouse (2002) Septic Tank Additives, *Small Flow Quarterly*, Vol 3, No. 1.

U.S. EPA (2002) *Onsite Wastewater Treatment Systems Manual*, Office of Water; Office of Research and Development, U.S. Environmental Protection Agency, Washington DC.

Washington State Department of Health (2001) List of Approved On-Site Sewage System Additive Products, available at www.doh.wa.gov/ehp/ts/WW/Additives.pdf

4-5 Septic tank outlet (effluent) filters and pump vaults

The use of a screen effluent filter can significantly improve the effluent quality from primary treatment systems and are relatively inexpensive. Water inside of the septic tank or pump vault must pass through the outlet screen to exit the tank. Screens are available in a variety of mesh sizes, ranging from 0.125 in to 0.0156 in, some manufacturers offer filters with graded screen sizes. As wastewater flows through the screen, solids gradually blind the screen. Periodically the accumulated solids must be removed from the screen. Alarm systems may be used to alert the system owner that the water level in the septic tank is rising and that the filter needs to be cleaned. In many cases, the alarm can alert the system owner that the septic tank may need to be pumped as well.

Most manufacturers offer models that are located inside the septic tank (attached to the outlet) or systems that are located outside of the septic tank in a separate tank (i.e., pump vault). Most systems are also available with an integrated pump, for use with septic tank effluent pump (STEP) systems or other pressure distribution system. For larger flow rates, a manifold may be used to connect multiple effluent filters in parallel.

Advantages

Effluent screens are an effective way to reduce the solids being discharged to subsequent wastewater treatment processes. Clogging of the effluent filter can remind system owner that septic tank may need to be pumped out. Some systems provide a level of flow equalization. High water alarms can be used to alert system owner of pending filter clogging.

Disadvantages

Effluent screens require periodic maintenance to maintain effectiveness. Care needs to be exercised when cleaning filter to avoid discharging solids to subsequent wastewater management processes.

Operation and maintenance

Effluent filters will need to be cleaned periodically; the smaller screen openings and filter surface area will require more frequent cleaning. If an alarm system is in place, the alarm should be checked regularly to confirm its operation, and the effluent filter should be cleaned whenever the alarm is activated because of a high water level. Filter cleaning is generally provided by a septic tank servicing agency. The screened solids are typically washed back into the tank; the outlet should be blocked during cleaning to ensure that solids are not discharged. The effluent filter should always be cleaned during tank pumping, while the septic tank is empty.

Cost

The cost of effluent filters can range from around $50 for basic units that attach to the outlet inside of the septic tank, to $1,500 for advanced external units with additional features. Installation and maintenance will require an additional fee.

4-5.1 Bio-kinetic™ (BK 2000)

Norwalk Wastewater Equipment Company, Inc.
220 Republic St
Norwalk, OH 44857
Phone (419) 668-4471
Fax (419) 663-5440
Web www.norweco.com
Model description

Post septic tank effluent filtration systems that also provide flow equalization, rated for flow rates up to 2,000 gpd.

Model	Description
2000 X	Standard
2000 C	With chlorination
2000 CD	With dechlorination

Figure 4-9

The Bio-Kinetic wastewater management system from Norweco. (Adapted from Norwalk Wastewater Equipment Company, Inc.)

4-5.2 Biotube®

Orenco Systems Inc.
814 Airway Ave.
Sutherlin, OR 97479
Phone (541) 459-4449
(800) 348-9843
Fax (541) 459-2884
Web www.orenco.com
Model description

Filter screens with various size openings (typically 0.125 and 0.063 in), filter cartridges available in diameters of 4, 8, 12, and 15 in to accommodate a range of flowrates. May be used in new and retrofit applications as an outlet filter.

4-5.2 BIO WEIR FILTERS

11 College St.
Newnan, GA 30263
Phone (770) 301-6603
Fax (770) 251-2681

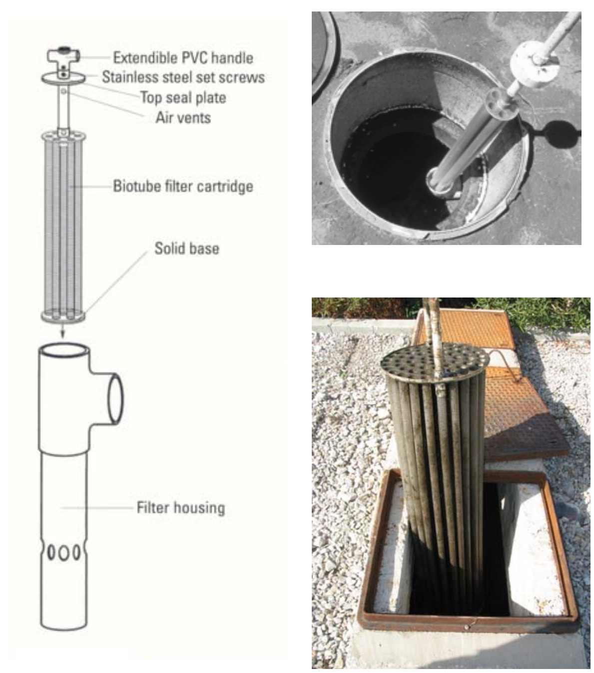


Figure 4-10

Diagram of the Biotube effluent filter (left), Biotube Jr. installed on the outlet of a septic tank, and larger Biotube filter installed on the outlet of a constructed wetland (right top). (Adapted from Orenco Systems, Inc.)

4-5.4 FLOWLINK MANUFACTURING COMPANY

7225 Pacific Ave., SE
Olympia, WA 98503
Phone (360) 491-2900; (800) 982-5393
Fax (360) 491-1990

4-5.5 Premier Tech Environment

7051 Meadow Lark Dr., Building 200, Suite 208
Birmingham, AL 35242
Phone (877) 295-5763
Fax (205) 408-8783
Web www.premiertech.com
Model description
EFT-080
Surface area = 1092 cm^2
Maximum flowrate = 3300 gpd

Figure 4-11
The Premier Tech effluent filter. (Adapted from Premier Tech.)

4-5.6 Presby Maze™

Presby Environmental
PO Box 617 Route 117
Sugar Hill, NH 03585
Phone (800) 473-5298
Fax (603) 823-8114
Web www.PresbyEnvironmental.com
Model description
A series of plastic mesh panels that trap suspended solids and improve the hydraulics of the septic tank.

Figure 4-12
The Presby Maze septic tank insert. (Adapted from Presby Environmental.)

4-5.7 Polylok, Inc.

173 Church St
Yalesville, CT 06492
Phone (800) 234-3119
Fax (203) 265-4941
Web www.polylok.com

Model description

The PL-122 is a modular outlet filter
1 PL-122 / 1600 GPD average flow
2 PL-122 / 3200 GPD average flow
3 PL-122 / 4800 GPD average flow
4 PL- 122 / 6400 GPD average flow
5 PL-122 / 8000 GPD average flow

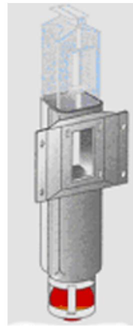


Figure 4-13

The Polylok modular effluent filter can be customized for flowrate. (Adapted from Polylok, Inc.)

4-5.8 NCS

PO Box 73399
Puyallup, WA 98373
Phone (800) 444-2371
Fax (253) 840-0877
Web www.ncswastewater.com
Model description

NCS Stacked/Disk Screened Vaults utilizes graded filter disks stacked vertically in an upright vault. Gravity and integrated effluent pump models available.

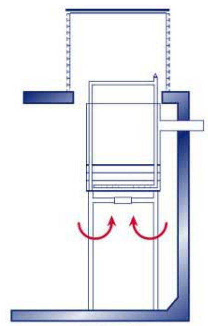


Figure 4-14

The NCS gravity effluent filter. (Adapted from NCS, Inc.)

4-5.9 saniTEE-THORSBY&BOWNE

3790 Honolulu Ave.
Eugene, OR 97404
Phone (503) 345-3001
Fax (503) 345-9354

4-5.10 SIM/TECH Filter

06598 Horton Bay North Rd.
Boyne City, MI 49712
Phone (231) 582-7327; (888) 999-3290
Fax (231) 582-7324
E simtech@freeway.net
Web www.gag-simtech.com
Model description

STF-100 effluent filter with 0.0625 in screen, rated at 83.8 gpm. Manifold used for connecting multiple units together for higher flow rates. Disposable filter sock available in 0.023, 0.006, and 00039 in sizes.

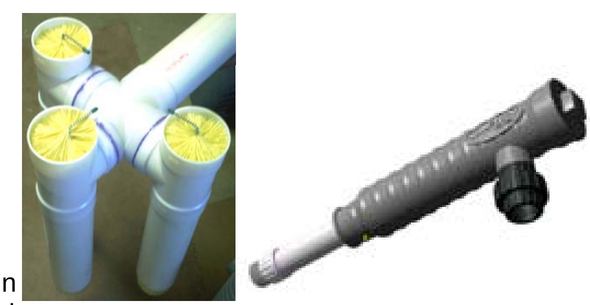


Figure 4-15

The Sim/Tech effluent filter. (Adapted from SIM/TECH.)

4-5.11 TREIT FILTERS COMPANY

3404 57th St. NW, Suite A
Gig Harbor, WA 98335
Phone (253) 853-5340
Fax (253) 853-4224
Model description
- Model EF-1830
- Model EF-1840
- Model EF-2530
- Model EF-2540

4-5.12 TUF-TITE DRAINAGE AND SEPTIC PRODUCTS

1125 Old Rand Rd.
Wauconda, IL 60084
Phone (708) 487-7000; (800) 382-7009
Fax (708) 487-7003

4-5.13 Zabel Environmental Technology

PO Box 1520
Crestwood, KY 40014
Phone (800) 221-5742
Web www.zabelzone.com
Model description

Series	Screen (in)	Flow rate (gpd)
A1800	0.0625	800
A100	0.0625	1200 to 6000
A300	0.0313	3000 to 6000
A600	0.0156	3000 to 6000

Fig 4-16

Zabel effluent filters (form left to right) Models A600, A1800 (internal), and A1800 (external). (Adapted from Zabel Environmental, Inc.)

4-5.14 Zoeller Pump Company

3649 Cane Run Rd.
Louisville, Kentucky 40211-1961
Phone (502) 778-2731
Fax (502) 774-3624
Web www.zoeller.com
Model description

Model	Screen (in)	Flow rate (gpd)
170-0016	0.0625	3240
170-0017	0.0313	3240
170-0058	0.0313	850
170-0078	0.0625	1000

Figure 4-17

Zoeller effluent filters for residential and commercial applications. (Adapted from Zoeller Pump Company.)

4-6 Septic tank liners/sealants

Liners and sealants are products that prevent the leakage of untreated sewage into the ground from a ruptured septic tank. Watertight septic tanks provide an additional barrier for groundwater protection.

4-6.1 Concrete Sealants, Inc.

8917 South Palmer Road, P. O. Box 176
New Carlisle OH 45344
Phone (937) 845-8776; (800) 332-7325
Fax (937) 845-3587
E hello@conseal.com
Web www.conseal.com
Model description
Butyl Resin Sealant formula, providing flexible, watertight joints for precast concrete structures

Fig 4-18

Butyl resin sealant applied to the rim of a precast tank. (Adapted from Concrete Sealants, Inc.)

4-6.2 Universal Liner™

Miller Environmental Products, Inc.
P.O. Box 334
East Bridgewater, MA 02333
Phone (508) 697-3710
Fax (508) 697-0606
Web www.millerenvironmentalinc.com
Model description
Interior and exterior PVC liner that can be cast-in-place or retrofit into an existing tank on the outside (excavated tank) or inside (non-excavated tank).

Figure 4-19

The Universal Liner completely seals septic tanks to prevent leakage. (Adapted from Miller Environmental Products, Inc.)

Anaerobic and anoxic treatment processes are characterized by the absence of free oxygen from the treatment process. Many of the aerobic treatment systems described in other sections of this report utilize anoxic or anaerobic stages to accomplish specific treatment objectives. Anaerobic treatment processes are typically used for the treatment of waste that has a high concentration of biodegradable organic material. Anoxic and anaerobic processes do not require the input of oxygen, which is typically an energy intensive process in aerobic systems.

5-1 Anoxic systems

Anoxic processes are typically used for the removal of nitrogen from wastewater. The process of biological nitrogen removal is known as denitrification. Denitrification requires that nitrogen be first converted to nitrate, which typically occurs in an aerobic treatment process such as a trickling filter or aerated suspended growth system. The nitrified water is then exposed to an environment without free oxygen. Organisms in this anoxic system use the nitrate as an electron acceptor and release nitrogen in the form of nitrogen gas or nitrogen oxides. A readily biodegradable carbon source is also needed for efficient denitrification processes to occur. It should be noted that sulfate can also be used as an electron acceptor, resulting in the formation of hydrogen sulfide.

Anoxic attached growth reactors
The basic form of the anoxic attached growth reactor is a submerged basin filled with a support medium and, in some cases, carbon source. Anoxic upflow rock filters have been used for nitrogen removal from nitrified wastewater. Nitrified wastewater flows into the bottom of the filter and is mixed with the carbon source as it flows up through the fixed packing. The organic matter is septic tank effluent is the most common carbon source used because of its availability; however, methanol or an alternate compound (e.g., soap) may also be used to supply carbon.

Anoxic suspended growth reactors
The suspended growth reactor is simply a tank in which nitrified wastewater is mixed with a carbon source, typically septic tank effluent. In some cases, nitrified wastewater is discharged back to the primary treatment stage, such as a septic tank, for denitrification. Nearly all of the suspended growth treatment systems and multi-pass trickling biofilter systems make use of an anoxic stage, through recycle of the aerobic stage effluent, to accomplish denitrification.

Anoxic processes that are coupled with aerobic systems are discussed with the respective aerobic process in Chaps. 6, 7, and 8.

5-1.1 AWT Anoxic Filter

Category	Advanced treatment
Technology	Continuous flow, anoxic attached growth
Input	Secondary effluent (nitrified wastewater), carbon source
Function	Denitrification
Applications	Individual, community, and institutional systems

Background
The AWT Anoxic Filter is a biological reactor with a fixed packing for attached growth of denitrifying organisms. The primarily use of this technology is for the removal of nitrogen from wastewater.

Description of process
Nitrified process water flows into the anoxic reactor and is combined with a supplemental carbon source, typically a dilute methanol solution. Chemical is metered by calibration with an electrical signal from the feed pump. Treatment process includes devices for flow monitoring, float

switches, and alarms. Effluent from the anoxic reactor is treated in a septic tank for solids removal before being discharged.

Performance
Expected nitrogen removal to below 10 mg/L total nitrogen.

Operation and maintenance
Carbon source will need to be replenished periodically. Pumps and other electrical/mechanical devices will need to be inspected regularly.

Contact
Aquapoint / AWT Environmental, Inc.
241 Duchaine Blvd.
New Bedford, MA 02745
Phone (508) 998-7577
Fax (508) 998-7177
E awt@aquapoint.com
Web www.aquapoint.com

5-1.2 Nitrex™ Trickling Biofilters

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Nitrified wastewater
Function	Primarily denitrification
Applications	Removal of nitrate for wastewater, agricultural runoff, and landfill leachate

Background
The Nitrex filter was developed at the University of Waterloo and is effective for the removal of nitrate from wastewater. The unit is filled with a proprietary wood byproduct mixture that promotes nitrogen removal. Typically the units are single-pass and do not require pumping.

Description of process
Wastewater containing nitrate, such as nitrified wastewater, agricultural runoff, and landfill leachate, is applied to the surface of the Nitrex filter. As the wastewater moves through the organic medium, microbial reduction of the nitrate nitrogen (denitrification) occurs. The bed must remain submerged for this to occur due to the anaerobic nature of this reaction.

System footprint
A typical system will have a surface area of 60 to 75 ft^2. System is typically buried to take advantage of gravity flow. Influent should be a nitrified wastewater, such as sand filter or other aerobic treatment effluent.

Advantages
Near complete removal of nitrogen from wastewater. Passive process with low energy and maintenance requirements.

Disadvantages
Requires aerobic pretreatment.

Performance
Manufacturer claims near complete removal of nitrate nitrogen. With adequate upstream aerobic process (e.g., trickling biofilter, aerated treatment process), total nitrogen removal is expected to be greater than 95%. Other effluent constituent concentrations are not known.

Operation and maintenance
Relatively low maintenance needs; however, media may need to be replaced over time.

Power and control
Can be operated with or without pumps depending on specific site characteristics and design. Annual power usage expected to range from negligible (no pump/control) to 50 kWh.

Cost
System for treatment of residential wastewater expected to cost from $1500 to 2000, not including shipping and installation costs.

Contact

Wastewater Science Inc.
Waterloo, Ont.
Phone (519) 885-1366
E wroberts@sciborg.uwaterloo.ca
Web www.nitrexfilter.com

Greg Ford
Septech Environmental Co.
London, Ontario
Phone (519) 433-0808
Fax (519) 433-2913

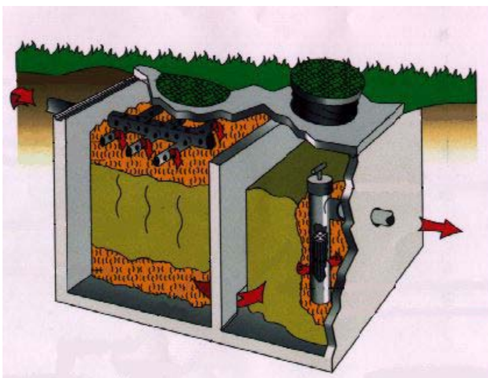


Figure 5-1
Diagram of Nitrex unit (left) and installation of a Nitrex unit to receive effluent from a sand biofilter (right). (Adapted from Wastewater Science, Inc.)

5-1.3 Rock Denitrification Tank

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Nitrified wastewater, carbon source
Function	Denitrification
Applications	Removal of nitrate for wastewater

Background/description of process
The rock tank is used in combination with a sand filter or other nitrifying treatment system. The nitrified wastewater flows into the tank with a submerged packing, typically an aggregate media such as rock. A carbon source is added to the system to stimulate denitrification.

System footprint
The anoxic rock tanks are typically designed with a 1 to 3 day hydraulic retention time.

Advantages
Depending on the carbon source used, nitrogen removal ranging from 30 to 100% can be achieved.

Disadvantages
Requires aerobic pretreatment for proper operation.

Performance
A research study by Lamb *et al*. (1990) found that the denitrification process was affected by the carbon source used, see Table 5-1.

Table 5-1
Summary of reported rock denitrification tank performance (Lamb *et al*., 1990)

Carbon source added to rock tank	Carbon source to sand filter effluent ratio	C:N ratio in rock tank	Mean denitrification, %
Septic tank effluent	1 to 4	0.7 to 1	25
Methanol	1 to 2,000	4 to 1	99
Ethanol	1 to 7,000	2 to 1	99

Operation and maintenance
The system for distribution of the external carbon source will require additional monitoring and maintenance compared to the passive system. The carbon source will need to be replenished periodically.

Power and control
Typically, a peristaltic pump is used to deliver the carbon source into the anoxic tank.

References and other resources
Lamb B.E., A.J. Gold, G.W. Loomis, and C.G. McKiel (1990) Nitrogen Removal for Onsite Sewage Disposal: A Recirculating Sand Filter/Rock Tank Design, *Transactions of the ASAE*, Vol. 33, No. 2, pp. 525-531.

Sandy A.T., W.A. Sack, and S.P. Dix (1987) Enhanced Nitrogen Removal Using a Modified Recirculating Sand Filter (RSF^2), *Proceeding of the Fifth National Symposium on Individual and Small Community Sewage Systems,* American Society of Agricultural Engineers, St Joseph, MI.

Sikora L.J., and D.R. Keeney (1976) Denitrification of Septic Tank Effluent, *Journal of the Water Pollution Control Federation*, Vol. 48, pp. 2018-2025.

5-4 RUCK® SYSTEMS INC.

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems, commercial

Background
The RUCK system utilizes the natural distribution of wastewater constituents to promote denitrification activity. RUCK systems are in use at residential and commercial sites in the United States and other countries.

Description of process
The RUCK system requires separate plumbing for collection of the greywater and blackwater. In the standard system, greywater is used as the carbon source for denitrification of the blackwater. To obtain nitrification, the blackwater is processed in a standard septic tank followed by a trickling biofilter. Greywater sources are collected in a separate septic tank for solids separation.

Because greywater typically has a high concentration of carbon and low concentrations of nitrogen, and blackwater processed in the trickling biofilter has a low concentration of carbon and a high concentration of nitrate, combining these two wastewater streams results in the transformation of nitrate into nitrogen gas. Diagrams of the RUCK system are shown in Figs. 5-2 and 5-3.

The denitrification step occurs in a separate anoxic biofilter, where the two wastewater streams are combined and allowed to percolate into the soil. For commercial and residential systems that have insufficient carbon for denitrification, a supplemental carbon source (typically a specially formulated soap) is added to the nitrified blackwater.

System footprint

Typical system will have a surface area of 300 to 400 ft^2.

Advantages

There is a potential for high nitrogen removal. The system is relatively simple to operate and maintain. Most of the materials needed for construction are locally available.

Disadvantages

The system performance is highly dependent on user activities. Retrofit of existing systems is more difficult because of the need to separate greywater and blackwater. There may be space limitations because of the large area needed for installation of all system components.

Performance

The RUCK systems have demonstrated excellent nitrogen removal. Due to the variation in household wastewater constituent concentrations, the specific performance of any particular system is variable. Systems receiving wastewater from clusters of homes or small communities have resulted in more stable performance due to an averaging effect and overall reduction in concentration peaks. Additional performance specifications from representative research studies are presented in Table 5-2.

Table 5-2

Selected representative studies of RUCK system performance

Parameter	Unit	Location of study		
		Florida[b]	Massachusetts[b]	Vermont[c]
Description of system		Residential	Residential	Residential
System performance[a]				
COD	mg/L	n/a	n/a	
BOD_5	mg/L	12 (95%)	30 (75%)	48
TSS	mg/L	10	30 (75%)	63
TN	mg/L	12 (75%)	8 (90%)	6
NO_3-N	mg/L	11	3	0.35
NH_3-N	mg/L		5	3.5
TP	mg/L	3 (66%)		3.5
Fecal coliform	CFU/100 mL		5000 (3)	

[a] Performance reported as average effluent concentration with average removal in parentheses, where applicable.

[b] Typical values from individual home systems; performance is dependent on water usage.

[c] Average of effluent from system serving cluster of 8 homes.

Operation and maintenance
Operation and maintenance requirements are similar to those for standard biofilter systems. For systems that use a supplemental carbon source, the carbon source will need to be replenished occasionally and the supply pump will need maintenance as required or specified by manufacturer. Systems should be inspected regularly for ponding of wastewater on the biofilter surface (or otherwise reduced infiltrative capacity) due to clogging. Correct pump and control system operation should be confirmed. The replenishment of the external carbon source may also be necessary.

Power and control
The basic system design is passive and does not require the use of pumps. Control, pumping, and monitoring systems can be used as for other systems.

Cost
An estimated cost of $7,000 to 9,000 includes capital and installation costs for the RUCK components only (does not include standard septic system).

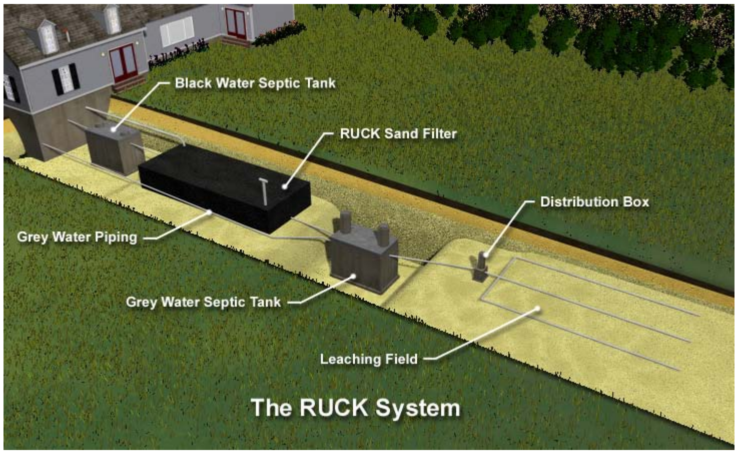


Figure 5-2
Diagram of residential RUCK system. (Adapted from Innovative RUCK Systems, Inc.)

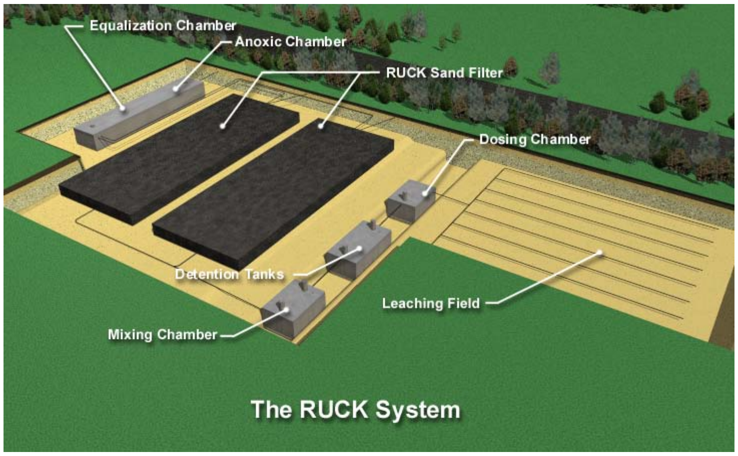


Figure 5-3
Diagram of commercial RUCK system. (Adapted from Innovative RUCK Systems, Inc.)

Contact

RUCK Systems. Inc.
149 Browns Rd.
Storrs Mansfield, CT 06268
Phone (860) 423-4417
Fax (860) 456-0803
Web www.rucksystems.com
RUCK Systems provides proprietary system design to authorized professional engineers.

Innovative RUCK Systems
200 Main St, Room 201
Falmouth, MA 02540
Phone (508) 548-3564
Web www.irucks.com
IRUCKS provides designs for RUCK Systems under license from RUCK Systems, Inc.

Model description

System design is available from an authorized professional engineer. Most materials needed are available locally, other components are available from the manufacturer. Biofilter media can generally be obtained from site location.

References and other resources

Laak, R., and M.A. Parese (1981) Denitrification of Blackwater with Greywater, *Journal of Environmental Engineering*, American Society of Civil Engineers, Vol. 7, No. EE3, pp. 581-591.

5-2 Anaerobic systems

Anaerobic processes are used for treating wastewater with high concentrations of biodegradable organic materials, such as concentrated domestic wastewater, biosolids, animal manure slurry, and food processing wastes. There are many types of anaerobic processes available, including the following:

> Anaerobic continuous flow stirred tank reactor – A suspended growth mixed anaerobic digestion process where all anaerobic biochemical reactions are occurring in the same reactor.

> Anaerobic plug-flow reactor – A reactor with a high length to width ratio where influent wastewater enters one end, flows through the reactor, and exits the opposite end. All anaerobic reactions occur in the same reactor.

> Upflow anaerobic sludge blanket (UASB) reactor – Influent wastewater is discharged into the bottom of a reactor and flows upwards through a layer of naturally forming sludge pellets.

> Anaerobic sequencing batch reactor – A batch reaction process where influent wastewater sequentially undergoes anaerobic treatment, clarification, and discharge.

> Anaerobic biofilter (fixed media packing) – A fixed packing submerged biofilter, typically operated in the upflow mode and operated at higher loading rates than suspended growth systems.

> Anaerobic fluidized bed – Attached growth anaerobic process where the influent wastewater enters the bottom of the reactor under sufficient pressure to expand the packing and cause liquefaction.

> Anaerobic mixed biofilm reactor – A reactor similar to a continuous flow stirred tank reactor with the addition of suspended media for fixed film anaerobic organisms.

> Staged anaerobic processes – Anaerobic reactors operated in series for improved process control.

> Phased anaerobic processes – Anaerobic reactors operated in a way that separates the biochemical reactions of hydrolysis/acidogenesis and methanogenesis for improved methane production and process control.

Additional details on these processes may be found in Speece (1996). All of these processes make use of anaerobic biochemical reactions for the removal of organic material and the mineralization of nutrients. The three biochemical reactions that characterize anaerobic processes are:

> Hydrolysis – enzyme mediated transformation of complex organic compounds into simple compounds.

> Acidogenesis – Bacterial conversion of simple compounds into substrates for methanogenesis (acetate, formate, hydrogen, carbon dioxide).
> Methanogenesis – Bacterial conversion of methanogenic substrates into methane and carbon dioxide.

The methanogenesis process is more sensitive to changes in pH and the presence of toxic compounds than aerobic treatment systems. Because of the sensitivity of the anaerobic bacteria to environmental variables, these processes are often used on a larger scale with more process monitoring and control. In some cases, methane, also known as biogas, may be captured for the recovery of energy. Biogas production and wastewater stabilization through anaerobic digestion may be a feasible option for applications that produce sufficient amounts of organic waste.

References

Speece, R. (1996) *Anaerobic Biotechnology for Industrial Wastewaters*, Archae Press, Nashville, TN.

5-2.1 Glendon Biofilter™

Category	Secondary treatment
Technology	Anaerobic upflow/trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Anaerobic digestion, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background

The Glendon Biofilter was developed in Washington State and has been used extensively in areas that have poor soils and high groundwater conditions. The process is known for its high quality treatment and relative low maintenance needs.

Description of process

The components of the Glendon Biofilter are a standard septic tank, a pump tank, an upflow sand filter process, and an aerobic capillary flow process. Septic tank effluent is collected in a pump tank and metered in small doses (on demand) to the anaerobic upflow biofilter unit. After moving upward through the bed of sand, the wastewater spills over the rim of the anaerobic reactor and then moves downward through the surrounding medium for aerobic treatment. The process is shown in Fig. 5-4.

System footprint

Requires about 200 ft^2 for treatment unit and surrounding soil adsorption area.

Advantages

Excellent treatment performance. Adaptable to sites that have restrictions for other types of treatment systems, such as areas with high groundwater. Low maintenance and energy usage. Does not require subsequent soil distribution system.

Disadvantages

Treatment system leaves mounded area on property (may be landscaped).

Performance

Process design is based on meeting treatment standards set by Washington State of BOD_5 and TSS less than 10 mg/L, and fecal coliform bacteria less than 200 CFU/100 mL. Specific performance data has not been obtained, but may be available from manufacturer.

Operation and maintenance

System maintenance is performed by a certified technician. System includes one pump, high water alarm, and control panel. Electrical components will need to be monitored to confirm that the system is operating correctly. Excessive water use or pump failure will result in activation of the high water alarm. The system incorporates a septic tank that will require periodic servicing for solids removal.

Power and control

Relatively passive process, which uses one pump (110 Volt electric pump), control panel, and high water alarm. The expected annual power usage ranges from 50 to 150 kWh.

Cost

The estimate includes capital and installation costs for biofilter component only is $5,000 to 8,000.

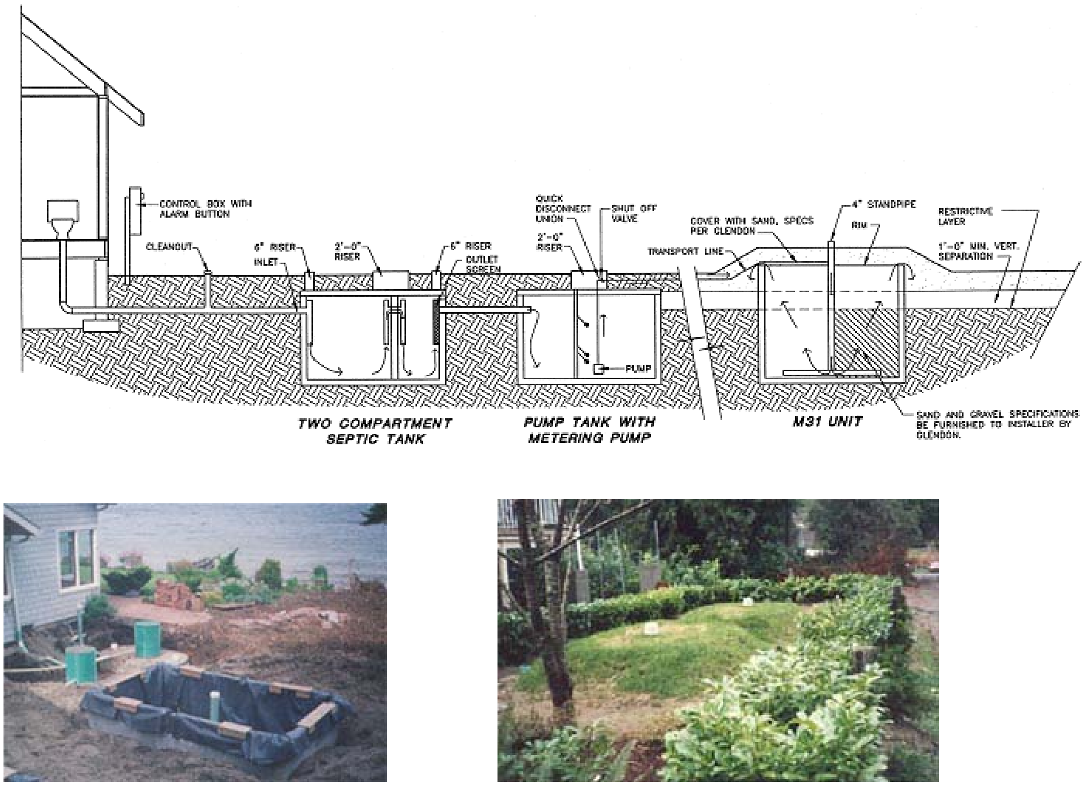


Figure 5-4

A diagram of the Glendon Biofilter system (top), the installation of a Glendon Biofilter (bottom left), and a completed system at a residence (bottom right). (Adapted from Glendon Biofilter Technologies, Inc.)

Contact

Glendon Biofilter Technologies, Inc.
25448 Port Gamble Rd. N.E.
Poulsbo, WA 98370
Phone (360) 297-7066
Fax (360) 297-8479
E info@glendon.com
Web www.glendon.com
Model description
M3 (240 to 480 gpd)
M31 (90 to 528 gpd)

Manufacturer support

Two year warranty on treatment system, one year warranty for the pump and timer.

5-2.2 Upflow Anaerobic Sludge Blanket (UASB) Reactor

Category	Secondary treatment
Technology	Anaerobic upflow biofilter
Input	Untreated waste/wastewater, septic tank effluent
Function	Anaerobic digestion, pathogen reduction
Applications	Community wastewater, agricultural and industrial wastes

Background/description of process

The UASB reactor was developed in the Netherlands (Lettinga *et al*., 1980) and is widely used in Europe and South America. The wastewater flows in the bottom of the anaerobic reactor and through a layer of naturally forming, dense biological sludge granules. The sludge particles range in size from flocculants to granules with a diameter of 0.25 in. Gases formed in the digestion process generate mixing action and promote granule formation in the sludge layer. The methane gas is captured in a reservoir at the top of the reactor and may be used for energy reclamation. The process is shown in Fig. 5-5.

System footprint

For an individual residence, a UASB reactor receiving septic tank effluent would have a volume between 35 and 70 ft^3. Additional arrangements for biogas management would also be needed.

Advantages

Anaerobic systems do not require aeration, which is typically a significant cost for aerated systems. The amount of sludge produced is less than that produced by a comparable aerobic systems.

Disadvantages

There is a potential for odors associated with anaerobic digestion. The treatment process is more sensitive to the presence of toxic compounds and changes in temperature than aerobic systems. Minimal nutrient removal occurs without the application of a subsequent treatment process.

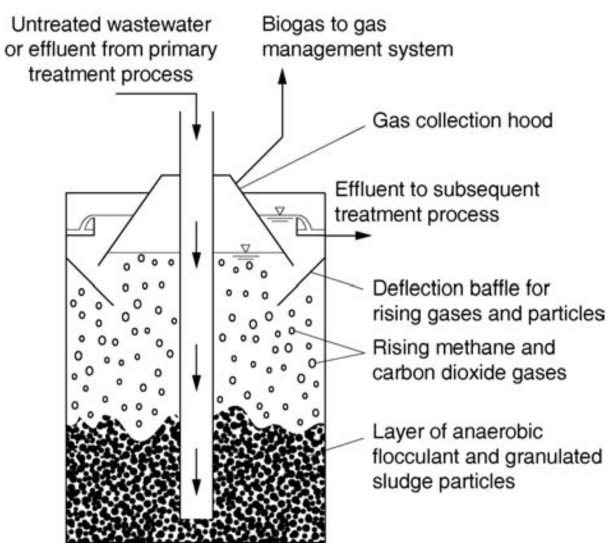


Figure 5-5

Diagram of the UASB treatment process.

Performance
Anaerobic processes are effective at COD removal from concentrated waste streams, typically 60 to 90 percent COD removal; however, these systems mineralize nutrients and thus do not remove them from the water phase. Anaerobic systems are suited for nutrient recovery applications, such as through agricultural reclamation. If nutrient removal is the objective, subsequent treatment will be needed. In cool climates, performance may be similar to a septic tank.

Operation and maintenance
Process monitoring is important to ensure that the pH is within the required range of 6.6 to 7.6, particularly if methane recovery is to be considered. Periodic sludge removal may be necessary.

Power and control
Aeration is not needed for anaerobic systems.

References
Lettinga, G.A., A.F.M. van Velsen, S.W. Hobma, W.J. de Zeeuw, and A. Klapwijk (1980) Use of the Upflow Sludge Blanket (USB) Reactor Concept for Biological Wastewater Treatment, *Biotechnology and Bioengineering*, Vol. 22, pp. 699-734.

Zeeman, G., and G.A. Lettinga (1999) The Role of Anaerobic Digestion of Domestic Sewage in Closing the Water and Nutrient Cycle at the Community Level, *Water Science and Technology*, Vol. 39, No. 5, pp. 187-194.

CHAPTER 6
TRICKLING BIOFILTERS
(ATTACHED GROWTH AEROBIC TREATMENT SYSTEMS)

The biological treatment of wastewater with a trickling biofilter is among the oldest and most well characterized technologies. These systems have also been described as intermittent (medium) filters, packed bed filters (PBFs), trickling filters (TFs), attached growth processes, and fixed film processes.

The fundamental components of the trickling biofilter system are (1) a medium upon which a microbial community (biofilm) develops, (2) a container or [lined] excavated pit to house the medium, (3) a system for applying the water to be treated to the medium, and (4) a system for collection and distribution of the treated water. The water to be treated is applied, periodically, in small doses to the medium. Trickling biofilters can be operated in single-pass or multi-pass configurations, as described below.

Single-pass systems
In a single-pass system, the water to be treated is only applied to the biofilter one time before being collected and conveyed to subsequent treatment or dispersal. In some cases, with appropriate topography and land area, it may be possible to operate without, or with minimal, pump usage.

Multi-pass systems
Repeated application of the water to be treated to the biofilter before release to subsequent treatment is known as a multi-pass system. After a dose of the water to be treated passes through the biofilter, a portion (return flow) is returned to the septic tank or intermediate storage for reapplication, and the remainder (effluent) is discharged to subsequent treatment. The return flow is combined with the process influent water (typically effluent from a septic tank) before reapplication to the biofilter. The combining of the return flow (treated) with the process influent (untreated) results in a combined water with intermediate quality. Due to the dilution of the process influent, the hydraulic loading rate (HLR) can be increased and the overall filter surface area decreased relative to the single-pass system. Because of the need for repeated application (recirculation) of the wastewater, pumping and control system needs may be increased, as compared to single-pass systems.

Other configurations
Other configurations for trickling biofilters include dosing at intermediate depths within the biofilter medium, bottomless containers that allow biofilter effluent to infiltrate directly into the soil, the separate treatment of greywater and blackwater (for improved denitrification), and placement of the biofilter inside of the septic tank.

System components
The most common components of trickling biofilter systems are discussed below. For both single-pass and multi-pass systems, the system components include (1) a support medium for the attached biofilm, (2) a wastewater distribution system for the biofilter material, (3) a container for the biofilter material, and (4) a collection system for the water after it has passed through the biofilter.

Support medium
Trickling biofilter systems are primarily distinguished by the material that is used to support the active microbial community. Variations in material properties such as surface area, infiltration capacity, and porosity can have a significant impact on the operation and performance of the system. The categories of media used in trickling biofilters (discussed in Secs. 6-1 to 6-3) are (1) inorganic granular, (2) organic, and (3) synthetic.

Distribution system

The primary methods for applying wastewater to the biofilter for treatment are the (1) orifice system and the (2) spray system. For the orifice distribution system, a layer of pea stone is often included on the surface of the filter medium to promote the lateral distribution of wastewater. For high infiltrative capacity media, the need for uniform distribution of wastewater to the surface of the filter has led to the use of closer orifice spacing for the orifice distribution system and full-cone spray nozzles for the spray distribution system. When media with a high infiltrative capacity are used, increasing the orifice density (i.e., closer together) or the use of spray distribution is recommended.

For gravity flow systems, dosing siphons may be used to perform the periodic application of wastewater. Pressure dosed systems are required when there is insufficient slope for gravity flow and when additional process control is desired. Pressure dosed systems can use high or low head pumps, timing devices, and float switches/alarms.

Container

Various containers have been used to house the support medium for the attached microbial community, including plastic, fiberglass, concrete, and PVC lined pits. In some installations, the biofilter has been integrated into the landscape using decorative bricks and/or used as a raised bed planter. For lightweight materials, such as synthetic media, in high groundwater areas, care should be taken to ensure that the tank does not become buoyant under high groundwater conditions.

Collection system

The collection system specified depends on the type of biofilter medium used. For granular media filters, the most common type of underdrain is a slotted PVC pipe covered by a coarse gravel or rock drain layer and an intermediate sized gravel layer. The active filter material is then placed on top of the intermediate sized gravel layer, to limit the granular biofilm support material from migrating into the underdrain system. For lightweight synthetic materials, a less complex system can be used, such as a support screen above an effluent drain.

Tankage

Additional vessels may be needed depending on the type of system, including pump basins, mixing and recirculation tanks, and equalization basins. Equalization is used to normalize highly variable flows and can occur in a separate tank or in the septic tank. Mixing and recirculation tanks can include intermediate tanks for temporary storage and mixing of water to be reapplied to the biofilter (multi-pass systems). Pump basins may be used for dosing the biofilter or delivering biofilter effluent to a soil adsorption area.

Control systems

Dosing of trickling biofilters can be accomplished on a timed dosing or on-demand basis. The timed dosing regime offers the advantage of even application of wastewater to the biofilter, resulting in improved performance. Given the typical variation in residential water use, the timed system is recommended to obtain more even dosing of wastewater.

Operational parameters

The performance of trickling biofilters is dependent on several process control variables, including hydraulic loading rate (HLR), organic loading rate (OLR), hydraulic application rate (HAR), dosing frequency (DF), and recirculation ratio (α). Each of these terms is defined below.

Hydraulic loading rate

In single-pass systems the HLR is equal to the volume of wastewater per unit time applied to the biofilter medium. The most common expression for the HLR is gallons of wastewater applied per ft^2 of biofilter surface area per day ($gal/ft^2 \cdot d$). For the multi-pass systems, the HLR is equivalent to the volume of filter effluent produced, i.e., leaving the system, per unit time. It should be noted that, due to the multiple application of the wastewater to the filter, the actual volume of water applied to the biofilter surface is greater than the HLR by a factor equal to α, as discussed below. The peak HLR should be used for system design purposes.

Organic loading rate

The organic loading rate (OLR) is a measure of the oxygen demanding compounds (soluble and particulate organic materials) applied to the biofilter on an area basis. The OLR is calculated by multiplying the 5 day biochemical oxygen demand (BOD_5) or chemical oxygen demand (COD) by the HLR and an appropriate unit conversion factor. The OLR is an estimate of the amount of organic material that is being processed by the microbial community. For wastewaters that have a significantly higher organic concentration (i.e., high BOD_5), sizing the treatment process based on the HLR may result in organic overloading. Typical units for the OLR are lb $BOD_5/ft^2 \cdot d$.

Dosing frequency

The number of applications of wastewater to the biofilter surface over a specific time period is described as the dosing frequency (DF). The DF is selected based on the specific configuration and operation of the treatment system. In general, it has been determined that applying small doses more frequently (i.e., increased DF) improves the performance of trickling biofilters.

Hydraulic application rate

The hydraulic application rate (HAR) is used to characterize the size of the dose applied to the biofilter. The hydraulic application rate is defined as:

$$\text{HAR, in/dose} = \frac{(0.01114)(\text{Hydraulic loading rate, HLR, gal/ft}^2 \cdot \text{d})(1+\text{Recirculation ratio, } \alpha)}{(\text{Dosing frequency, DF, dose/d})}$$

For single-pass systems, the recirculation ratio is equal to zero, and thus only needs to be considered for multi-pass systems. The recirculation ratio is discussed below.

Recirculation ratio

For multi-pass systems, α is defined as the statistical number of times that the wastewater is applied to the biofilter surface before being returned to the recirculation tank or released as effluent from the system. Values for α are typically in the range from 2:1 to 9:1. Reduced denitrification has been observed when high recirculation is used due to the increased volume of oxidized water returned to the anaerobic/anoxic treatment process. Alternately, low values of α may result in insufficient contact time for meeting treatment objectives and intermittent odor problems.

Failure

System failure can be attributed to operational problems and to equipment failure. Equipment failure can include pump breakdown, power outages, control system malfunction, or a tripped circuit breaker. High water alarms can be used to provide warning in case of equipment failure. Operational problems may be due to organic, solids, or hydraulic overloading; inadequate design or construction; extreme temperatures that inhibit biological growth; or other situations that result in ponding of wastewater on the biofilter surface. When an operation problem causes wastewater to accumulate on the biofilter surface, several actions may be taken to renovate the problem, including excavation and replacement of part or all of the media and adjusting the operational features (e.g., reduced hydraulic or constituent loading, increased dosing frequency). In cases where the medium in a failed system has not replaced, it has been observed that several weeks may be required for the effluent quality to return to normal.

Monitoring and maintenance

A monitoring and maintenance program is recommended for all systems to ensure long-term treatment performance. Monitoring procedures should include regular (about every 3 months) inspection of system components, operation, and effluent quality.

System components

The system components to be inspected include the control panel, pumps, pump basins, float switches, dosing siphons, and media surface. Any electrical power and control components that are not working properly should be serviced or replaced. Solids that accumulate in pump basins should be pumped out regularly, typically at the same time that solids are pumped from an upstream septic tank.

Operation

System operation should be monitored to ensure that overloading is not occurring. System operational parameters to be checked may include pressure in the distribution system during dosing, hydraulic application rate, and surface accumulations. Accumulation of solids or water on the surface of the media is an indication that the operational parameters need to be adjusted. The surface layer of the filter may be raked or excavated if necessary. If clean-out ports have been installed, the distribution system can be flushed to remove solids that have accumulated.

Effluent quality

System performance can be monitored by inspecting the effluent quality. The two types of analysis are qualitative (sensory analysis) and quantitative (lab analysis). In most cases a qualitative analysis should be sufficient to determine if the system is functioning correctly. To perform a qualitative analysis, the water sample is collected from an appropriate effluent sampling port into a clear glass container. If a valve is opened to dispense the sample, it should be allowed to flow for a short period to flush solids that have been dislodged. A properly operating secondary treatment process, such as a trickling biofilter should have minimal suspended material and be free of offensive odors. If quantitative analysis is desired, the samples should be handled in a manner consistent with Standard Methods for the Examination of Wastewater (2000).

6-1 Granular media trickling biofilters

In the original trickling biofilter systems, sand was used as the medium for attached biofilm growth. Because of its availability and historical utilization, sand is still one of the most commonly used media in trickling biofilters. Other granular inorganic media that are used include gravel, crushed glass, expanded aggregates, and slag.

While granular materials have performed well in trickling biofilter systems, there is a correlation between media properties and system performance and failure. The material needs to be relatively free of fine material that can result in the formation of a clogging lens within the biofilter. In addition, the material needs to have sufficient surface area and matrix properties to support the biofilm. The infiltrative capacity of the medium may also be useful in assessing the relative ability of the material to accept the applied wastewater.

6-1.1 Activated carbon biofilter

Category	Secondary/tertiary treatment
Technology	Trickling biofilter, adsorption
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
Activated carbon is a high surface area material used for adsorption of various compounds. While not commonly used in biofilter applications, activated carbon may be an effective material for the adsorption of microorganisms as well as wastewater constitutes. Additional research is needed to characterize the performance of activated carbon for the tertiary wastewater treatment.

Operation and maintenance
After reaching its adsorptive capacity, the carbon can be regenerated or replaced. Cost needs to be evaluated to determine if process is feasible.

Contact
Activated carbon is widely used for air treatment and drinking water treatment. Local suppliers are available in most areas.

References and other resources
Stevik T.K., G. Ausland, P. Jenssen, and R.L. Siegrist (1999) Removal of E. Coli During Intermittent Filtration of Wastewater Effluent as Affected by Dosing Rate and Media Type, *Water Research*, Vol. 33, No. 9, pp. 2088-2098.

6-1.2 AIRR™ wastewater recovery system

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The alternating intermittent recirculating reactor (AIRR) is a trickling biofilter with a sand/gravel medium. The process was developed in 1977, and the original installations are still in operation.

Description of process
The biofilter is divided into two sections, a treatment section and a polishing section. Septic tank effluent is collected and distributed to the treatment biofilter section of the system. After passing through the treatment biofilter, the water is collected and applied to both the treatment biofilter and the polishing biofilter. The portion of the water applied to the treatment biofilter is returned for recirculation flow, and the effluent that passes through the polishing biofilter is discharged. The concept is that it is not possible for water that has not passed through the treatment biofilter to be applied to the polishing biofilter for discharge.

Performance
Manufacturer reports typical effluent concentrations of BOD_5 and TSS in the range of 2 to 3 mg/L.

Operation and maintenance
Manufacturer provides operation and maintenance instructions to system owner. Recommend maintenance on an annual basis. Systems have been successfully operated in both hot and cold climates.

Contact

SPEC Industries, Inc.
550 Parkson Road
Henderson, NV 89012
Phone (702) 558-4444
Fax (702) 558-4563
E SPECindustries@juno.com

References and other resources

U.S. EPA (2001) *CEIT Virtual Trade Show: AIRR Wastewater Recovery Systems (available at www.epa.gov/region1/steward/ceitts/wastewater/techs/airr.html).*

6-1.3 Ashco-A RSF III™

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Contact

Ashco-A-Corporation
1946 Grafton Rd.
Morgantown, WV 26508-0000
Phone (304) 291-0808
Fax (304) 291-0843
Model description
RSF II (cluster systems and commercial applications)
RSF III (single unit residential systems)

6-1.4 Crushed brick biofilter

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background

Crushed red brick has been found to have enhanced phosphorus removal capacity when placed beneath a drip irrigation system (Anderson, 1998). Similar results could be expected when using this material in a trickling biofilter or related application.

Description of process

A lined bed of crushed brick is periodically dosed with septic tank effluent. The crushed brick serves as a medium for microbial attachment and adsorbs excess phosphorus from the wastewater.

Performance

A lined crushed brick biofilter was evaluated by Ayers Associates as part of the Florida Keys Onsite Wastewater Nutrient Reduction System Demonstration Project. The crushed brick biofilter was expected to have excellent phosphorus adsorption capability for 10 years (Florida Dept of Health, 2000). Additional research is needed to evaluate the phosphorus removal capability of locally obtained crushed brick.

Operation and maintenance
Phosphorus adsorption will eventually reach capacity and will require the medium to be regenerated or replaced. The medium may be useful as a soil amendment.

Contact
Locally available in many areas, check local landscape supply outlets.

References and other resources
Anderson D.L., M.B. Tyl, R.J. Otis, T.G. Mayer, and K.M. Sherman (1998) Onsite Wastewater Nutrient Reduction Systems (OWNRS) for Nutrient Sensitive Environments, in *Proceeding of the Eight National Symposium on Individual and Small Community Sewage Systems, Orlando, FL.*

Florida Department of Health (2000) *Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project – Phase II Addendum*, Florida Department of Health.

6-1.5 EnviroFilter™ modular recirculating media filter

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single residential and small community/institutional systems

Background
The EnviroFilter developed by Earthtek Environmental Systems, Inc. is a self-contained trickling biofilter system. The system offers the advantage of not requiring a detailed engineering design due to its pre-packaged nature. All system components come pre-assembled and housed in a container, minimizing installation costs.

Description of process
The basis of the EnviroFilter design is a multilayer biofilter. The biofiltration media is layered to reduce the overall footprint of the system. Currently the system utilizes a granular medium to support fixed film growth; however, future development may include the use of high porosity synthetic materials.

Performance
The EnviroFilter unit includes a recirculation feature that can be expected to contribute to additional total nitrogen removal. Manufacturer reported performance values are presented in Table 6-1.

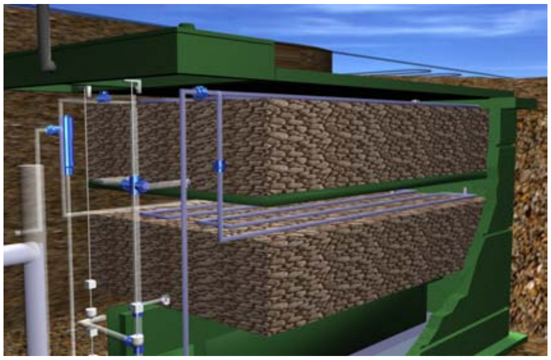
Table 6-1
Typical performance of the EnviroFilter treatment system[a]

Parameter	Removal efficiency
$CBOD_5$	98%
TSS	98%
TN	70%
Fecal coliform	2 logs

[a] Adapted from manufacturer brochure.

Operation and maintenance
System should be inspected periodically to ensure proper operation. Pumps and control devices will need periodic inspection and servicing as required. Standard drip irrigation system will need to be flushed.

Cost
Total cost for complete system installer (including septic tank and drip irrigation system) in the range to $11,000 to 13,000.



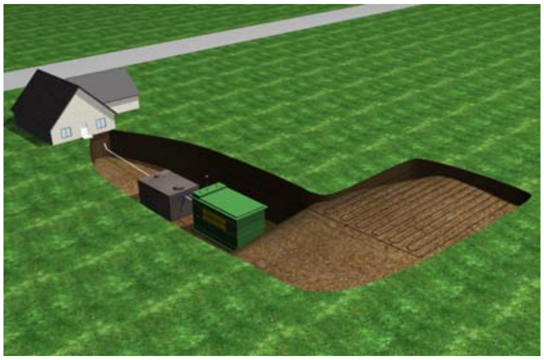


Figure 6-1
EnviroFilter modular treatment unit cutaway view showing multi-layer design (left) and installed system with drip irrigation system (right). (Adapted from Earthtek Systems, Inc.)

Earthtek Environmental Systems, Inc.
204 South St.
Batesville, IN 47006
Phone (812) 934-5035
Fax (812) 934-5018
E kchaffee@earthtekonline.com
Web www.earthtekenvironmental.com
Earthtek Environmental Systems, Inc.
Model descriptions
EnviroFIlter 500B (3 bedrooms)
EnviroFIlter 600B (4 bedrooms)
EnviroFIlter 750B (5 bedrooms)
Vendor support
Manufacturer recommended/required service contract.

6-1.6 Eparco

Category	Secondary treatment
Technology	Trickling biofilter
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
Eparco manufactures complete wastewater treatment systems for individual homes and communities. The system consists of a specially designed primary treatment module (septic tank), a pre-treatment module, a compact treatment biofilter, and a tertiary sand biofilter. The Eparco system is gravity flow and operated in series similar to a single-pass sand biofilter system.

Performance
Typical effluent quality of BOD_5 and TSS concentrations less than 5 mg/L, nitrification, and some nitrogen removal. The system does not incorporate a distinct denitrification step.

Operation and maintenance
Passive process that requires little regular operation and maintenance. Manufacturer guarantees septic tank will not need pumping for 4 to 10 years.

Contact
Eparco
5420 North Service Road
Burlington, Ontario, Canada L7L 6C7
Phone (905) 319-8100
Fax (905) 319-1987

6-1.7 Expanded aggregate biofilters

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single home and small community residential systems

Background
When shale, clay, or slate are heated in a rotary kiln at high temperature (1000 to 2000 ^oF), a porous structure develops and is referred to as lightweight expanded aggregate. Expanded aggregates typically have a bulk density of 45 to 50 lb/ft^3, or about 50 percent less than other granular materials such as sand and gravel. Because of the low bulk density, these materials are often referred to collectively as lightweight aggregates (LWA). This material is available at low cost and has been used as an alternative biofilter medium in some cases.

Description of process
Expanded aggregate materials have been used in single-pass and multi-pass biofilter arrangements. These materials have been found to perform well as support materials for the attached biomass in trickling biofilters and as a support medium in constructed wetlands.

Influent should be settled wastewater without high concentrations of particulates or oil and grease. Effluent management will depend on characteristics of the receiving location. Effluent may be distributed through drip irrigation (after disinfection) or other soil treatment system.

System footprint
Typical system will have a surface area of 100 ft^2,based on loading of 450 gal/d of typical settled residential wastewater and an estimated loading 5 gal/ft$^2\cdot$d. Systems can be installed above ground, partially buried, or fully buried. Top of filter may be planted or otherwise integrated into landscape for aesthetic purposes.

Advantages
Material does not contain the fine materials that are implicated in clogging of sand biofilters. Material is lightweight and cost is competitive with other materials. Excellent phosphorus adsorption properties.

Disadvantages
May require electricity for pump operation. Somewhat limited design specifications available. For systems that rely on pumps, extended power failure can result in wastewater backup.

Performance

The performance of LWAs to remove microorganisms and phosphorus has been documented in several studies. Zhu *et al*. (1997) documented that Utelite (Coalville, UT) LWA had the highest phosphorus adsorption of 12 materials evaluated (3.46 g P/kg of material) and that phosphorus adsorption is dependent on the calcium content of the material. Stevik *et al*. (1999) reported complete E. Coli removal in spiked wastewater samples applied to crushed expanded aggregate biofilter. Additional performance specifications from representative research studies are presented in Table 6-2.

Table 6-2

Selected representative studies of expanded aggregate trickling biofilter performance

		Location of study		
Parameter	Unit	Maryland[a]	Maryland[a]	Florida[b]
Description of system		Expanded shale	Expanded slate	Drip irrigation to 24 in bed of LECA[c]
HLR	gal/ft^2•d			1.35
System performance[d]				
BOD_5	mg/L	20 (92%)	20 (92%)	1 (99%)
TSS	mg/L	36 (67%)		5 (95%)
TN	mg/L	23 (60%)	30 (48%)	29 (39%)
NO_3-N	mg/L			28
NH_3-N	mg/L			0.9
P	mg/L			0.5 (94%)
Fecal coliform	CFU/100 mL	2.9E3 (2)	2.5E2 (3.1)	

[a] Medium known as Filtralite-P™ LECA designed for phosphorus removal.
[b] Anne Arundel County National Onsite Demonstration Project.
[c] Anderson *et al*. (1998) and Florida Department of Health (2000).
[d] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.

Operation and maintenance

If expanded aggregates are used for the adsorption of phosphorus, the medium will need to be regenerated or replaced after reaching its adsorptive capacity (estimated 10 year lifespan). Other operation and maintenance is similar to that for other trickling biofilters, including removal of sludge from primary treatment, maintenance of septic tank effluent filtration devices, and inspection of control devices. Expanded aggregates generally have a large enough particle size that surface clogging is not a concern. Systems should be inspected regularly for ponding of wastewater on biofilter surface (or otherwise reduced infiltrative capacity) due to clogging. Correct pump and control system operation should be confirmed. Phosphorus adsorption capability estimated to be 10 years.

Power and control

Treatment system can be operated with or without pumps depending on specific site characteristics and design. Alarm and monitoring equipment recommended. Can be dosed on a timed (recommended) or on-demand basis. Annual power usage expected to range from negligible (no pump/control) to 150 kWh.

Cost

Estimated capital cost $2,000 to 3,000 (LWA currently available in bulk for $\$40/yd^3$) for treatment system only, additional cost for standard septic system (including effluent management system), engineering and permitting fees, operation, and maintenance.

Contact

Local suppliers can be located by contacting the Expanded Shale, Clay, and Slate Institute www.escsi.org

Optiroc Group
Po. Box 216 Alnabru,
Brobekkveien 84
0614 Oslo, Norway
Phone +47 22 88 77 00
Fax +47 22 64 54 54
Web www.filtralite.com

Scancem AB
PO Box 60066
SE-216 10 Malmö, Sweden
Phone +46 (0)40-16 50 00
Fax +46 (0)40-16 51 43
E info@hq.scancem.com
Web www.scancem.com
Description
LECA and Filtralite-P™ LECA.

TXI - Ontario
3500 Porsche Way Suite 150
Ontario, CA 91764
Phone (909) 635-1880
Fax (909) 635-1899
Web www.txi.com

Utelite Corporation
PO Box 387
Coalville, Utah 84017-0387
Phone (435) 336-5301 or (801) 467-2800
Fax (801) 467-6765
E utelite@allwest.net
Description
One of the best performing materials is manufactured in Utah (Utelite), with an estimated phosphorus adsorption capacity of 3.5 g P/kg of media.

Figure 6-2

LECA material with particle diameter of 0.3 to 0.4 in. (Adapted from Scancem AB.)

Figure 6-3

Utelite expanded aggregate (available in coarse, medium, and fine sizes).

Figure 6-4

Filtralite™ aggregate media. (Adapted from Optiroc Group, Inc.)

References and other resources

Anderson D.L., M.B. Tyl, R.J. Otis, T.G. Mayer, and K.M. Sherman (1998) Onsite Wastewater Nutrient Reduction Systems (OWNRS) for Nutrient Sensitive Environments, in *Proceedings of the 8th National Symposium of Individual and Small Community Sewage Systems* - 2001, American Society of Agricultural Engineers, pp. 235-244, St. Joseph, MI.

Expanded Shale, Clay, and Slate Institute <www.escsi.org>.

Florida Department of Health (2000) *Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project – Phase II Addendum*, Florida Department of Health.

Heistad, A., P.D. Jenssen, and A.S. Frydenlund (2001) A New Combined Distribution and Pretreatment Unit for Wastewater Soil Infiltration Systems, in *Proceedings of the 9th National Symposium of Individual and Small Community Sewage Systems* - 2001, Fort Worth, TX, American Society of Agricultural Engineers, pp. 235-244, St. Joseph, Michigan.

Johansson, L. (1997) The Use of LECA (Light Expanded Clay Aggregates) for the Removal of Phosphorus from Wastewater, *Water Science and Technology*, Vol. 35, No. 5, pp. 87-93.

Stevik, T.K., G. Ausland, P. Jenssen, and R.L. Siegrist (1999) Removal of E. Coli During Intermittent Filtration of Wastewater Effluent as Affected by Dosing Rate and Media Type, *Water Research*, Vol. 33, No. 9, pp. 2088-2098.

Zhu, T., P.D. Jenssen, T. Maehlum, and T. Krogstad (1997) Phosphorus Sorption and Chemical Characteristics of Lightweight Aggregates (LWA) – Potential Filter Media in Treatment Wetlands, *Water Science and Technology*, Vol. 35, No. 5, pp. 103-108.

6-1.8 Glass (crushed) biofilters

Category	Secondary treatment
Technology	Trickling biofilter (single-pass and multi-pass)
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
Crushed glass has been evaluated as a biofilter medium in several research projects. Glass is widely available as a product from solid waste recycling programs that often has little value due to the presence of contamination and lack of color separation. Glass crushing equipment can be used to prepare glass of various grades and the crushed glass can be screened to obtain the desired medium specifications. Because of the difficulty in obtaining appropriately sized sand in some areas, crushed glass may be economically preferable.

Description of process
The operation of the crushed glass filter is similar to other aggregate media filters (i.e., sand, gravel, etc.). Most literature reports describe single-pass systems; however, crushed glass has also performed well in multi-pass configurations. In general, increasing dosing frequency and distribution uniformity is believed to improve system performance. Influent should be a settled, typical residential wastewater without high concentrations of particulates, large particles, or oil and grease. A septic tank screening device is recommended. Effluent management will depend on characteristics of the receiving location. Effluent may be distributed through drip irrigation (after disinfection) or other soil treatment system.

System footprint
Typical systems will have a surface area of 400 ft^2. Systems can be installed above ground, partially buried, or fully buried. The top of the filter may be planted or otherwise integrated into landscape for aesthetic purposes.

Performance
The performance of the crushed glass as a medium is not significantly different from the performance of sand, when both materials meet certain size specifications. Crushed glass material generally has a coarse texture (as determined by sieve analysis) and higher infiltrative

capacity than comparable sand used in similar applications. Additional performance specifications from representative research studies are presented in Table 6-3.

Table 6-3
Selected representative studies of crushed glass trickling biofilter performance

Parameter	Unit	Location of study			
		King Co, WA[b]	Oswego, NY[c]	Ronald, WA[b]	Davis, CA[d]
Description of system		Residential	Residential	Residential	Experimental
Pretreatment		Septic tank with outlet filter	Septic tank	Septic tank with outlet filter	Primary effluent
ES (d_{10})	mm	0.24	0.7	0.24	0.44
UC (d_{60}/d_{10})	unitless	7.8	5.6	7.8	5.0
Depth of medium	ft	2	2.5	2	1.25
α	unitless	1	3	1	1
HLR	$gal/ft^2 \cdot d$	1.2	1.8	1.6	1
DF	dose/d	4	n/a	n/a	24
Temp	^oF	55	64	61	
pH	unitless	6.4	7.3	7	
System performance[a]					
COD	mg/L		39.7 (83%)		8 (95%)
BOD_5	mg/L	7 (96%)	10.7 (94%)	7 (97%)	
TSS	mg/L	4 (91%)	2.5 (95%)	4 (94%)	0 (>99%)
Oil/grease	mg/L	6 (79%)		7 (85%)	
TN	mg/L	30 (29%)	19.7 (55%)	29.8 (48%)	
NO_3-N	mg/L	28	12.7	25.8	
NH_3-N	mg/L	<1	4.1	2.1	
Fecal coliform	CFU/100 mL	1.6E3 (2.7)		2.3E3 (3.3)	
Total coliform	MPN/100 mL				4400 (3.4)
Native phage	PFU/mL				2 (3.1)

[a] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.
[b] CWC (1997) study of individual residential systems.
[c] Elliott (2001) reported operation and performance of a small community system.
[d] Emerick *et al*. (1997) conducted research project at UC Davis.

Advantages
Medium used is available statewide as a component recovered from solid waste recycling activity, however, use of crushed glass may include cost preparing glass (i.e., grinding and shipping). Design and performance are similar to sand medium.

Disadvantages
May require electricity for pump operation. Somewhat limited long-term performance data available. For systems that rely on pumps, pump failure, control panel failure, and extended

power outages can result in wastewater backup. Improper design, construction, or loading can lead to system failure (ponding of water on surface of biofilter).

References and other resources

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Emerick, R., R. Test, G. Tchobanoglous, and J. Darby (1997) Shallow Intermittent Sand Filtration: Microorganism Removal, *The Small Flows Journal*, v3, n1, pp12-21.

State of Washington (1999) Intermittent Sand Filter Systems – Recommended Standards and Guidance for Performance, Application, Design, and Operation and Maintenance, Washington State Department of Health, Seattle, WA.

6-1.9 Glass (sintered) biofilter

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background/description

A high surface area material used for fine particle filtration and used in some experimental systems as a medium for biological attached growth.

6-1.10 Gravel biofilter (multi-pass systems)

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background

The multi-pass gravel trickling biofilter has been used for onsite wastewater treatment since its development in the 1970s. The system uses a coarse sand or gravel medium for biofilm growth. Additional details on multi-pass sand/gravel filters are presented in Table 6-4.

Description of process

Multi-pass systems have been configured in a variety of ways, depending on the method of recirculating the filter effluent. As shown in Fig. 6-5, the filter effluent can be recirculated to one of the chambers in the septic tank or to a separate tank (recirculation tank). One or two pumps are required for system operation, depending on the specific design. Influent should be settled wastewater without high concentrations of particulates or oil and grease. Effluent management will depend on characteristics of the receiving location. Effluent may be distributed through drip irrigation (after disinfection) or other soil treatment system.

System footprint

Typical system will have a surface area of 110 ft^2. Systems can be installed above ground, partially buried, or fully buried. Top of filter may be planted or otherwise integrated into landscape for aesthetic purposes.

Performance

Additional performance specifications from representative research studies are presented in Table 6-4. Recirculation and mixing of the filter effluent with septic tank effluent reduces the overall oxygen demand of the water to be treated, allowing for higher loading rates.

Table 6-4

Selected representative studies of gravel (multi-pass) trickling biofilter performance

		Location of study			
Parameter	Unit	Minnesota[b]	Martinez, CA[c]	East Lansing, MI[d]	Gloucester, MA[e]
Description of system		Residential	Community	Residential	Residential
ES (d_{10})	mm		3	0.3	
UC (d_{60}/d_{10})	unitless		<2	4	
Depth of medium	ft	2	2	4	2
α	unitless	5	5	5	5
HLR	$gal/ft^2 \cdot d$	5	3	3.1	3
DF	dose/d			14	
pH	unitless		7.6	7.0	
System performance[a]					
BOD_5	mg/L	18 (93%)	<5 (96%)	6 (96%)	7 (98%)
TSS	mg/L	23 (81%)	4.9 (93%)	2 (95%)	12 (85%)
Oil/grease	mg/L		0		2.3 (94%)
TN	mg/L	43 (47%)	12.6 (80%)	26 (53%)	60.8 (36%)
NO_3-N	mg/L	29	12.2	24	38.8
NH_3-N	mg/L	9	0	2.1	17.5
P	mg/L	10 (34%)		7 (56%)	3 (66%)
Fecal coliform	CFU/100 mL	1.1E5 (1.1)		14 (2.4)	1E4 (1.5)

[a] Performance reported as average effluent concentration with average removal in parentheses, where applicable, coliform reported as effluent concentration and log removal in parentheses.

[b] Christopherson *et al*. (2001).

[c] Crites *et al*. (1997).

[d] Louden *et al*. (1985).

[e] Jantrania (1998).

Advantages

Gravel medium (or substitute) used can be obtained in most locations. Requires less land area than comparable single-pass filters. Relatively easy to maintain and operate.

Disadvantages

Requires more electricity than single-pass systems. If appropriate medium not readily available, cost to implement will be higher. Potential for wastewater backup in case of prolonged power outage.

Operation and maintenance
The operation of recirculating filter generally requires at least one pump and/or dosing siphon. The pump can be operated on demand or timed dosing, requiring float switches, high water alarms, and control panel. Periodic inspection of system components for proper operation is recommended. Qualitative assessment of effluent sample also confirms proper operation. Systems are generally maintenance free besides periodic inspection. Pumps and electrical components can be assumed to have at least a 10 year lifespan. Systems should be inspected regularly for ponding of wastewater on biofilter surface (or otherwise reduced infiltrative capacity) due to clogging. Correct pump and control system operation should be confirmed.

Power and control
Requires at least one pump, possibly two pumps, depending on specific site characteristics and design. Alarm and monitoring equipment recommended. Can be dosed on a timed (recommended) or on-demand basis. Annual power usage expected to be in range of 300 to 1000 kWh.

Cost
Estimated cost of multi-pass gravel biofilter system is a function of medium availability, typically $6,000 to 8,000, includes capital and installation costs of biofilter component only.

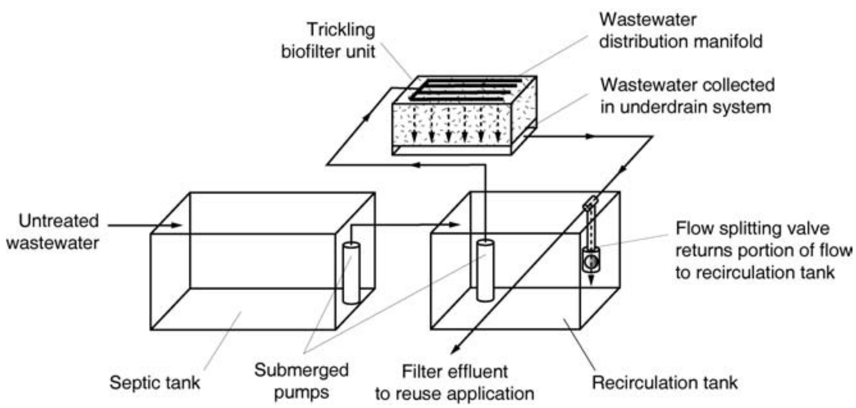

Figure 6-5
Diagram of recirculating trickling biofilter process (note: recirculation to the septic tank is also common and does not require an additional mixing tank) (top) and multi-pass gravel trickling filter installed at a residential site in Stinson Beach, CA (left).

Contact
Standard trickling biofilters systems utilizing sand medium are not proprietary and may be designed by a qualified engineer. Orenco Systems specializes in design services and provides system components.

Orenco Systems Inc.
814 Airway Avenue
Sutherlin, Oregon 97479
Phone (800) 348-9843; (541) 459-4449
Fax (541) 459-2884
Web www.orenco.com

References and other resources

Christopherson, S.H., J.L. Anderson, and D.M. Gustafson (2001) Evaluation of Recirculating Sand Filters in Minnesota, in *Proceedings of the 9th National Symposium of Individual and Small Community Sewage Systems* - 2001, Fort Worth, TX, American Society of Agricultural Engineers, pp. 207-214, St. Joseph, Michigan.

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Louden, T.L., D.B. Thompson, and L.E. Reese (1985) Cold Climate Performance of Recirculating Sand Filters, *Proceedings of the 4th National Symposium of Individual and Small Community Sewage Systems* - 1984, New Orleans, Louisiana, American Society of Agricultural Engineers, pp. 333-342, St. Joseph, Michigan.

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Piluk R.J., and O.J. Hao, (1989) Evaluation of Onsite Waste Disposal Systems for Nitrogen Removal, *Journal of Environmental Engineering*, Div. ASCE, Vol. 115, No. 4, pp. 725-740.

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U.S. EPA (1980) *Design Manual: Onsite Wastewater Treatment and Disposal Systems*, EPA 625-1-80-012, U. S. Environmental Protection Agency, Washington, D.C.

Whitmyer, R.W., R.A. Apfel, R.J. Otis, and R.L. Meyer, (1991) Overview of Individual Onsite Nitrogen Removal Systems, On-site Wastewater treatment: *Proceedings of the 6th National*

Symposium on Individual and Small Community Systems - 1991, Chicago, Illinois, American Society of Agricultural Engineers, pp. 143-154, St. Joseph, MI.

6-1.11 PHOSPHEX™ system

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The Phosphex System uses a reactive media that is able to precipitate phosphorus out of water. The material evaluated in the development of the treatment system is a waste product (slag) from steel manufacturing which has a chemical composition high in metal oxides, especially calcium. The filter bed is a combination of metal oxides, limestone, and sand. This process was developed at the University of Waterloo and is not yet commercially available.

Description of process
The biofilter is located in series after a standard septic tank or other primary treatment device. Wastewater is distributed into the packed bed and allowed to percolate through for sufficient time to achieve phosphorus adsorption and precipitation. Effluent from the Phosphex system can then be discharged to an effluent management system.

System footprint
Surface area of Phosphex unit is about 75 ft^2 (estimated based on 450 gal/d of typical settled residential wastewater).

Advantages
Removes phosphorus to very low levels, may be feasible in areas that are sensitive to phosphorus loading. Expected near complete phosphorus removal from septic tank effluent.

Disadvantages
Not currently commercially available (estimate 2004).

Performance
Expect 90 to 99% phosphorus removal form septic tank effluent. Other effluent parameters not known, possibly similar to other biofilter systems.

Operation and maintenance
Operation and maintenance would include inspection of system components. If system includes electrical components, check for proper operation. Medium may need to be replaced after reaching capacity for phosphorus adsorption. Media replacement will be needed after 15 to 20 years.

Power and control
Passive process does not require the use of pumps or control system.

Cost
$2500 to 3500 (estimate), includes capital costs for installation of biofilter component only.

Contact
G.G.H Gray
E gghgray@uwaterloo.ca
Web www.research.uwaterloo.ca/ttlo/technologies/GroundWater/index.htm

References and other resources

Baker MJ, DW Blowes, and CJ Ptacek (1998) Laboratory Development of Permeable Reactive Mixtures for the Removal of Phosphorus form Onsite Wastewater Disposal Systems, *Environmental Science and Technology*, Vol. 32, No. 15, pp. 2308-2316.

U.S Patent #5,876,606.

6-1.12 RIGHT® system

Catagory	Primary and secondary treatment
Technology	Multi-pass trickling biofilter
Input	Household wastewater
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Individual home, cluster, and community residential systems

Background

The RIGHT system is a pre-assembled sand/gravel biofilter system. Because the system is preassembled, installation time is significantly reduced.

Description of process

The system is composed of two tanks, the integrated dosing tank and a biofilter unit. The integrated dosing tank is divided into three sections for primary treatment, mixing/recirculation flow, and effluent chamber. The biofilter module is divided into two sections, one section discharges to the recirculation tank and the other section discharges to the effluent tank. The recirculation of the process water allows for enhanced denitrification.

Performance

The RIGHT system performance can be estimated from the results of the Washington Island Project, as presented in Table 6-5.

Operation and maintenance

Crest Precast offers a management agreement in which the homeowner has very little responsibility except for periodic observation of the system to confirm that electrical components are still functioning properly.

Table 6-5

Reported performance results for the RIGHT systems from the Washington Island Project[a]

		System[b]				
Parameter	Unit	1	2	3	4	5
Media depth						
Fine	ft	1	2	0	1	2
Coarse	ft	1	0	2.3	1	0
HLR	$gal/ft^2 \cdot d$	5		3.4	3.5	3.7
α	unitless	4		6.8	8.1	3.8
BOD	mg/L	12 (96%)	12.4 (94%)	3.8 (98%)	10 (98.6%)	8.6 (96%)
TSS	mg/L	6 (95%)	12.6 (89%)	4.7 (97%)	5.9 (96%)	5.8 (99%)
TN	mg/L	12 (70%)	15.7 (59%)	16.8 (80%)	13.7 (89.3)	17.4 (59%)

[a] Venhuizen *et al*., 1998

[b] Performance reported as average effluent concentration with average removal in parentheses.

Advantages
Treatment system is prepackaged and pre-engineered to reduce construction errors and reduce overall system cost.

Disadvantages
Treatment system requires electrical power for pumping and control systems.

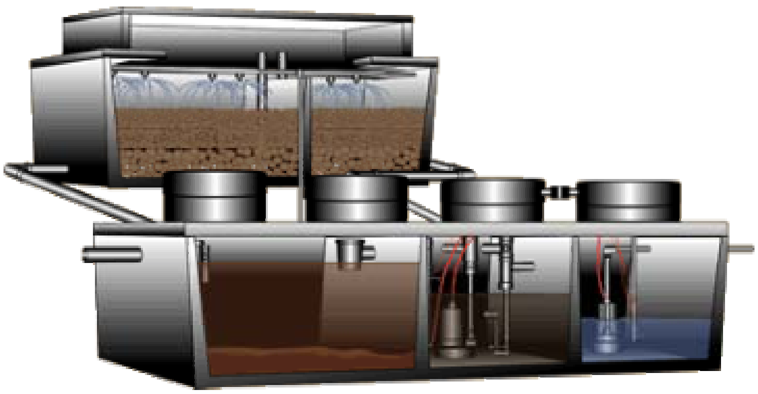

Figure 6-6
The RIGHT System for wastewater treatment. (Adapted from RIGHT System, LLC.)

Contact

Crest Precast, Inc.
609 Kistler Drive, LaCrescent, MN 55947
Phone (877) 743-4231
Web www.rightsystem.com
Description
Supplies prepackaged RIGHT System and optional drip distribution system.

The RIGHT System, LLC
P.O. Box 238
Washington Island, WI 54246
Phone (877) 843-4231
Fax (262) 843-3142
E info@RIGHTSystem.com

References and other resources
Venhuizen, D., J.H. Wiersma, and J.A. Williams (1998) Washington Island Project: Evolution of the Denitrifying Sand Filter Concept, *in Proceedings of the Eighth National Symposium on Individual and Small Community,* pp. 470-479, American Society of Agricultural Engineers, St. Joseph, MI.

6-1.13 Sand biofilters (single-pass)

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single home and small community residential systems

Background
The single-pass sand filter is one of the most well-known and studied systems for the treatment of wastewater from primary treatment processes. When designed and used correctly, these systems are very reliable and provide excellent treatment. However, due to site limitations and the availability of sand medium, these systems may not be cost effective in all areas.

Description of process
Sand biofilter systems are often referred to as intermittent sand filters or single-pass sand filters. The term intermittent is a classification of the dosing regime; the water to be treated is applied to the biofilter in discrete doses, as opposed to continuous dosing. The single-pass categorization is a specification for obtaining treatment with only one application of the wastewater before discharge to subsequent treatment or use. However, the classification as a filter is somewhat misleading because the system is a biological treatment process. A diagram of the single-pass biofilter system is presented in Fig. 6-7. Sand biofilters can be operated under gravity flow or under pressure. The gravity flow system is an option when sufficient slope and land area are available for a tiered system. The pressurized configuration is more used in areas with insufficient slope and requires the use of one or two pumps.

System footprint
Typical system will have a surface area of 400 ft^2. Systems can be installed above ground, partially buried, or fully buried. Top of filter may be planted or otherwise integrated into landscape for aesthetic purposes.

Performance
Many studies have been conducted to characterize the performance and operation of single-pass sand biofilter systems. Performance specifications of representative research findings are presented in Table 6-6.

Table 6-6
Selected representative studies of single-pass sand biofilter performance

Parameter	Unit	Location of study		
		Placer Ct, CA[a]	Gloucester, MA[b]	Oregon[c]
Description of system		Compiled from 30 residential systems	Demonstration project	Compiled from 8 residential systems
ES (d_{10})	mm	0.25 to 0.65	0.8	
UC (d_{60}/d_{10})	unitless	3 to 4	1.5	
Depth of medium	ft	2	2	
HLR	$gal/ft^2 \cdot d$	1.23	86	
System performance[d]				
BOD_5	mg/L	2 (98%)	15	3.2 (99%)
TSS	mg/L	16 (78%)	8	9.6 (93%)
TN	mg/L	37 (40%)	61.3	30.3 (47%)
NO_3-N	mg/L	31	13.4	29.1
NH_3-N	mg/L	5	37.5	0.25
P	mg/L		8.3	
Total coliform	MPN/100 mL	7.3E2 (3)		1.8E4 (2)
Fecal coliform	MPN/100 mL	1.1E2 (3)	5E4	407 (3)

[a] Oregon Department of Environmental Quality (1982).
[b] Cagle and Johnson (1994).
[c] Jantrania *et al*. (1998).
[d] Performance reported as average effluent concentration with average removal in parentheses, where applicable, coliform reported as effluent concentration and log removal in parentheses.

Advantages
Design and performance is well characterized. Technology can be used in many locations when correctly sized sand media is readily available. Operation and maintenance are relatively easy.

Disadvantages
May require electricity for pump operation. For systems that rely on pumps, extended power failure can result in wastewater backup. Correctly sized media may be difficult to procure in some areas due to relative site location and/or media availability.

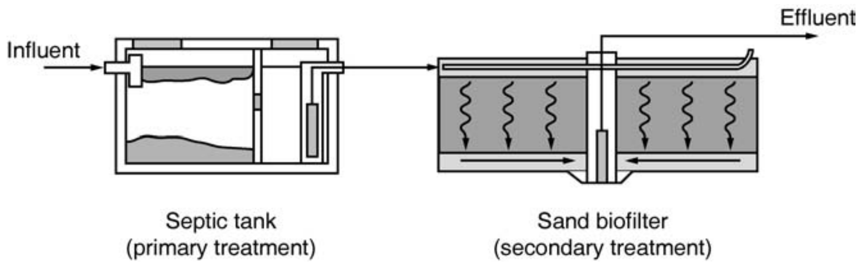

Figure 6-7
Diagram of single-pass trickling biofilter process (top) and installation of a single-pass sand trickling biofilter (left).

Operation and maintenance
Proper operation and maintenance are recommended for long-term system performance. For proper operation, specifications for hydraulic and constituent loading should be met to avoid overloading to the biofilter. Maintenance procedures should include inspection of the system for accumulation of solids and water on the surface, solids accumulation in pump basins, and other types of pump or electrical component malfunction or failure. Systems should be inspected regularly for ponding of wastewater on biofilter surface (or otherwise reduced infiltrative capacity) due to clogging. Correct pump and control system operation should be confirmed.

Power and control
Can be operated with or without pumps depending on specific site characteristics and design. Alarm and monitoring equipment recommended. Can be dosed on a timed (recommended) or on-demand basis. Annual power usage expected to range from negligible (no pump/control) to 150 kWh.

Cost
Estimated cost ranges from $3,000 to 5,000, including capital and installation costs for installation of sand biofilter component only. Range a function of cost to procure correctly sized medium, may be expensive in remote areas..

Suppliers
Standard trickling biofilters systems utilizing sand medium are not proprietary and may be

designed by a qualified engineer. Orenco Systems can provide design assistance and products for sand biofilters.

Orenco Systems Inc.
814 Airway Avenue
Sutherlin, Oregon 97479
Phone (800) 348-9843; (541) 459-4449
Fax (541) 459-2884
Web www.orenco.com

References and other resources

Cagle, W.A. and L.A. Johnson (1994) Onsite Intermittent Sand Filter Systems, A Regulatory/Scientific Approach to Their Study in Placer County, California, in *Proceedings of the 7th National Symposium of Individual and Small Community Sewage Systems* - 1994, Atlanta, GA, American Society of Agricultural Engineers, pp. 283-291, St. Joseph, Michigan.

Crites, R., and G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems*, The McGraw Hill Companies, New York, New York.

Darby, J., G. Tchobanoglous, M.A. Nor, and D. Maciolek (1996) Shallow Intermittent Sand Filtration: Performance Evaluation, *The Small Flows Journal*, Vol. 2, No. 1, Morgantown, WV.

Emerick, R.W., R.M. Test, G. Tchobanoglous, and J. Darby (1997) Shallow Intermittent Sand Filtration: Microorganism Removal, *The Small Flows Journal*, Vol. 3, No. 1, Morgantown, WV.

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Mancl, K.M., and J.A. Peeples (1991) One Hundred Years Later: Reviewing the Work of the Massachusetts State Board of Health on the Intermittent Sand Filtration of Wastewater from Small Communities, *Proceeding of the 6th National Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural Engineers, pp. 22-30, Chicago, Illinois.

Roynayne, M.P., R.C. Paeth, and S.A. Wilson (1982) *Final Report: Oregon Onsite Experimental Systems Program*, Oregon Department of Environmental Quality, Portland, OR.

U.S. EPA (1980) *Design Manual: Onsite Wastewater Treatment and Disposal Systems*, EPA 625-1-80-012, U. S. Environmental Protection Agency, Washington, D.C.

U.S. EPA (1999) *Wastewater Technology Fact Sheet: Intermittent Sand Filters*, EPA 932-F-99-067, United States Environmental Protection Agency, Office of Water, Washington, D.C.

6-1.14 Sand biofilters (stratified, single-pass)

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater from septic tank with effluent filter
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single home and small community residential systems

Background

The concept of the stratified sand filter is that by gradually reducing the effective size of the sand media with depth in the biofilter, it is possible to improve overall performance. Coarse gravel layers are placed between the sand layers to allow for gas exchange and to supply oxygen to the various depths of the biofilter.

Description of process

The process is identical in operation to the single-pass sand filter. Typical loading rate of screened septic tank effluent is 1 to 1.2 $gal/ft^2 \cdot d$. The sand used should meet certain requirements for optimal performance. The recommended effective size and uniformity coefficient for the sand is presented in Table 6-7.

Table 6-7

Specifications for stratified sand biofilter media[a]

Parameter	Units	Top layer[b]	Middle layer[b]	Bottom layer[c]
Effective size (d_{10})	mm	1.2	0.48	0.42
Uniformity coefficient, (d_{10}/d_{60})	unitless	1.26	1.28	1.50
Depth	in	10	4	10

[a] Adapted from Washington State Department of Health (2000).

[b] Supported by a 4 in deep layer of 0.75 in diameter gravel.

[c] Supported by the gravel underdrain.

Performance

The stratified sand biofilter, as outlined in the Washington State Department of Health Guidelines, is expected to produce an effluent (when used in conjunction with a septic tank with an effluent filter) with a BOD_5 and TSS less than 10 mg/L, and have fecal coliform less than 200 MPN/100 mL. Additional performance data can be found in Table 6-8.

Table 6-8

Reported results of stratified sand biofilter performance[a]

		Location of study
Parameter	Unit	Arkansas[b]
Description of system		Pilot-scale
ES (d_{10})	mm	0.39, 0.44, and 0.16[c]
UC (d_{60}/d_{10})	unitless	3.08, 2.0, and 1.5[c]
Depth of medium	in	10, 4, and 10[c]
HLR	$gal/ft^2 \cdot d$	1.25
DF	dose/d	12
System performance		
BOD_5	mg/L	1.21 (99%)
Fecal coliform	CFU/100 mL	< 2 (5.8)

[a] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.

[b] Gross and Jones (1999).

[c] Values represent coarse, medium, and fine layers, respectively.

Operation and maintenance
Proper operation and maintenance are recommended for long-term system performance. For proper operation, specifications for hydraulic and constituent loading should be met to avoid overloading to the biofilter. Maintenance procedures should include inspection of the system for accumulation of solids and water on the surface, solids accumulation in pump basins, and other types of pump or electrical component malfunction or failure.

Contact
Washington State Department of Health Office of Environmental Health & Safety
New Market Industrial Center, 7171 Cleanwater Lane, Building 4
PO Box 47825
Olympia, Washington 98504-7825
Phone (360) 236-3062
Fax (360) 236-2261
Web http://www.doh.wa.gov/ehp/ts
Description
The State of Washington has developed design and performance guidelines for the stratified filter.

References and other resources
Gross, M.A. and S.W. Jones (1999) Stratified Sand Filter and Ozonation for Wastewater Reuse, in *Proceedings NOWRA Conference*, 8th Annual Conference and Exhibit, Jekyll Island, GA.

Nichols, D.J., D.C. Wolf, M.A. Gross, and E.M. Rutledge (1997) Renovation of Septic Tank Effluent in a Stratified Sand Filter, *Site Characterization and Design of Onsite Septic Systems*, ASTM STP 1324, MS Bedinger, JS Fleming, and AI Johnson, American Society for Testing and Materials, West Conshohoken, PA.

Washington State Department of Health (2000) *Stratified Sand Filter: Recommended Standards and Guidance for Performance, Application, Design, and Operation and Maintenance*, Office of Environmental Health and Safety, Olympia, WA.

6-1.15 Slag biofilters

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single home and small community residential systems

Background
Several industrial processes result in the formation of a by-product known as slag. Slag materials can be produced in blast furnaces during the production of iron or in the bottom of boilers during the coal fired electricity generation, among other places. The materials properties are dependent on the specific nature of the material and the process used during formation of the material. The specific weight of slag can range from 50 to 100 lb/ft^3 depending on the source of the material. Slag materials have been used as a biofilm support medium in trickling biofilters.

Performance
Performance specifications from representative research studies are presented in Table 6-9.

Description of process
Process similar to that of single-pass or multi-pass biofilter system. If composition of material

is correct, biofilter should accomplish phosphorous removal as well as typical biofiltration treatment objectives.

System footprint
Size expected to be comparable to single-pass or multi-pass aggregate biofilter system, depending on specific configuration.

Advantages
Slag materials may be available in some locations as a waste product.

Disadvantages
Slag materials are not well established for wastewater treatment applications. Concern has been expressed regarding the leaching of constituents (e.g., metals) associated with the steel slag material into the soil. Additional research is needed to evaluate locally available slag materials for performance as well as leaching of undesirable constituents.

Operation and maintenance
Operational and maintenance needs have not been determined for this technology, however, expected to be similar to other biofilter units.

Table 6-9
Reported studies of slag trickling biofilter performance[a]

		Location of study	
Parameter	Unit	Montgomery County, VA	Montgomery County, VA
Description of system			
ES (d_{10})	mm	1.2	1.2
UC (d_{60}/d_{10})	unitless	1.67	1.67
Depth of medium	ft	2	2
α	unitless	27	23
HLR	$gal/ft^2 \cdot d$	2.5	5.6
DF	dose/d	48	68
pH	unitless	7.3	7.2
System performance[b]			
BOD_5	mg/L	4.9 (95%)	2 (98%)
NO_3-N	mg/L	39.6	43
NH_3-N	mg/L	0.4	0.2
P	mg/L	8.1 (10%)	6.1 (5%)
Fecal coliform	CFU/100 mL	22 (3.1)	145

[a] Reneau *et al.* (1998).
[b] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.

Contact
National Slag Association
Web www.nationalslagassoc.org

References and other resources

Reneau Jr., R.B., C. Hagedorn, and A.R. Jantrania (2001) Performance Evaluation of Two Pre-Engineered Onsite Treatment and Effluent Dispersal Technologies, in *Proceedings of the 9th National Symposium of Individual and Small Community Sewage Systems* - 2001, Fort Worth, TX, American Society of Agricultural Engineers, pp. 271-280, St. Joseph, Michigan.

6-1.16 Zeolite biofilter

Category	Cation exchange, removal
Technology	Trickling biofilter, adsorption
Input	Settled wastewater, septic tank effluent
Function	Ion exchange, nutrient removal
Applications	Various

Background

Zeolites are negatively charged minerals, similar in structure to clay. The zeolite structure is three dimensional, and creates an open, cage-like matrix, which is effective for ion exchange processes. Ammonia and heavy metals in wastewater are readily adsorbed onto the zeolite structure.

Description of process

While not common for onsite wastewater treatment processes, zeolites offer the advantage of removing ammonia nitrogen and other positively charged ions from wastewater. This type of system may be useful in areas that are sensitive to nitrogen discharges. The zeolite material may be used in a packed bed arrangement or as a fill material in soil treatment systems.

Performance

Zeolites are effective ion exchange materials and can be expected to remove a significant amount of positively charged ions. The adsorption capacity of natural zeolites is typically in the range of 1 to 6 mg metal/g zeolite and 1 to 2 mg ammonia/g zeolite. Synthetic zeolites generally have a higher adsorptive capacity. The removal efficiency also depends on the selectivity of the constituent to be removed and the pH of the wastewater.

Operation and maintenance

Because the zeolites acts as an ion exchange resin, it will need to be regenerated periodically as it reaches the exchange capacity.

Cost

Suppliers of zeolite should be contacted directly to determine cost of material. Construction costs can be estimated from cost to install single-pass sand biofilter. The zeolite regeneration may be a significant cost.

References

Ouki, S.K. and M Kavannagh (1999) Treatment of metals-contaminated water by use of natural zeolites, *Water Science and Technology*, Vol. 39, No. 10-11.

Contact

International Zeolite Association
Web www.iza-online.org

Zeoponix
Web www.zeoponix.com

6-2 Organic media trickling biofilters

The use of organic materials as the support medium in the trickling biofilter may have advantages over other types of media, including the potential for enhanced nutrient removal, a lightweight material, and potentially locally available. Peat moss has been the primary organic material used as a biofiltration medium.

6-2.1 Ecoflo® biofilter

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The Ecoflo biofilter (ST-650) system developed by Premier Tech uses sphagnum peat moss as the medium for the attached growth of a microbial community. The technology is compact and modular, allowing for flexibility in installation.

Description of process
The process does not use any electrical components and influent to the biofilter is settled wastewater from a septic tank or similar device. Wastewater is distributed over the surface of a treated peat medium. After passing through the treatment process, the effluent can be directly discharged into the soil through the bottomless filter or collected and discharged to an alternate effluent management system. In addition, the Ecoflo technology has been used for the polishing treatment of secondary treated wastewater and landfill leachate. The basic Ecoflo unit is bottomless allowing effluent to discharge into soil below. Effluent management will depend on characteristics of the receiving location. Effluent may be distributed through drip irrigation (after disinfection) or other soil treatment system.

System footprint
Ecoflo module has a length of 14 ft, width of 8 ft, height of 4.5 ft, and weight of 275 lbs. Systems normally buried below grade, but can be installed above ground or partially buried.

Advantages
Modular system offers flexible installation. Bottomless filter does not require additional system for effluent distribution. Potential for passive operation.

Disadvantages
May require electricity for pump operation. Somewhat limited performance data available. Biofilter medium will need to be replaced periodically. If overloaded, system may pond.

Performance
Expected effluent quality for BOD_5 and TSS concentrations less than 10 mg/L, and fecal coliforms less than 25,000 MPN/100 mL (as verified by Environmental Technology Verification (ETV) Canada). Nitrogen and phosphorus removal data not available at this time.

Operation and maintenance
System based on single-pass operation and does not require a pump if site conditions permit gravity flow. Peat filtration material expected to last maximum of 7 to 8 years under normal use, after this time will need to be replaced. Manufacturer recommends annual inspection and upkeep. Systems should be inspected annually if passive system. If pump and control system is used, should be inspected more frequently.

Power and control
Pump and control system is not part of basic unit, but can be used if needed. With pump, expected annual power usage 50 to 150 kWh.

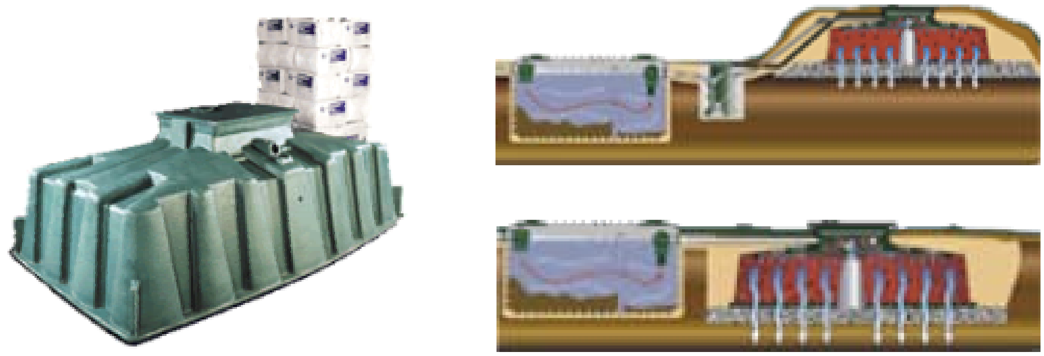

Figure 6-8

A photo of the Ecoflo biofilter wastewater treatment unit (left) and diagrams showing bottomless Ecoflo biofilter system in pressure dosed configuration (right top) and gravity flow configuration (right bottom). (Adapted from Premier Tech Environment.)

Cost

Estimated cost range from $4,000 to 5,000 which includes capital costs for biofilter component only. The range is a function of open bottom design or closed bottom design (for remote soil treatment).

Contact

Premier Tech Environment
6021 Terrace Hills Dr
Birmingham, AL 35242
Phone (205) 408-9691; (877) 295-5763
Fax (205) 408-8783
E ecoflo@premiertech.com
Web www.premiertech.com

Model description

Basic unit is the ST-650 for treating wastewater for households up to 10 bedrooms. The biofilter is available with or without a bottom collection pan. Units can be assembled in parallel to treat high flow rates, such as for cluster systems.

Manufacturer support

A seven year service contract is included in the purchase price. After seven years, peat media is replaced and service contract is renewed.

References and other resources

Lacasse, R., G. Belanger, Y. Henry, P. Talbot, J. Mlynarek, and O. Vermeersch (2001) A Denitrification Process Based on a New Filtering Media for Onsite Wastewater Treatment, *Proccedings of the Ninth National Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural Engineers, pp. 235-244, St. Joseph, MI.

U.S. EPA (2001) *CEIT Virtual Trade Show: Ecoflo Biofilter (available at www.epa.gov/region1/steward/ceitts/wastewater/techs/ecoflo.html).*

6-2.2 ECO-PURE® peat biofilter

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The ECO-PURE peat biofilter is a modular wastewater treatment unit housed in a watertight polyethylene tank. The tank is equipped with anti-float baffles for areas with high ground water conditions. The ECO-PURE systems are in use in most eastern states.

Description of process
Primary treated wastewater (septic tank effluent) is dispersed on the surface of the peat biofilter and is treated as it moves through the biofilter. Effluent is collected and dispersed with a drip irrigation system.

Performance
Manufacturer claims system performance of BOD_5 and TSS less than 10 mg/L in effluent. Fecal coliform also significantly reduced, effluent concentrations often less than 200 MPN/100 mL.

Operation and maintenance
Maintenance is performed by manufacturer or service representative under service contract. Periodic inspection to confirm that system is operating properly. Replacement of peat material may be needed after about 10 years.

Power and control
Pump and control system not part of basic unit, but can be used if needed. With pump, expected annual power usage is about 1,000 to 2,000 kWh.

Cost
$2,000 to 3,000, includes capital costs for biofilter component only.

Suppliers / contacts
ECO-PURE Waste Water Systems
17305 Pine Ridge Road
Fort Meyers, FL 33931
Phone (888) 999-0936
Fax (888) 999-5259
Model description

Eco-pure 300 series (450 gal/d, 600 gal/d max surge capacity)

Manufacturer support

Five year maintenance contract included with purchase price. After five years, new service contract is required. Manufacturer warrants Eco-pure components for 3 years from date of purchase.

6-2.3 Peat moss trickling biofilters

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single home and small community residential systems

Background
Peat used for wastewater treatment is generally the harvested and dried sphagnum moss plant that grows across Canada and in some parts of the United States. Peat as a biofilter medium has been researched in the United States since the 1970s. Much of the initial research on using peat as an onsite biofilter material was performed by Dr. Joan Brooks of the University of Maine (see references).

Description of process
Can be operated in single-pass or multi-pass configurations, similar to standard sand and gravel biofilters. Primary effluent is sprayed onto the surface of the peat biofilter. Wastewater constituents are removed through adsorption into the attached microbial community which inhabits the peat material. The peat is often supported above a standard gravel collection system. The properties of peat that are believed to contribute to its high performance include acidic nature of the material, support of fungal communities, high cation exchange capacity, high surface area, and other antibiotic properties.

Advantages
Medium is a natural, lightweight, high porosity material. In many research studies, peat has been an effective biofilter material, particularly for the removal of fecal coliform. Potential for long term reliable treatment with relatively low maintenance requirements.

Disadvantages
May require electricity for pump operation. Peat must be imported from northern areas where it is harvested. If overloaded, system may pond.

Performance
Performance specifications from representative research studies are presented in Table 6-10.

Table 6-10
Selected representative studies of peat moss biofilter performance[a]

		Location of study[b]		
Parameter	Unit	Maine	Maine	Maine
Description of system		Residential	Residential	Residential
Depth of medium	ft	2.5 to 3	2.5 to 3	1 to 3
HLR	gal/ft^2·d	0.4	0.18	0.8
DF	dose/d	On demand	On demand	On demand
Temp	^{o}F	36 to 57	37 to 68	
pH	unitless	5.4 tp 6.4	5.8 to 6.5	5.3 to 6.4
System performance				
COD	mg/L	82 (86%)	108 (82%)	121 (84%)
BOD_5	mg/L	15 (94%)	14 (94%)	24 (91%)
TSS	mg/L	16 (90%)	9 (88%)	
TN	mg/L	8.1 (83%)	16.7 (76%)	20.3 (69%)
NO_3-N	mg/L	4.2	4.4	0.3
NH_3-N	mg/L	2.4	10.4	17.7
P	mg/L	3.2 (58%)	14.9 (62%)	0.5 (96%)
Fecal coliform	CFU/100 mL	< 1 (6.8)	16 (6.4)	

[a] Brooks *et al*., 1984.
[b] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.

System footprint
Typical system will have a surface area of 250 to 400 ft^2. Systems can be installed above

ground, partially buried, or fully buried. Top of filter may be planted or otherwise integrated into landscape for aesthetic purposes.

Operation and maintenance

Operation and maintenance needs are similar to other biofilter systems, including pumping of solids from the septic tank as needed, cleaning of any effluent filter used, inspection of pumps and other control and monitoring devices. In addition, the peat material used may decompose over time, especially in hot climates. In the case of peat decomposition, the material should be removed and replaced with new peat material. Systems should be inspected regularly for correct pump and control system operation. Pumping of septic tank and cleaning of septic tank effluent filter are also needed.

Power and control

Can be operated with or without pumps depending on specific site characteristics and design. Alarm and monitoring equipment recommended. Can be dosed on a timed (recommended) or on-demand basis. Annual power usage expected to range from negligible (no pump/control) to 50 to 150 kWh.

Cost

Estimated cost range ranges from $3,000 to 5,000, including capital and installation costs for biofilter component only

Figure 6-9

A Natural peat bog in Canada

Contact

Peat used in treatment systems is typically proprietary, however, may be available from nurseries or landscape supply outlets. Peat from different regions and the quality of the peat used may affect overall treatment performance. Prefabricated and engineered peat treatment systems are currently available.

References and other resources

Brooks, J.L. (1980) *A field study of the efficiency of sphagnum peat as a medium for the treatment of residential wastewater*. M. S. Thesis. (unpublished). University of Maine, Orono, ME.

Brooks, J.L., C.A. Rock, and R.A. Struchtemeyer (1984) Use of peat for on-site wastewater treatment: II. Field studies. *Journal of Environmental Quality*, Vol. 15, pp. 524-530.

Brooks, J.L., and J.A. McKee (1992) Application of peat on-site wastewater treatment systems in the Ontario environment, *Conference Proceedings of Alternative Septic Systems for Ontario,* Waterloo Centre for Groundwater Research, University of Waterloo, pp. 23-30.

Canadian Sphagnum Peat Moss Association <www.peatmoss.com>.

Couillard, D. (1994) The use of peat in wastewater treatment, *Water Resources*, Vol. 26, pp. 1261-1274.

Coupal, B., and J. Lalancette (1976) The treatment of wastewaters with peat moss, *Water Research*, Vol. 10, p. 1071.

Farnham, R.S., and J.L. Brown (1972) Advanced wastewater treatment using organic and inorganic materials. Part I. Use of peat and peat-sand filtration medias. *Proceedings of the 4th International Peat Congress*, International Peat Society, pp. 271-286, Helsiniki, Finland.

Lindbo, D.L., and V.L. MacConnell (2001) Evaluation of a Peat Biofilter Treatment System, in Onsite Wastewater Treatment, *Proceedings of the Ninth National Symposium on Individiual and Small Community Sewage Systems*, Fort Worth, TX, American Society of Agricultural Engineers, pp. 225-234, St. Joseph, MI.

McKee, J.A., and J.L. Brooks (1994) Peat filters for on-site wastewater treatment. *Proceedings of the Seventh National Symposium on Onsite Wastewater Treatment Systems*, American Society of Agricultural Engineers, pp. 526-541, St. Joseph, MI.

Nichols, D.S., and D.H. Boelter (1982) Treatment of secondary sewage effluent with a peatsand filter bed, Journal of Environmental Quality, Vol. 11, pp. 86-92.

O'Driscoll, J.P., K.D. White, D.W. Salter, and L. Garner (1998) Long term performance of peat biofilters for onsite wastewater treatment. *Proceedings of the Eighth National Symposium on Onsite Wastewater Treatment Systems*, American Society of Agricultural Engineers, pp. 530-537, St. Joseph, MI.

Rana, S.M., and T. Viraraghaven (1987) Use of peat in septic tank effluent treatment-column studies, *Water Pollution Research Journal of Canada*, Vol. 22, pp. 491-504.

Rock, C.A., J.L. Brooks, S.A. Braden, and R.A. Struchtemeyer (1984) Use of peat for on-site waste water treatment: I. Laboratory evaluation, *Journal of Environmental Quality*, Vol. 13, pp. 518-523.

Talbot, P., G. Belanger, M. Pelletier, G. Laliberte, and Y. Arcand (1996) Development of a biofilter using organic medium for on-site wastewater treatment. *Water Science and Technology*, Vol. 34, pp. 435-441.

Talbot, P., H. Ouellett, and G. Laliberte (1998) Development of a new on-site wastewater treatment technology in the evolving context of the last decade, *Proceedings of the Eighth National Symposium on Onsite Wastewater Treatment Systems*, American Society of Agricultural Engineers, pp. 538-544, St. Joseph, MI.

Viraraghaven, T., and S.M. Rana (1991) Use of adsorption models for the design of peat based on-site systems, *Proceedings of the Eighth National Symposium on Onsite Wastewater Treatment Systems*, American Society of Agricultural Engineers, pp. 165-172, St. Joseph, MI.

Winkler, E.S., and P.L.M. Veneman (1991) A denitrification system for septic tank effluent using sphagnum peat moss. *Proceedings of the Eighth National Symposium on Onsite Wastewater Treatment Systems*, American Society of Agricultural Engineers, pp. 155-164, St. Joseph, MI.

6-2.4 Puraflo® peat biofilter

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The Puraflo peat biofilter is a modular treatment system generally composed of a septic tank fitted with an effluent filter, a pump or recirculation tank, modular peat biofilter units, and a soil treatment/adsorption field.

Description of process
The Puraflo biofiltration system is similar to other single-pass systems. Effluent from a septic tank (typically with an effluent filter) is distributed over the surface of the peat media. After passing through the biofilter, the water is collected in a collection system and discharged to a soil adsorption system.

Performance
Puraflo peat biofilters have been effective for the treatment of wastewater in both single-pass and multi-pass configurations. Additional performance specifications from representative research studies are presented in Table 6-11.

Table 6-11
Selected representative studies of Puraflo peat biofilter performance

Parameter	Unit	Location of study			
		Minnesota[a]	Minnesota[a]	Maryland[b]	Maryland[b]
Description of system		Residential, single-pass	Residential multi-pass	Demonstration, single-pass	Demonstration, multi-pass
HLR	gal/d	285	175		
System performance[c]					
BOD_5	mg/L	4,5 (98%)	9 (97%)	4.5 (97%)	2.2 (98%)
TSS	mg/L	2.5 (96%)	3.3 (94%)	10.1 (85%)	13 (88%)
TN	mg/L	66 (29%)	51 (43%)	36 (31%)	26 (56%)
NO_3-N	mg/L	43	33		
NH_3-N	mg/L	25	19		
P	mg/L	14 (14%)	12 (19%)		
Fecal coliform	CFU/100 mL	2E3 (2.5)	2E2 (3.4)	2E3 (1.6)	4E2 (3.2)

[a] Anne Arundel County National Onsite Demonstration Project
[b] Geerts *et al*., 2001
[c] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.

System footprint
Typical system composed of three modular units, with a length of 7 ft, width of 4.6 ft, and depth of 2.5 ft (total surface area of biofilter units is 100 ft^2). Systems can be installed above ground, partially buried, or fully buried.

Advantages
Well documented performance. Modular system installation is adaptable to site conditions. Treatment system is effective and has low space requirements.

Disadvantages
May require electricity for pump operation. If overloaded, system may pond. Peat medium will need to be replaced periodically.

Operation and maintenance
Periodic inspection for proper operation. Peat media may need to be replaced after 8 to 15 years (cost approximately $500 per module). Correct pump and control system operation should be confirmed.

Power and control
System includes septic tank effluent pump, alarm, and control equipment. Annual power usage expected to be 150 to 1000 kWh, for single-pass and multi-pass configurations, respectively.

Cost
Estimated cost of $5,000 to 6,000, includes capital costs for biofilter modules, electrical supplies, effluent filter, piping, and valves.

Figure 6-10
Installation of Puraflo peat biofilter system (left), and completed installation (right). (Adapted from Bord na Móna Environmental, Inc.)

Contact
Bord na Móna Environmental
P.O. BOX 77457
Greensboro, NC 27417
Phone (336) 547-9338
1-800-PURAFLO (787-2356)
FAX (336) 547-8559
E bnm-us@bnm-us.com
Web www.bnm-us.com
Model description
Each Puraflo module is rated for 125 gal/d for typical residential wastewater.
Manufacturer support
Two year guarantee on treatment system, associated service contract not determined.

References and other resources
Geerts, S.D., B. McCarthy, R. Axler, J. Henneck, S. Heger Christopherson, J. Crosby, and M. Guite (2001) Performance of Peat Filters in the Treatment of Domestic Wastewater in

Minnesota, in *Proceedings of the 9th National Symposium of Individual and Small Community Sewage Systems* - 2001, Fort Worth, TX, American Society of Agricultural Engineers, pp. 295-303, St. Joseph, MI.

O'Driscoll, J.P., K.D. White, D.W. Salter, and L. Garner (1998) Long Term Performance of Peat Biofilters of Onsite Wastewater Treatment, in *Proceedings of the 8th National Symposium of Individual and Small Community Sewage Systems* - 1998, and Orlando, FL, American Society of Agricultural Engineers, pp. 530-537, St. Joseph, MI.

Walsh, J., and H. Henry (1997) Performance of the Puraflo Peat Biofilter Using Selected Peat FIbre, *Proceeding of the Waterloo Center for Groundwater Research Conference on Septic Odour, Commercial Wastewater, and Phosphorus Removal.*

6-2.5 Woodchip trickling biofilters

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The use of woodchips as a biofilter material is not well documented in the literature; however, it is feasible that this material will be evaluated for its potential as a biofilter medium in the future. In addition, wood chips of various sizes are available for free or at low cost.

Contact
Woodchips and other wood by-products may be obtained locally as a waste material.

6-3 Synthetic media trickling biofilters

The use of synthetic materials, including foam and geotextile, for use as biofiltration media offers several advantages over other materials. These materials are lightweight, have a high porosity and surface area, and are resistant to surface clogging. This combination of material properties makes it possible to apply higher loading, when compared with granular materials, resulting in a significantly smaller overall system footprint.

6-3.1 Advantex® trickling biofilters

Catagory	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single, cluster, and community residential systems, commercial applications

Background
The Advantex filter is a high porosity attached growth treatment system manufactured by Orenco Systems Inc. The Advantex unit is relatively small, lightweight, and provides effective treatment of septic tank effluent. Loading rates are typically 15 to 30 times higher than for fine sand biofilter devices.

Description of process
Primary treated water (septic tank effluent) is distributed to the surface of the filter and flows by gravity over the fixed film media. Because the media has a high porosity, clogging is not expected, as with sand biofilters. After passing through the medium, the treated water is

collected and a fraction is discharged and the remainder is returned to the first chamber of the septic tank for denitrification.

System footprint
Typical system will have a surface area of 10 to 32 ft^2 (length of 8 ft, width of 4 ft, and height of 2.5 ft). Systems can be installed above ground, partially buried, or fully buried. In many cases, system can be installed directly above the septic tank.

Advantages
Treatment unit has small footprint and modular design, typically installed flush with the ground. Excellent and stable performance under fluctuating loading. Lightweight and efficient pre-packaged units. Potential for high nitrogen removal. High porosity media not likely to clog, serviceable without replacement of media. Low maintenance requirements.

Disadvantages
Fecal coliform removal is inconsistent. Requires electricity for proper operation.

Performance
The Advantex system has been found to provide effective, stable treatment of septic tank effluent, frequently under 10 mg/L of BOD_5 and TSS. Additional performance specifications from representative research studies are presented in Table 6-12. The Advantex treatment systems performance has also been NSF standard 40 certified for class 1 treatment.

Table 6-12
Selected representative studies of Advantex performance

		Location of study			
Parameter	Unit	La Pine, OR[b]	Roseburg, OR[c]	La Pine, OR[d]	NSF[e]
Description of system		Residential	Country Store	Residential	
HLR	gal/d	340	411		500
DF	dose/d	72			
System performance[a]					
BOD_5	mg/L	9.2	5 (98%)	11.4	5
TSS	mg/L	4.6	3 (90%)	8.7	4
Oil/grease	mg/L			3	
TN	mg/L	7.1	7 (78%)	15	13
NO_3-N	mg/L	3.1	2.9	8.5	
NH_3-N	mg/L	2.3	1	0.8	
P	mg/L			9.3	
Fecal coliform	CFU/100 mL			2E5	

[a] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.
[b] Results reported first year of performance on system after startup, RX30 effluent recycled to septic tank (Orenco Systems Inc., 2001).
[c] Bounds *et al*. (2000).
[d] Estimated from La Pine National Onsite Demonstration Project Results.
[e] NSF Standard 40.

Operation and maintenance
The Advantex treatment system pumps are generally operated on a timed dosing basis using logic controllers to set the dosing regime. The pumps, control panel, and float alarms will need periodic inspection to ensure that they are working to design specifications. The septic tank will require periodic pumping and if an effluent filter is present, it will also need a periodic cleaning. System should be inspected periodically to ensure all components are working. Sludge removal from septic tank. Remote monitoring reduces owner responsibility.

Power and control
Operate with one or two pumps depending on specific site requirements. Control panel and alarm systems standard. Telemetric monitoring optional. Estimated annual power usage 500 to 1,000 kWh.

Cost
Estimated cost ranges from $3,000 to 5,000, including capital costs for Advantex unit, pumps, and controls. Contact Orenco for local dealers and more specific cost information.

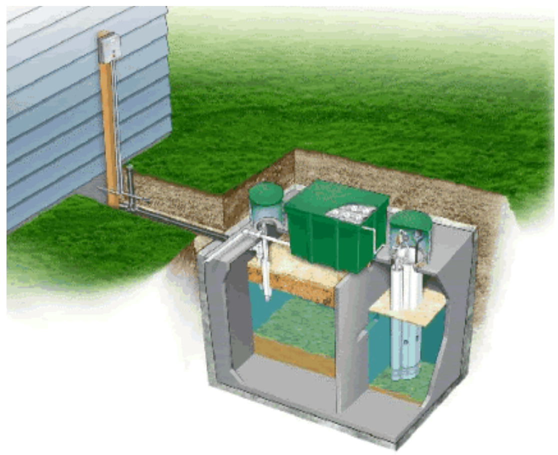

Figure 6-11

Orenco Advantex wastewater treatment systems under evaluation at University of California, Davis (top left), installed at a residential location (bottom left), and a diagram of the system installed with a septic tank (right). (Adapted from Orenco Systems, Inc.)

Contact
Orenco Systems Inc.
814 Airway Avenue
Sutherlin, Oregon 97479
Phone (800) 348-9843; (541) 459-4449
Fax (541) 459-2884
Web www.orenco.com
Model Description
AX15 (400 gal/d, 800 gal/d peak)
AX20 (500 gal/d, 1000 gal/d peak)
AX100
Manufacturer support
Three year limited warranty on treatment system, authorized service providers.

References and other resources

Bounds, T., E.S. Ball, and H.L. Ball (2000) Performance of Pakced Bed Filters, in *Proceedings of the National Onsite Wastewater Recycling Association Conference*, Jekyll Island, GA.

Orenco Systems Inc. (2001) La Pine, Oregon Demonstration Site

Leverenz, H., L. Ruppe, G. Tchobanoglous, and J. Darby (2001) Evaluation of High-porosity Medium in Intermittently Dosed, Multi-Pass Packed Bed Filters for the Treatment of Wastewater, *Small Flows Quarterly*, Spring 2001, Vol. 2, No.2.

Roy, C., R. Auger, and R. Chenier (1998) Use of Non-woven Fabric in Intermittent Filters, in *Proceeding of the Eight National Symposium on Individual and Small Community Sewage Systems, Orlando, FL,* American Society of Agricultural Engineering, St Joseph, MI.

US Patents 5,531,894; 5,480,561; 5,492,635; and 4,439,323.

6-3.2 Aerocell™ treatment system

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background

The Aerocell treatment system uses the Waterloo biofilter open-cell foam technology adapted to the Zabel line of products.

Description of process

The treatment systems are composed of several modular units that can be configured to suit specific site requirements. The Aerocell treatment system is generally operated in a multi-pass mode, and consists of 4 to 6 modules for a 3 to 4 bedroom home, respectively. Wastewater is distributed over the surface of the biofilter with a spray nozzle and collected in the bottom of the units for return to the septic tank (for denitrification) or to subsequent treatment (e.g., soil adsorption).

System footprint

Typical system will have a surface area of 25 ft^2. Dimensions of modular unit are 2.2 ft in diameter and 3.2 ft in height, and each weighing about 25 lbs (total surface area for 4 unit system is 15 ft^2. A typical home system will require 4 to 6 of these units.

Advantages

Modular treatment system offers flexibility of installation. Units come preassembled, reducing installation time. Lightweight and movable by one person.

Disadvantages

Requires electricity for pump operation. Somewhat limited performance data available. For systems that rely on pumps, extended power failure can result in wastewater backup.

Performance

Manufacturer performance claims of BOD_5 less than 25 mg/L, TSS less than 30 mg/L, and 20 to 60 percent total nitrogen removal. Treatment performance is expected to be similar to that achieved by the Waterloo Biofilter (see Sec. 6-3.7).

Operation and maintenance
Basic operation and maintenance consists of regular inspection and cleaning of the spray nozzle, control panel, pumps, and other system components as needed. Maintenance includes checking system components for proper operation, and settings for electrical devices. Removal of sludge from septic tank and periodic cleaning of spray nozzles may be necessary.

Power and control
Recirculating systems will require a pump. Other components include control panel, float switches, and alarm device. Estimated annual power usage 500 to 1,000 kWh.

Cost
$3,000 to 4,500, includes capital costs biofilter and associated pump, control panel, effluent filter, and distribution components.

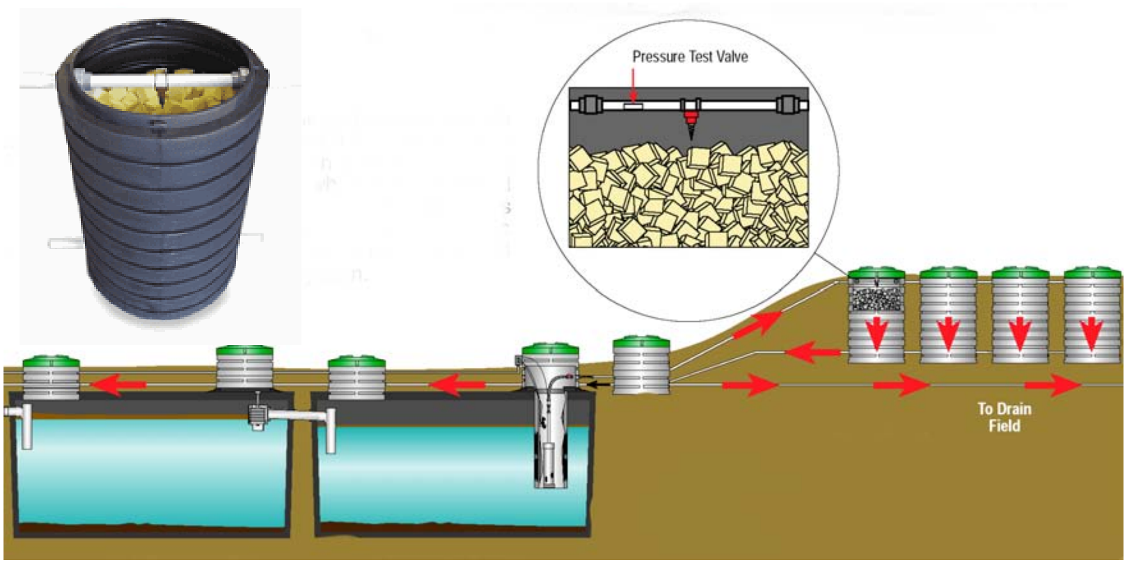

Figure 6-12

Aerocell treatment system with primary treatment, distribution tank, and modular treatment units. (Adapted from Zabel Environmental Technology, Inc.)

Contact
Zabel Environmental Technology
PO Box 1520
Crestwood, KY 40014
Phone (502) 992-8200
(800) 221-5742
Fax (502) 992-8201
Web www.zabelzone.com
Model Description
ATS AC 3 (450 gal/d)
ATS AC 4 (600 gal/d)
Manufacturer support
Not determined

References and other resources
Aerocell product brochure (2002) Zabel Environmental Technologies.

6-3.3 Bioclere™ trickling biofilters

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home, small community, commercial, institutional

Background

The Bioclere modular wastewater treatment system is a modified trickling filter placed over a clarifier. The system is adaptable to larger flow rates by placing units in parallel. The Bioclere wastewater treatment system has been certified under NSF Standard 40 as producing a Class 1 effluent. The Bioclere RF (roughing filter) is an alternate design for reducing concentrated wastewater (high strength) to residential concentrations. Applications for this type of process include malls, institutions, restaurants, and other facilities.

Description of process

Wastewater from the septic tank flows into the 500 gal baffled clarifier of the Bioclere unit. A pump suspended in the upper section of the clarifier doses the fixed film process using a splash plate or spray distribution system. Sloughed biomass and the treated wastewater are returned to the clarifier. A pump at the bottom of the clarifier periodically returns settled material to the septic tank to enhance nitrogen removal. A fan is also incorporated to provide sufficient aeration to the fixed film process. The medium used in the Bioclere process is a randomly packed, high porosity plastic that has a high surface area for microbial attachment.

System footprint

Typical residential system will have a surface area of 20 ft^2 (diameter of 5 ft, depth of 9 ft) not including septic system and effluent management components. Systems normally installed partially buried for ease of maintenance.

Advantages

Modular preassembled unit increases efficiency of installation and flexibility of installation. Effective and stable treatment process, high removal of oil and grease from wastewater. NSF approved, Standard 40, Class1. Contained in a sealed and insulated container to buffer temperatures and reduce noise output.

Disadvantages

Require electricity for pump and fan operation. Requires additional processes for high degrees of nitrogen and phosphorus removal.

Operation and maintenance

The Bioclere system utilizes several electrical and mechanical components which will require periodic servicing. The basic process utilizes two pumps and a fan. Regular inspection is recommended to ensure process is operating as designed. Systems only sold to qualified management districts to ensure operation and maintenance activity. Pumps, fan, and system components should be checked regularly.

Performance

The Bioclere effluent concentrations for BOD_5 and TSS are expected to be less than 20 mg/L. The Bioclere RF is designed to reduce wastewater with BOD_5 and TSS greater than 1,000 mg/L to typical residential strength. Additional performance specifications from representative research studies are presented in Table 6-13.

Table 6-13
Selected representative studies of Bioclere trickling biofilter performance

Parameter	Unit	Location of study	
		Gloucester, MA[a]	Gloucester, MA[b]
Description of system		Residential	Residential
System performance[c]			
BOD_5	mg/L	29 (80%)	51 (79%)
TSS	mg/L	33 (31%)	42 (93%)
Oil/grease	mg/L	2.7 (95%)	4.8 (90%)
TN	mg/L	26.7 (32%)	29.2 (63%)
NO_3-N	mg/L	12.8	7
NH_3-N	mg/L	7.6	14.2
P	mg/L	6.4 (15%)	4.8 (52%)
Fecal coliform	CFU/100 mL	7.0E3 (1.5)	1.0E5 (1)

[a] Five bedroom residential site, average of 3 to 4 years of data.
[b] Four bedroom residential site, average of 3 to 4 years of data.
[c] Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.

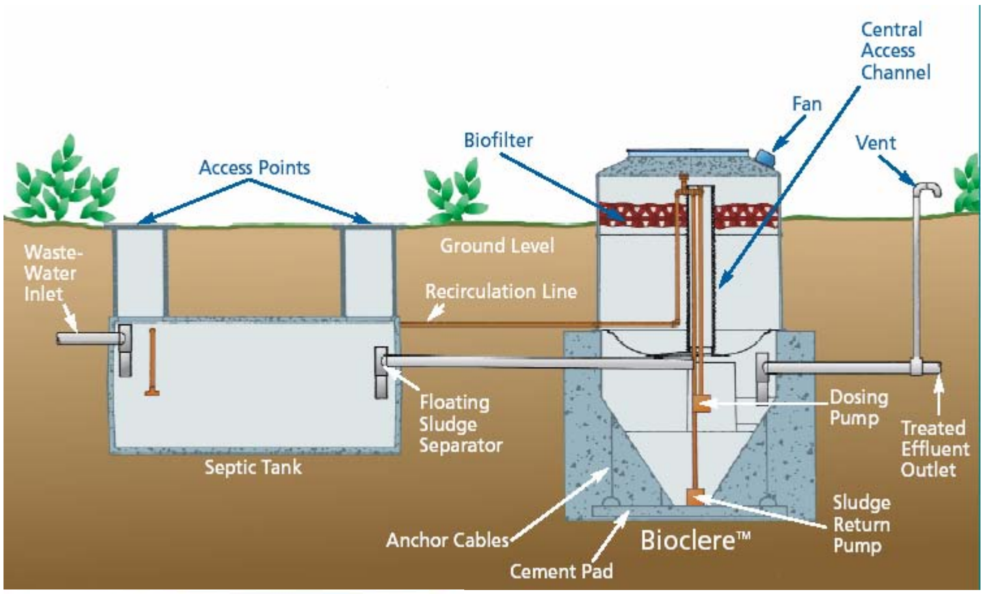

Figure 6-13
A diagram of the Bioclere wastewater treatment system (top) and installed (left). (Adapted from Aquapoint, Inc.)

Power and control
Power requirements include two pumps and a fan. Annual power usage expected to range from 1,000 to 2,000 kWh.

Cost
Estimated cost from $3,000 to 4,000 (for Bioclere unit only), cost reduced when used for the treatment of wastewater from housing clusters. Contact manufacturer for more detailed cost information.

Contact
The Bioclere unit and several other patented wastewater treatment systems are manufactured by AWT Environmental Inc. Other systems provided by this manufacturer include units for nitrogen and phosphorus removal and roughing filters for reducing concentrated wastewaters to residential wastewater concentrations.

Aquapoint / AWT Environmental, Inc.
241 Duchaine Blvd.
New Bedford, MA 02745
Phone (508) 998-7577
Fax (508) 998-7177
E awt@aquapoint.com
Web www.bioclere.com
Model descriptions
Bioclere Model 16/12 (500 to 1000 gal/d)
Bioclere other models (systems for flow rates of 1,000 to 150,000 gal/d)
Bioclere RF (for BOD and TSS greater than 1000 mg/L)
Manufacturer support
Recommended semi-annual or quarterly inspection. Expected 2 year service agreement as specified under NSF certification. Units only sold to qualified management districts to ensure operation and maintenance.

References and other resources
Aquapoint company literature (2002), available at www.bioclere.com.

Jantrania, A.R., K.C. Sheu, A.N. Cooperman, and O.C. Pancorbo (1998) Performance Evaluation of Alternative Systems – Gloucester, MA, Demonstration Project, in *Proceedings of the Eight National Symposium on Individual and Small Community Sewage Systems,* Orlando, FL, American Society of Agricultural Engineering, St Joseph, MI.

6-3.4 Rubber (shredded tire) biofilter

Category	Secondary treatment, soil treatment system
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Substitute for aggregate fill in various applications

Background
Work to find markets for waste materials has resulted in some products being evaluated for various types of fill projects. Shredded tires and crushed glass are both materials collected in solid waste management systems. However, for shredded tires there may be concern over leaching of metals and other carcinogenic and non-carcinogenic organic compounds.

Description of process
Tires are known to leach organic and inorganic constituents such as iron, manganese,

aluminum, chromium, copper, zinc, chloride, and sulfate. The concentration of these constituents in the leachate has been found to be below drinking water standards (Sengupta and Miller, 1999).

Performance
Shredded tires have not been evaluated for performance as trickling biofilter medium.

References and other resources
Burnell, B.N., and G. McOmber (1997) Used Tires as a Substitute for Drainfield Aggregate, *ASTM STP 1324*, American Society for Testing Materials.

Sengupta, S., and H.J. Miller (1999) Preliminary Investigation of Tire Shreds for Use in Residential Subsurface Leaching Field Systems, *Chelsea Center for Recycling and Economic Development Technical Research Program,* University of Massachusetts, Lowell, MA.

6-3.5 SCAT™ treatment system

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Single home and small community residential systems

Background
The SCAT treatment system uses the Waterloo Biofilter open-cell foam technology adapted to the Zabel line of products.

Cost
$2,000 to $4,500, includes capital costs of the biofilter and associated pump, control panel, effluent filter, and distribution components.

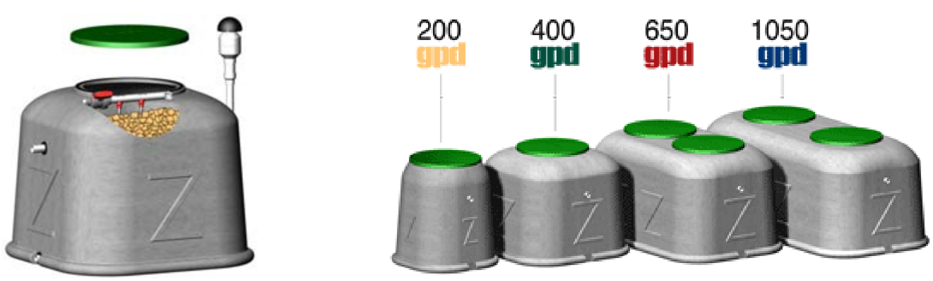

Figure 6-14
The SCAT advanced wastewater treatment system (left) comes preassembled for easy installation and in a range of sizes (right). (Adapted from Zabel Environmental Technology, Inc.)

Contact
Zabel Environmental Technology
PO Box 1520
Crestwood, KY 40014
Phone (502) 992-8200
(800) 221-5742
Fax (502) 992-8201
Web www.zabelzone.com

6-3.6 SeptiTech™ wastewater pre-treatment systems

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single home and small community residential systems

Background

The SeptiTech system is composed of a standard two chamber septic tank, a multi-pass trickling biofilter module, and an effluent distribution system (pressure drainfield or UV disinfection and drip irrigation). Hydrophobic polystyrene beads are used as the medium for fixed film growth.

Description of process

Clarified septic tank effluent flows by gravity into the recirculation chamber of the SeptiTech unit. A submerged pump periodically sprays wastewater onto the attached growth process and the wastewater percolates through the packing material. The treated water then flows back into the recirculation chamber and mixes with the contents, resulting in some denitrification. Treated water flows into a clarification chamber and is periodically discharged to an effluent management system. The system includes an integrated logic controller to modify the system operation for optimal treatment under varying loading conditions.

System footprint

Typical residential system will have a length of 8.5 ft, width of 5.5 ft, and height of 5.5 ft. Systems normally installed fully buried for cold protection or above ground if bedrock limits excavation.

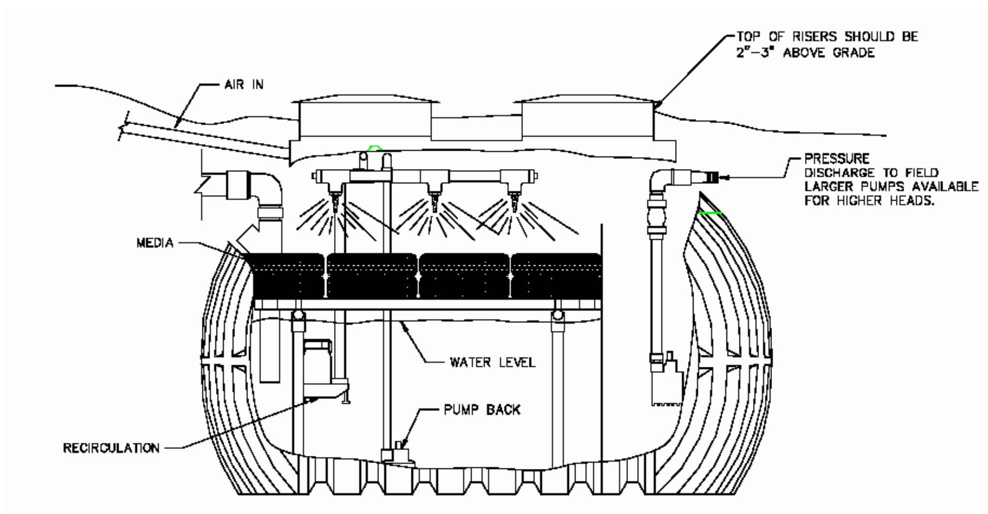

Figure 6-15

Diagram of the SeptiTech residential wastewater treatment system. (Adapted from Septitech, Inc.)

Advantages

System designed for low maintenance requirements. Integrated logic controller to optimize treatment under variable flow conditions. Optional UV disinfection and drip irrigation components. Designed for sites with seasonal use.

Disadvantages
Requires electricity for pump operation. Will require periodic sludge removal. System performance not well established.

Performance
Manufacturer performance claim of effluent BOD_5 and TSS concentrations of less than 10 mg/L, some nitrogen removal, and 2 log coliform removal.

Operation and maintenance
SeptiTech offers two year warranty and service contract included with purchase price of unit. After two years owner is given the option to extend this service contract. Manufacturer also advertises that homeowner will not be required to do any maintenance to this system, alarm will notify owner of any problems. Service contract provided for first two years, renewable thereafter. Relatively low service requirements.

Power and control
Power requirements include pumps and control panel. Annual power usage expected to range from 1,500 to 2,000 kWh.

Cost
$5,000 to 6,000, includes capital and installation costs for installation of biofilter component only. UV disinfection and drip irrigation systems will increase cost of system.

Contact
SeptiTech
220 Lewiston Road,
Gray. ME 04039
Phone (207)657-5252
Fax (207)657-5246
E septi@septitech.com
Web www.septitech.com
Model descriptions
M400 and M400UV (440 gal/d)
M500, M550, M550UV (660 gal/d)
M750, M750UV (880 gal/d)
Commercial models up to 50,000 gal/d
Vendor support
System comes with a two year warranty and service contract. Option to renew warranty after initial service agreement ends.

6-3.7 Waterloo biofilter®

Category	Secondary treatment
Technology	Trickling biofilter
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, pathogen reduction
Applications	Individual, cluster, small community, commercial systems, and landfill leachate

Background
The Waterloo Biofilter was developed in Ontario for the treatment of domestic wastewater. The system has also been used for the treatment of wastewater from resorts, small municipalities, landfills, and food processing facilities. This system has been implemented in cold climates and in applications in which the treated water has been reused onsite.

Description of process

The medium used in the Waterloo Biofilter is an open-cell foam that is lightweight, has a high surface area, and is resistant to clogging. Settled wastewater is applied to the surface of the biofilter with a spray distribution system. The biofilter can be placed above ground or below ground according to site conditions and can be used in single-pass and multi-pass configurations. The basic system flow diagrams are shown in Fig. 6-16.

System Footprint

The typical system will have a surface area of 32 ft^2. System often housed in wooden shed with a length of 8 ft, width of 4 ft, and height of 5 ft. Systems can be installed above ground, partially buried, or fully buried.

Advantages

Relatively low maintenance, recovers quickly in event of process disturbance, adaptable to most sites including flow rate and unit placement, performs well in cold climates, can be used at sites with limiting site conditions, and has a small system footprint.

Disadvantages

Requires electricity for pump operation. Extended power failure can result in wastewater backup. May be more expensive than non-proprietary systems which use locally available medium.

Performance

The Waterloo Biofilter system has been included in many onsite demonstration projects. Typical treatment performance, after single-pass treatment of residential wastewater, is 90 to 95 percent removal of BOD_5, 90 to 95 percent removal of TSS, and 20 to 40 percent removal of TN. Forced aeration and multi-pass treatment typically improves treatment. Additional performance specifications from representative research studies are presented in Table 6-14.

Operation and maintenance

The Waterloo Biofilter system requires periodic maintenance. The system generally uses one or two submersible pumps to transport water to the biofilter system and to subsequent wastewater management operation, depending on site characteristics. The pump can be operated on a demand or timed basis. The pump and control panel should be inspected regularly along with other system components, including inspection and cleaning of the spray nozzles and medium. Under normal use conditions, the medium is not expected to clog or require changing for 20 to 30 years (manufacturer's claim). Systems should be inspected regularly for clogging of spray distribution system and overall system operation. Correct pump and control system operation should be confirmed.

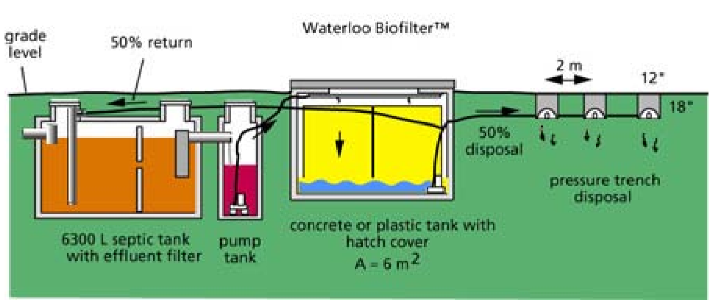

Figure 6-16

A diagram of the Waterloo Biofilter (left) and view of internal packing (right). (Adapted from Waterloo Biofilter Systems, Inc.)

Power and control
Generally uses one or two pumps depending on specific site characteristics and design. Alarm and monitoring equipment recommended, especially for large and/or remote systems. Can be dosed on a timed or demand basis. Annual power usage expected to range from 500 to 1000 kWh.

Cost
$7,000 to 8,000, includes capital and installation costs for installation of biofilter component only.

Table 6-14
Selected representative studies of Waterloo Biofilter performance

Parameter	Unit	Location of study		
		Massachusetts[a]	Acton, ON[b]	Gloucester, MA[c]
Description of system		Demonstration	Golf Club	Residential
HLR	gal/d	330	8000	
DF	dose/d	15		
Recirculation	unitless	2		2
System performance[d]				
BOD_5	mg/L	9.5 (92%)	3 (99%)	12 (93%)
TSS	mg/L	6.2 (87%)	3 (98%)	7 (87%)
Oil/grease	mg/L			
TN	mg/L	13.2 (63%)	10 (88%)	55.9 (28%)
NO_3-N	mg/L	9		23
NH_3-N	mg/L	1	0.5	26.5
P	mg/L		0.7 (89%)	8.4 (0%)
Fecal coliform	CFU/100 mL	1.5E4 (2.2)		1.0E3 (2)

[a] Massachusetts Alternative Septic System Test Center (2001) Evaluation of Waterloo Biofilter.
[b] Jantrania *et al*. (1998).
[c] Jowett (1997).
[d] Performance reported as average effluent concentration with average removal in parentheses for all parameters except for coliform, which is reported as geometric mean and log removal in parentheses.

Contact
Waterloo Biofilter Systems Inc.
143 Dennis Street, Rockwood
Ontario NOB 2K0
Phone (519) 856-0757
Fax (519) 856-0759
E craig@waterloo-biofilter.com
Web www.waterloo-biofilter.com
Model description
Designs and manufactures system components including effluent filter, biofilter, and soil adsorption system. Company also provides additional components for phosphorus removal, membrane filtration, and disinfection.

References and other resources

Jantrania, A.R., K.C. Sheu, A.N. Cooperman, and O.C. Pancorbo (1998) Performance Evaluation of Alternative Systems – Gloucester, MA, Demonstration Project, in *Proceedings of the Eight National Symposium on Individual and Small Community Sewage Systems,* Orlando, FL, American Society of Agricultural Engineering, St Joseph, MI.

Jowett, E.C., and M.L. McMaster (1995) On-Site Wastewater Treatment Using Unsaturated Absorbent Biofilters, *Journal of Environmental Quality*, Vol. 24, Pp. 86-95.

Jowett, E.C. (1999) Immediate Re-Use Of Treated Wastewater for Household and Irrigation Purposes, Presented at 10th Northwest On-Site Wastewater Conference, University of Washington, Seattle, September 21, 1999.

Jowett, E.C., J.D. Redman, F.C. Ford, S. Klint, G.L. Prentice, and C.P. Hughes (1999) Bio-Remediation Of Landfill Leachate With Remote Monitoring And On-Site Disposal, *Battelle Conference Proceedings*, San Diego, April 1999.

Jowett, E.C., W.G. Cook, G.L. Prentice, C.P. Hughes, F.C. Ford, and S. Klint (1997) Removal Of VOCs From Landfill Leachate Using Absorbent Aerobic Biofiltration, *American Chemical Society*, Ninth Annual Symposium on Emerging Technologies in Hazardous Waste Management, Pittsburgh, September 15-17, 1997.

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Jowett, E.C. (1997) Sewage And Leachate Wastewater Treatment Using The Absorbent Waterloo Biofilter, Site Characterization and Design of On-Site Septic Systems", ASTM STP 1324, M.S. Bedinger, J.S. Fleming, and A.I. Johnson, Eds., American Society for Testing and Materials, West Conshohoken, PA 1997, p. 261-282.

Jowett, E.C., and D. Pask (1997) Innovative Septic Systems and Nutrient Removal Technologies in Canada and the United States, In: 9th NW On-Site Wastewater Treatment Short Course, University of Washington, September 22, 1997.

Jowett, E.C. (1997) Design And Start-Up Of Domestic Wastewater Re-Use System In The CMHC Toronto 'Healthy House', National Onsite Wastewater Recycling Association 6th Annual Conference, October 24, 1997, College Station, Texas.

Millham, N.P., G. Heufelder, B. Howes, and J. Costa (2000) Performance of Three Alternative Septic System Technologies and a Conventional Septic System, *Environment Cape Cod*, Vol. 3, No. 2, Pp. 49-58.

Townshend, A.R., E.C. Jowett, R.A. LeCraw, D.H. Waller, R. Paloheimo, C. Ives, P. Russell, and M. Liefhebber (1997) Potable Water Treatment And Reuse Of Domestic Wastewater in the CMHC Toronto 'Healthy House', Site Characterization and Design of On-Site Septic Systems, ASTM STP 1324, M.S. Bedinger, J.S. Fleming, and A.I. Johnson, Eds., American Society for Testing and Materials, West Conshohoken, PA 1997, p. 176-187.

US patents 5,707,513; 5,980,739; and 5,762,784. This technology is also licensed to several other companies including Zabel (Aerocell), Links-Loo Inc, and ACP Inc. (Eco-Nomad).

A suspension of wastewater and treatment organisms in an aerated tank is known as the activated sludge process. The activated sludge process can be used for onsite wastewater treatment, generally requiring the addition of an air pump to deliver oxygen to the system and provide mixing energy. Suspended growth treatment systems can be secondary only (require supplemental primary treatment) or combined primary and secondary treatment processes. Designs typically consist of aeration, clarification, and sludge return processes. Some systems operate under an extended aeration mode for enhanced constituent transformation.

Types of processes

The principle types of processes may be classified as (1) continuous flow, (2) sequencing batch, and (3) membrane bioreactor.

Continuous flow reactors

Continuously mixed systems keep the bacterial culture that provides treatment in suspension by adding mixing energy to the system. Mixing and aeration are often supplied with air compressors that introduce air into the reactor through a diffuser mechanism. Wastewater flows through the treatment process as fresh wastewater enters the system. The complete-mix system is similar in function and operation to the conventional activated sludge system used at many municipal treatment facilities.

Sequencing batch reactors

In the sequencing batch reactor, wastewater is stored in the reaction chamber of the treatment system until sufficient volume (a batch) is collected at which point the treatment process begins. The batch of wastewater is seeded with an active bacterial culture and aerated for the treatment period. After the reaction is complete, aeration and mixing are stopped the flocculated bacteria and other solid particles settle out. The clear layer (supernatant) is discharged from the reaction chamber and wastewater to be treated begins to flow into the reaction chamber again. The fill, react, settle, discharge cycle is repeated continuously.

Membrane bioreactors

Submerging a fine pore membrane in an activated sludge process is known as a membrane bioreactor. Membrane bioreactors are used for wastewater treatment and reclamation at communities of various sizes.

System components

Important components of aerobic suspended growth treatment systems are the reactor (container), the aeration and mixing devices, the outlet structure, and the control system. Each of these components is discussed below.

Container

The process tank is generally divided into three compartments, the primary separation chamber, the aeration chamber, and the settling chamber. Some systems accomplish primary treatment in a standard septic tank, making them suitable for upgrading sites which already have an existing septic system. The primary separation chamber is designed to separate settable and floatable substances from the influent wastewater. The primary separation compartment should be designed to have capacity to retain materials that may interfere with downstream processes. The aeration chamber is designed to provide sufficient volume for contact between the wastewater and the microbial biomass. The distribution of the fixed film media, placement of the aeration device, and hydraulic flow paths are important criteria for effective treatment. Clarification is the separation of wastewater solids (particles and microbial cells) from the treated water. The secondary settling chamber is used for clarification of the wastewater and should be sized to have adequate detention for secondary separation before discharge of the treated water.

Aeration and mixing devices
Mixing and aeration are, in most cases, accomplished by the same device. Generally, air is delivered to the bottom of the aeration tank and released through a diffusing mechanism to increase the surface area and, thus, oxygen transfer efficiency, to the aerobic treatment process. As the air bubbles move up the water column, oxygen is consumed and the contents of the tank are mixed. Important factors to be considered for the aeration mechanism are the (1) maintenance requirements, (2) expected lifespan and reliability, (3) the noise generated during operation, (4) access to the device, and (5) durability under adverse conditions. The common types of aeration and mixing devices are presented in Table 7-1. Because these treatment processes are aerobic, the device or method used to compress and deliver the air to the aeration tank are critical elements.

Outlet structures
The outlet is designed to release clarified, treated water from the treatment system. The outlet structure should be designed to keep residual particles from exiting with the process effluent. Commonly used devices are baffled outlet structures, outlet (effluent) filters, and floating and fixed overflow weirs.

Control systems
Process control is generally accomplished by float switches to monitor water level, pumps to transfer water between processes, and timers to regulate the treatment process. Many systems are incorporating programmable logic controllers to make the treatment process more adaptable to the challenges of onsite treatment.

Operational parameters
Operational parameters are used to define system application. Most treatment processes are rated based on the daily hydraulic capacity for wastewater with an assumed composition. In some of the processes, the solids retention time (SRT) is also used as a control parameter. Because onsite treatment systems are often exposed to highly variable loading, processes are often oversized. A robust treatment process should provide design performance under a range of adverse loading conditions. The parameters used to categorize system operation include the loading rate, retention time, surge capacity, aeration characteristics, flow configurations, and process failure.

Table 7-1
Mixing and aeration devices used for onsite wastewater treatment systems

Device	Description
Air diffusers	Air diffusers are porous fixtures located in the aeration tank. Compressed air is pushed through the holes in the diffuser, causing the formation of discrete air bubbles. The compressed air may be supplied by a diaphragm, rotary vane, or piston pump (rated for continuous use).
Aspirators	Aspirators have a small impeller below a hollow shaft (draft tube), when the propeller and shaft are rotated, a vacuum is created that draws air down the draft tube into the aeration tank and is simultaneously dispersed by the impeller into the water.
Air lift pumps	The air lift pump operates by injecting air into the bottom of a vertical submerged column (hollow shaft). The air that is released moves up the column and forces water to move upwards with it, accomplishing aeration and mixing.

Retention time

Each process within a treatment process has a liquid retention time based on the effective volume of the process and the expected hydraulic loading rate (HLR). The various treatment processes and the importance of proper retention time are presented in Table 7-2. Most aerated onsite treatment processes are extended aeration (i.e., long SRT) to reduce the overall sludge volume due to the inability to regularly remove this material.

Loading rate
The loading rate is the flow of a material, such as liquid or a specific constituent, through the system. The HLR is often defined as the daily volume of wastewater that the system is able to process. The organic loading rate (OLR) is defined as the daily BOD_5 input to the system. For residential applications, the constituent concentrations for typical domestic wastewater are used to estimate the OLR. Activities that can affect the loading rate include (1) variable loading, (2) over loading, (3) extended periods of non-operation, (4) electricity outage, and (5) equipment failure.

Table 7-2
Treatment processes and the importance of design retention time

Treatment process	Importance
Primary	Primary treatment processes require liquid retention time to accomplish solids separation from the water to be treated. If an adequate volume of hydraulic overload occurs, solids may be carried over into subsequent processes, reducing the overall effectiveness of the treatment process.
Aeration	Contact time in the aeration cycle is needed to ensure design oxidation of the process water. If the water is not in the aeration process for a sufficient length of time, the effluent discharged may have an increased BOD or ammonia concentration.
Secondary	Secondary processing is designed to separate the biomass and other suspended materials from the wastewater to be discharged. If not given enough time for settling, these solids will be discharged with the wastewater and may interfere with downstream processes. Outlet filters have reduced the possibility of inadvertent solids discharge.
Solids	The solids retention time is related to the length of time that the microbial biomass is kept in the treatment process. Because it is not realistic to remove solids from onsite treatment systems on a regular basis, solids are often recycled back to the primary treatment process or the aeration process for digestion. Solids recycling is accomplished by allowing the settled solids to flow back into the aeration process by gravity or with a submerged pump that periodically activates and discharges the solids to a specified location.
Disinfection	For systems that incorporate a disinfection step, adequate contact time with the effluent needs to be ensured to accomplish design performance.

Process failure
Process failure occurs when the treatment system discharges water with constituent concentrations that are above the acceptable limit as determined by the effluent management system. The failure of an aerated treatment process is often caused by (1) inadequate maintenance of the treatment system, (2) the discharge of toxic substances (such as chlorine) to the biological treatment system, and (3) failure of a component (such as an aeration device) needed for proper operation. Of these, proper maintenance is believed to be the most important aspect of long-term success of onsite treatment systems.

Monitoring and maintenance
The ongoing monitoring and maintenance of aerated treatment systems is important for keeping

these devices operating as designed. Monitoring and maintenance activities should be conducted regularly by a certified individual.

System components
The system components that should be inspected include the aeration device, the packing materials (if applicable), the inlet and outlet structures, pumps, and the air diffusers. Additional components may also need servicing as determined by the manufacturer. The system components and standard maintenance needs are presented in Table 7-3

Table 7-3
Recommended maintenance activities for aerated treatment systems

Component	Typical maintenance needs
Aeration device	Check air filters and clean if necessary. Also check oil seals, noise level, abnormal vibration, and heating output.
Inlet and outlet structures	Remove floating debris and scum that accumulates around outlet structures.
Process tanks	Check for excessive solids accumulation and remove as needed.
Pumps	Confirm that pumps are operating correctly.
Diffusers	Inspect diffuser for solids buildup and clean as necessary.
Timers	Check system timers and other control devices for correct settings as determined by manufacturer or system installer.
Float switches	Observe float switches to confirm proper operation.
Alarms	Confirm that alarms are functioning.
Effluent quality	Qualitative assessment of odor, color, and turbidity. Qualitative assessment may depend on the discharge location and can include BOD, TSS, nitrogen, phosphorus, and fecal coliform bacteria.

7-1 Complete-mix reactors

Complete-mix reactors utilize some type of mixing device to keep organisms in suspension. In most cases, the device that provides aeration also provides the mixing energy. Some systems are operated as combined primary and secondary treatment systems, while others require a septic tank or other pretreatment device to provide primary treatment.

7-1.1 AeroDiffuser™ wastewater treatment system

Category	Secondary treatment
Technology	Continuous flow, aerated suspended growth, extended aeration
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The AeroDiffuser system is an extended aeration treatment system. Water moves through the system by hydraulic displacement. A linear air pump is used to supply continuous aeration. A cone shaped compartment is used for clarification of the treated wastewater. Settled solids are returned to the aeration chamber. The control box and air pump are located in an attached compartment located on the top of the unit.

Description of process
The total volume of the unit is 875 gal, total retention time in the system is about 40 hours. Typical design flow rate is 500 gal/d. Primary effluent enters the aeration chamber and is

circulated and mixed with the activated sludge. The process water is then separated from the biomass in the clarifier and discharged through an outlet assembly or outlet filter.

System footprint
Unit is 5.2 ft in diameter and about 7.1 ft tall (total surface area 21 ft^2).

Advantages
Effective treatment, NSF approved, unit is modular and compact.

Disadvantages
Treatment systems requires electricity for proper operation. The air supply will require periodic maintenance for long term operation.

Performance
NSF certified system capable of producing secondary quality effluent.

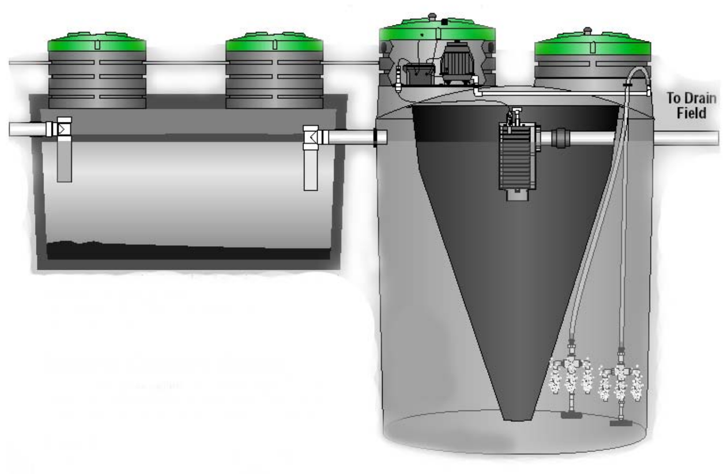


Figure 7-1

Diagram of the AeroDiffuser extended aeration plant. (Adapted from Zabel Environmental Technology.)

Operation and maintenance
Electrical and mechanical components will need to be inspected to confirm proper operation. Sludge accumulation in treatment system will need to be removed occasionally. If an outlet filter is included, it will need to be cleaned periodically. The aeration device will need to be checked for signs of wear and inlet screen cleaned periodically. Periodic inspection of system components and servicing as needed.

Power and control
System includes float switches, linear air pump, control panel, and alarms. Expected annual electrical usage is 2,000 to 3,000 kWh.

Cost
Estimated cost range from $4,500 to 5,000 for typical residential system. Cost estimate includes capital costs for treatment unit and necessary controls and system components only.

Contact
Zabel Environmental Technology
PO Box 1520
Crestwood, KY 40014
Phone (502) 992-8200/(800) 221-5742
Fax (502) 992-8201
Web www.zabelzone.com
Model description
ATS AD 500 (500 gal/d)
ATS AD 500 with effluent filter (500 gal/d)
Manufacturer support
Not determined

References and other resources
NSF (2000) Final Report Zabel Environmental Technology Model ATS-AD-500 Wastewater Treatment System, NSF International, Ann Arbor, MI.

U.S. Patent: 6,096,203, 5,266,239, 6,106,704, Foreign: D423,638, D424,659, D426,866.

7-1.2 AES IDEA BESTEP™

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems and cluster systems, commercial, institutional

Background
The intermittent decant extended aeration (IDEA) process is utilized in several treatment systems developed by Advanced Environmental Systems, Inc. The proprietary treatment system uses several techniques for wastewater treatment including intermittent aeration, continuous flow, and periodic decanting of the process effluent.

Description of process
Raw wastewater enters the treatment system and is dissipated and distributed with deflecting fixtures. A timer operates the aeration system on a predetermined schedule to accomplish the sequencing nature of the treatment process. The AES IDEA system differs from SBRs because influent flow is continuous and the process is modified to compensate for this equalization.

System footprint
Dimensions of treatment unit are equivalent to standard septic tank (10 ft long, 6 ft wide,and 6.5 ft high).

Advantages
All operations occur in a single basin; can be installed into an existing septic tank, relatively small space requirements. Effective treatment system, including potentially for high nitrogen removal.

Disadvantages
Treatment system requires energy to operate. Aeration system will require periodic maintenance.

Performance
System is NSF certified to meet secondary wastewater treatment. Performance specifications of representative research findings are presented in Table 7-4.

Operation and maintenance
Electrical components which will require servicing include the blower, a decanter pump, float switches, and the timer/control panel. Other features that will need to be inspected periodically include the decanting device, the inlet baffle, and the accumulation of sludge in the reactor. Unique technology lease program, AES installs, operates, and monitors (with telemetry) treatment system for monthly fee. Homeowner does not have responsibility for maintenance.

Power and control
Timer system used to control sequencing cycle, effluent discharge pump, blower to supply process oxygen, and float switches to monitor system. Estimated annual power usage in the range of 750 to 1000 kWh.

Cost
AES estimates cost to install denitrification upgrade to existing septic system will cost $1000 per bedroom, $35 monthly charge for lease/operation and maintenance services.

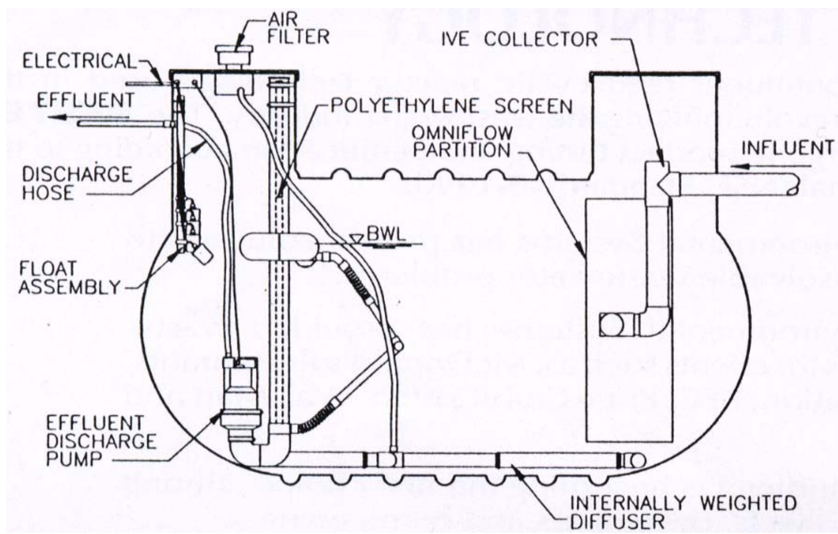


Figure 7-2

The AES IDEA BESTEP treatment system installed at a residential location (left top), installed in a fiberglass septic tank before installation (left bottom), and a diagram highlighting system components. (Adapted from Advanced Environmental Systems, Inc.)

Contact
Advanced Environmental Systems, Inc.
PO Box 2019
Kihel, Maui, Hawaii
Model description
BESTEP 10 (500 gal/d)
BESTEP 15 (750 gal/d)
Other systems can be designed for flows up to 25 mgd
Manufacturer support
Lease treatment system to homeowner for monthly fee, ongoing maintenance contract

References and other resources
Anderson, D.L., M.B. Tyl, R.J. Otis, T.G. Mayer, and K.M. Sherman (1998) Onsite Wastewater Nutrient Reduction Systems (OWNRS) For Nutrient Sensitive Environements, *Onsite Wastewater*

Treatment, Proceedings of the Eighth National Symposium on Individual and Small Community Sewage Systems, American Society of Agricultural Engineers, St. Joseph MI.

Florida Department of Health (2000) *Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project – Phase II Addendum*, Florida Department of Health.

NSF (1995) *Final Report Advanced Environmental Systems Inc*., Mini IDEA Model BESTEP 10, NSF International, Ann Arbor, MI.

Table 7-4

Reported results from of BESTEP performance[a]

Parameter	Unit	Location of study
		Florida[b]
Description of system		Demonstration site
System performance		
BOD_5	mg/L	4.16 (98%)
TSS	mg/L	6.85 (94%)
TN	mg/L	15.46 (60%)
NO_3-N	mg/L	14.3
TP	mg/L	6.24 (27%)

[a] Anderson *et al*. (1998).

[b] Performance reported as average effluent concentration with average removal in parentheses, where applicable.

7-1.3 Alliance wastewater treatment systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background

The Alliance wastewater treatment system is an extended aeration process housed in a concrete tank. Air is supplied by a blower and released through air diffuser located on the bottom of the aeration chamber. The distribution of this treatment system and the availability in California is not known.

Description of process

Process composed of two chamber (aeration and clarification) basin. Wastewater flows into the aeration basin and is circulated by air released from a diffuser placed at the bottom of the unit. Aerated water then flows into clarifier for sedimentation. Treated wastewater is discharged from outlet tee.

Performance

NSF certified for production of secondary quality wastewater (NSF 2000).

Contact
H.E. McGrew, Inc.
3508 Industrial Drive
Bossier City, LA 71112
Phone (318) 746-5122
Model description
Alliance 500 (500 gal/d)

References and other resources
NSF (2000) *Final Report HE McGrew Inc., Alliance 500 Wastewater Treatment System*, NSF International, Ann Arbor, MI.

7-1.4 B.E.S.T. 1

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
Extended aeration package plant.

Description of process
System consists of a three chamber (primary treatment, aeration, and secondary settling) tank. Wastewater flows through the system, receives treatment and is discharged.

Performance
NSF certified for production of secondary quality wastewater (NSF 2000).

Operation and maintenance
Standard inspection and maintenance of system components, including ¼ hp rotary vane blower and sludge removal.

Contact
American Wastewater Systems
917 Fieldspan Rd
Duson, LA 70529
Phone (337) 873-3128

References and other resources
NSF (2000) Final Report American Wastewater Systems, Inc., BEST 1 Wastewater Treatment System, NSF International, Ann Arbor, MI.

7-1.5 Bi-A-Robi

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, upgrade of existing systems

Background
Basis of the Bi-A-Robi system is the conversion of a septic tank to an aerobic reactor by the addition of an air compressor and circulation pump.

Operation and maintenance
Standard inspection and maintenance of mechanical devices (air pump and submerged circulation pump).

Contact
Bi-A-Robi Systems, Inc.
P.O. Box 133
Hamlin, PA 18427
Phone (717) 689-2307
Fax (717) 689-3089
E btraverse@aol.com

References and other resources
Ohio Department of Health (2001) *Individual Aerobic Wastewater Treatment Plants Approved By The Ohio Department Of Health*.

7-1.6 Brooks Anti-septic sewage treatment plant

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Domestic wastewater, individual residences

Background
The Brooks Anti-septic system was developed in the 1970s and manufactured in St. Louis, Missouri. Several units have been installed in California. The basis for the Brooks design is a unique basin geometry (oblique baffle) to optimize secondary settling.

Description of process
The system has three compartments, aeration, clarification, and outlet filtration. Domestic wastewater enters and moves through the aeration compartment, into the clarification compartment. Solids are settled out and are passively returned to the aeration compartment. The water is then discharged after flowing through an outlet filtration compartment. Air is supplied to the aeration tank by a remote blower.

Performance
Performance data supplied provided by the manufacturer is summarized in Table 7-5.

Table 7-5
Reported results of Brooks system performance

Parameter	Unit	Without outlet filter	With outlet filter
BOD	mg/L	41 (81%)	26 (83%)
TSS	mg/L	5 (95%)	1.4 (99%)

[a] Waste Not Inc. (2001)

Operation and maintenance
Standard maintenance requirements for the Brooks system include (1) cleaning of blower air intake filter every 6 months, (2) blower maintenance every two years (replacement of worn vanes), (3) fine adjustment of blower timer to optimize treatment, (4) removal of surface solids from treatment unit, and (5) cleaning of outlet filter as needed.

Contact
Waste Not, Inc.
32700 Albion Ridge Rd; PO Box 339
Albion, CA 95410
Phone (707) 937-5735
Fax (707) 937-3426
E paulex@mcn.org
Model description

Rated for single dwelling unit (1 to 12 people), if more than 12 people, may be arranged in parallel.

References and other resources

Waste Not, Inc. (2001) *Brooks Anti-Septic Sewage Treatment Plant Owners Manual*

7-1.7 Clearstream™ wastewater systems

Category	Secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Primary treatment
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, cluster systems

Background

The Clearstream wastewater treatment system is an extended aeration package plant. The system is typically housed in a concrete or fiberglass tank. Wastewater is pretreated in a septic tank before entering the Clearstream system. Wastewater is aerated in the outer chamber of the system and clarified in the inner chamber.

Performance

NSF certified for production of secondary quality wastewater (NSF 2000).

Figure 7-3

Diagram of the Clearstream wastewater treatment system. (Adapted from Clearstream Wastewater Treatment Systems, Inc.)

Operation and maintenance
Air supply pump will need to be serviced or replaced as needed. Air filter and diffuser will need to be cleaned. Alarm should be checked for proper operation. System will need to be shut down for periodic solids removal.

Contact
Clearstream Wastewater Systems, Inc.
P.O. Box 9337
Beaumont, TX 77709
Phone 409.755.1500
Fax 409.755.6500
Web www.clearstreamsystems.com
Model description

Model 500N	500 gal/d
Model 600N	600 gal/d
Model 750N	750 gal/d
Model 1000N	1000 gal/d
Model 1500N	1500 gal/d

References and other resources
NSF (2000) *Final Report Clearstream Wastewater Treatment Systems, Inc.*, NSF International, Ann Arbor, MI.

7-1.8 Envirocycle® USA advanced wastewater treatment

Category	Primary and secondary treatment, disinfection optional
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The Envirocycle wastewater treatment system is based on the Biocycle wastewater treatment system. The technology was developed in 1982 and patented in 1989 in the United States. More than 20,000 of these systems have been installed worldwide. The Envirocycle system includes drip dispersal of the process effluent, telemetry for continuous monitoring, and a quarterly service contract.

Description of process
The system is composed of a four compartment tank with an optional disinfection step. Wastewater is treated by primary settling, aeration, and clarification. An additional compartment with a submerged pump is used to store and distribute water to subsequent soil based system. The system has a design flow rate of 600 gal/d and large capacity (2378 gal) providing an additional 600 gal of storage capacity after activation of the high water alarm.

System footprint
Unit is 7.7 ft in diameter and 8.8 ft in height. Effluent management depends on characteristics of receiving area. Effluent typically dispersed with drip irrigation system.

Advantages
Effective treatment of domestic wastewater. Optional nitrogen reduction and disinfection. Mandatory service contract and telemetry systems ensure long-term management and performance.

Disadvantages
Treatment process requires electricity for proper operation. Required maintenance for long-term performance.

Performance
The Envirocycle unit has not been evaluated by NSF, however, its ability to produce secondary quality water has been verified by other researchers sampling from units installed at residential locations. In general, BOD_5 and TSS concentrations of less than 20 mg/L can be expected. The unit can be operated in a nitrogen reduction configuration and/or with an optional UV disinfection unit (Salcor Engineering, Inc.)

Operation and maintenance
A quarterly inspection and preventative maintenance contract is required for the life of the system. The service contract covers all maintenance activities associated with the treatment system, including blower and effluent pump replacement and solids removal. The current annual cost of this contract is $360.

Power and control
System includes telemetry system, blower for aeration, and 0.5 hp effluent pump. During normal operation, aerator is on for 30 minutes and off for 30 minutes, reducing overall electricity usage. Estimated annual electricity usage is 1,000 to 1,500 kWh.

Cost
$14,900 Includes capital and installation costs for complete system, including telemetry monitoring and drip distribution of effluent

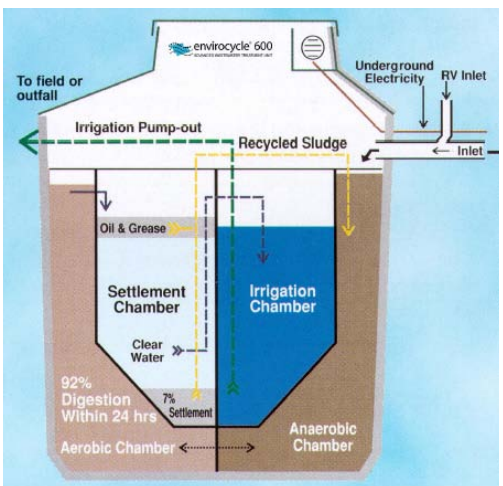


Figure 7-4

Diagram of the Envirocycle treatment system.
(Adapted from Envirocycle USA LLC.)

Suppliers
Envirocycle® USA LLC
PO Box 5698
Auburn, CA 95604
Phone (888) 694-4633
Fax (888) 694-4829
E sales@envirocycleusa.com
Web www.envirocycleusa.com

Model description

Model 600 (600 gal/d)

Manufacturer support

Manufacturer ensures long-term operation and maintenance through required service contract and telemetry monitoring

7-1.9 Hydro-Action®

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, cluster systems

Background

The Hydro-Action wastewater treatment system is an extended aeration package plant. The system consists of a trash tank, a combination aeration tank and cone type clarification chamber, and an effluent chlorine contact pump basin.

Performance

NSF certified for production of secondary quality wastewater (NSF, 2000).

Operation and maintenance

Manufacturer recommended service needs (and service intervals): repair or replace aerator (2 to 10 y), clean filters on aerator (6 mo to 2 y), break up scum on aerator (6 mo to 2 y), pump sludge from aeration tank (2 to 5 y), pump sludge from trash tank (2 to 5 y), check aeration diffuser (annually), check surge control weir (6 mo). If system is equipped with chlorination device, will also require periodic replacement of chlorine tablets and monitoring.

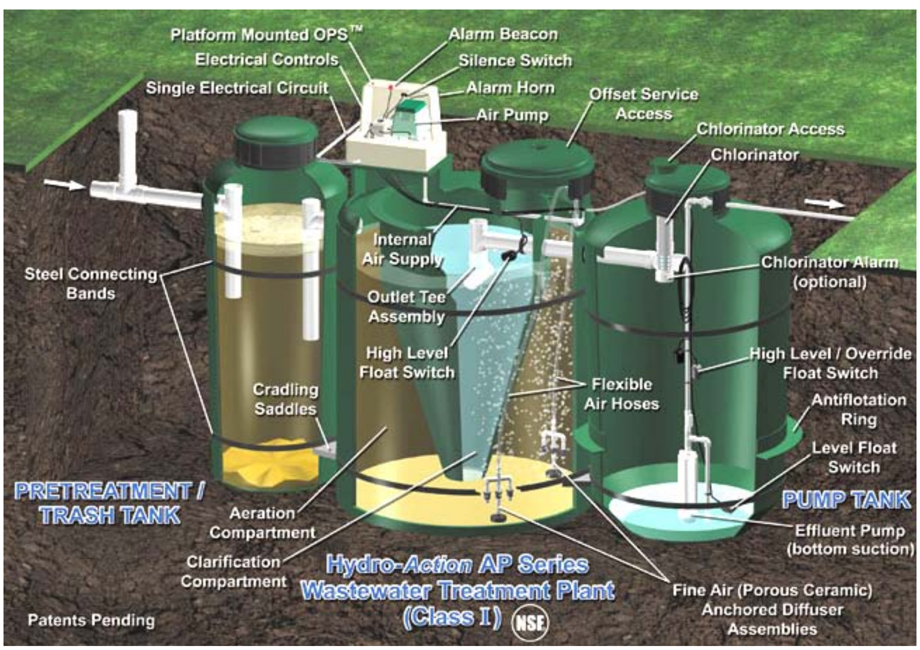


Figure 7-5

Diagram of the Hydro-Action wastewater treatment system. (Adapted from Hydro-Action, Inc.)

Contact
Hydro-Action, Inc.
8645 Broussard Rd.
Beaumont, TX 77713
Phone (409) 892-3600
Fax (409) 892-0005
Web www.hydro-action.com
Model description
    500N (500 gal/d)
    600N (600 gal/d)
    750N (750 gal/d)
    1000N (1000 gal/d)
    1500N (1500 gal/d)
Manufacturer support
    Guaranteed two year service period followed by optional extended service contract.

References and other resources

NSF (2000) *Final Report Hydro-Action, Inc. Model AP500 Wastewater Treatment System*, NSF International, Ann Arbor, MI.

7-1.10 JET commercial

Category	Primary and secondary treatment, disinfection optional
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	commercial and institutional facilities

Background
Jet Inc. manufactures package plant wastewater treatment facilities featuring a patented aeration diffuser. The units are modular in design and housed in pre-cast concrete tanks.

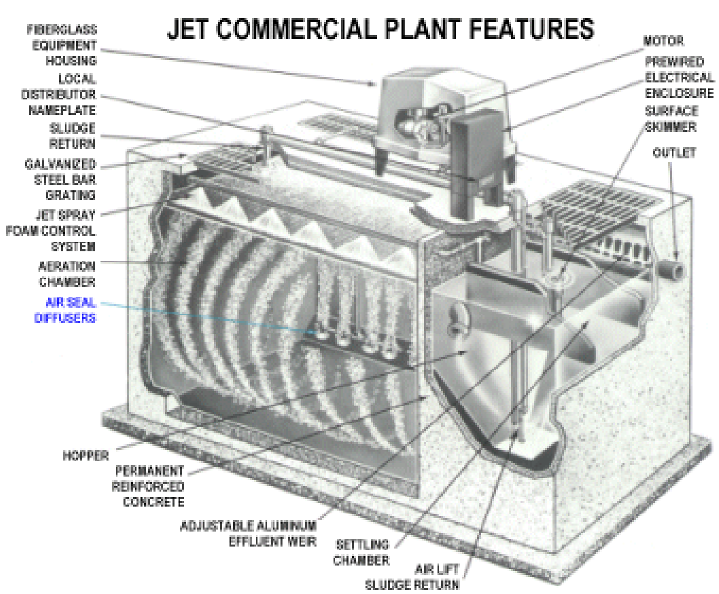


Figure 7-6

Diagram of the Jet commercial package plant. (Adapted from Jet, Inc.)

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000).

Contact
JET, Inc.
750 Alpha Dr.
Cleveland OH 44143
Phone (440) 461-2000
Fax (440) 442-9008
Web www.jetincorp.com

References and other resources
Jet Inc. (2001) *Jet commercial plant operator's manual.*

7-1.11 Mighty Mac wastewater treatment systems

Category	Secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Primary effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The Mighty Mac treatment system is an extended aeration process designed for ease of installation. The basic process configuration is an aeration system and interior cone clarifier. The unit has a float switch, air blower, and high water alarm.

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000).

Operation and maintenance
Standard inspection and maintenance of mechanical devices (air pump). Sludge removal from aeration tank and primary treatment tank.

Contact
H.E. McGrew, Inc.
3508 Industrial Drive
Bossier City, LA 71112
Phone (318) 746-5122

References and other resources
NSF (2000) *Final Report H.E. McGrew, Inc., Mighty Mack 500 Wastewater Treatment System*, NSF International, Ann Arbor, MI.

7-1.12 Modulair® treatment systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Commercial systems

Background
The Modulair treatment system is an extended aeration package plant for the treatment of wastewater from residential communities and commercial facilities.

Contact
Norwalk Wastewater Equipment Company, Inc.
220 Republic Street
Norwalk OH 44857-1196
Phone (419) 668-4471
Fax (419) 663-5440
Web www.norweco.com
Model description
Flow rates from 1,500 to 500,000 gal/d

References and other resources
Norweco (2001) Manufacturer product brochure, downloadable from www.norweco.com

7-1.13 Mudbug wastewater treatment system

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The Mudbug wastewater treatment system is a flow through, two compartment concrete tank. Wastewater enters directly into the aeration tank and then into the clarification tank. An outlet filter and secondary effluent filter are used to improve effluent quality.

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000).

Operation and maintenance
Standard inspection and maintenance of mechanical devices (air pump). Removal of sludge from the aeration process will be needed periodically. Outlet and effluent filters require servicing for optimal performance.

Contact
Rogers Treatment Systems
45232 Rogers Road
Hammond, LA 70401
Phone (985) 345-4096

References and other resources
NSF (2000) *Final Report Rogers Treatment Systems, Inc., Mudbug 5 Wastewater Treatment System*, NSF International, Ann Arbor, MI.

7-1.14 Multi-Flo waste treatment system

Category	Secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Primary effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, cluster systems

Background
The Multi-flo wastewater treatment system is an extended aeration process with a unique filtration mechanism.

Description of process
Wastewater flows into the center of the treatment unit and is aerated by a mechanical aspirating mixing device. The aerated wastewater must then travel upward through submerged filters. After passing through the filters, the water is discharged to subsequent management.

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000). Other studies have confirmed effluent BOD_5 and TSS concentrations of less than 10 mg/L and fecal coliform bacteria often less than 1,000 CFU/100 mL.

Operation and maintenance
Manufacturer recommended maintenance is based on the following schedule: 6 to 8 wk startup period, 2 to 4 y pumping frequency, 2 to 4 y filter cleaning frequency, 3 to 4 y aerator replacement, and 6 mo (minimum) routine inspections. The system is equipped with a high water alarm to warn of clogging filters.

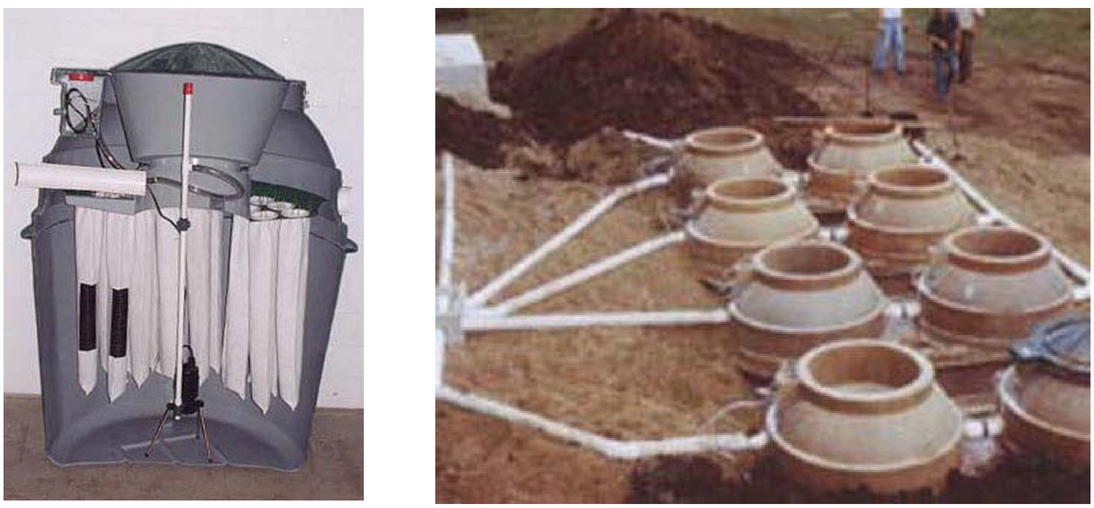


Figure 7-7
The Multi-flo treatment system cut-away view (left) and multiple units configured for treatment of larger flow rates (right). (Adapted from Consolidated Treatment Systems, Inc.)

Contact
Consolidated Treatment Systems, Inc.
2501 Commerce Center Drive
Franklin, OH 45005
Phone (937) 746-2727
Fax (937) 746-1446
Web www.consolidatedtreatment.com
Model description
- FTB 0.5 (500 gal/d)
- FTB 0.6 (600 gal/d)
- FTB 0.75 (750 gal/d)
- FTB 1.0 (1000 gal/d)
- FTB 1.5 (1500 gal/d)

Manufacturer support

Two year warranty and inspection period after installation. Manufacturer recommends extension of contract after initial period.

References and other resources

NSF (2000) *Final Report Multi-Flo Model FTB-0.5 Wastewater Treatment System*, NSF International, Ann Arbor, MI.

The University of Wisconsin has performed extensive evaluation of the Multi-flo treatment system.

7-1.15 Nayadic

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, cluster systems

Background

The Nayadic wastewater treatment system utilizes the extended aeration process.

Description of process

Wastewater enters the center aeration chamber and is aerated and mixed with a submerged air lift tube. A portion of the aerated effluent is directed into the outer ring of the unit which functions as the clarifier. Settled sludge is picked up and suspended by the air lift. Clarified water flows over a weir around the perimeter of the unit and flows out of the system.

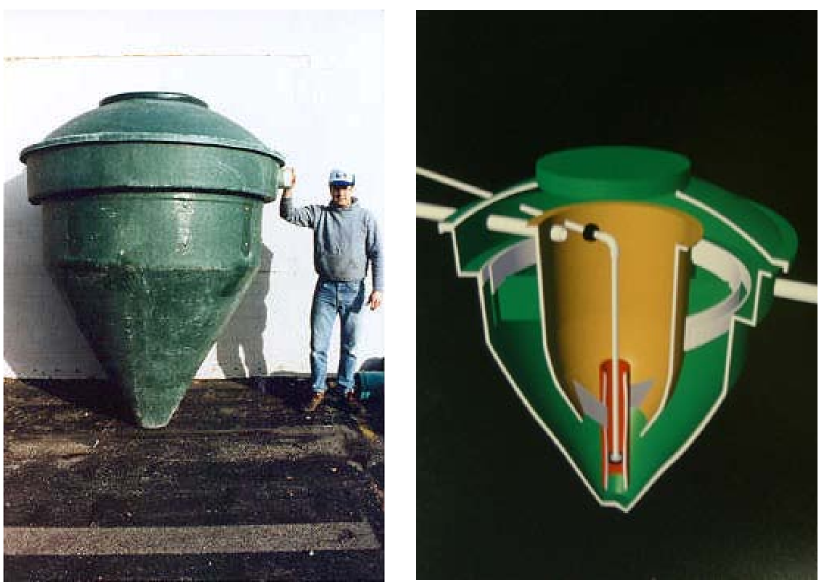


Figure 7-8

The Nayadic wastewater treatment system before installation (left) and shown in a cut away diagram. (Adapted from Consolidated Treatment Systems, Inc.)

Performance

NSF certified for production of secondary quality wastewater (NSF, 2000). In independent research evaluations, the Nayadic effluent typically has concentrations of BOD_5 and TSS less than 10 mg/L. Recirculation of process water through an anoxic tank has resulted in significant nitrogen removal, often with effluent concentrations less than 10 mg/L TN.

Operation and maintenance
Manufacturer recommended maintenance needs are as follows: 6 to 8 wk start up period, 2 to 4 y sludge pumping frequency, 3 to 5 y compressor replacement, 6 mo routine inspections or as directed by regulatory agency. If an anoxic tank or chemical addition is used for enhanced nutrient removal, addition maintenance actions will be needed.

Contact
Consolidated Treatment Systems, Inc.
1501 Commerce Center Drive
Franklin, OH 45005
Phone (937) 746-2727
Fax (937) 746-1446
Web www.consolidatedtreatment.com
Model description
M-6A (500 gal/d)
M-8A (600 gal/d)
M-1050A (800 gal/d)
M-1200A (1000 gal/d)
M-2000A (2000 gal/d)
Manufacturer support
Two year guarantee on system components

References and other resources
NSF (2000) Final Report Nayadic Model M-6A Wastewater Treatment System, NSF International, Ann Arbor, MI.

7-1.16 Singulair® Bio-Kinetic

Category	Primary and secondary treatment, optional disinfection
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential, cluster, and commercial systems

Background
The Singulair Bio-Kinetic wastewater treatment system utilizes an extended aeration process. The system is composed of four distinct processes, primary treatment, aeration, clarification, and effluent filtration housed in a concrete basin about the same size as a 1500 gal septic tank (Model 960-500). A unique characteristic of the Singulair system is the incorporation of flow equalization to improve process stability during variable flow events. The effluent filter may be operated with optional chlorination/dechlorination system.

Description of process
Wastewater enters the primary treatment chamber where settable and floatable solids are removed. Water to be treated flows into the aeration basin where an aspirator device is used to transfer oxygen into the water, after about 1 day in aeration (design flow), the water flows into a clarification chamber where a sloped bottom draws settled material back into the aeration chamber. Clarified water flows through a Bio-Kinetic effluent filtration device before discharge to subsequent wastewater management system.

System footprint
Unit is 9.25 ft long, 5.5 ft wide, and 6.5 ft in height (height depends on depth requirements.

Effluent management depends on characteristics of receiving area. If acceptable, effluent may be discharged to soil treatment system such as drip irrigation.

Advantages
Effective treatment of domestic wastewater. System is NSF approved. Optional nitrogen reduction and disinfection. Effluent filter and flow equalization improve process stability.

Disadvantages
Requires electricity for proper operation. System requires maintenance for long-term performance. Biological process performance subject to user activities.

Performance
NSF certified for production of secondary quality wastewater (NSF, 1995). Expected effluent composition of BOD_5 and TSS less than 10 mg/L. With the addition of a recirculation component, the Singulair treatment system can be expected to remove 50 to 70 percent of the wastewater nitrogen.

Operation and maintenance
Six month inspection of all system components including power usage, cleaning, and performance testing. Maintenance also includes refilling chlorination/dechlorination devices, completing and mailing maintenance records, and adjustment of systems operation. Aeration device is floodproof in case of high water event. Control system provides timing for aeration cycle, normal cycle is 30 minutes on, 30 minutes off. Audible alarm warns of high water event.

Power and control
System includes high water alarm (optional), aspirating mixer for aeration (floodproof), and timer for aeration cycle. During normal operation, aerator is on for 30 minutes, off for 30 minutes, reducing overall electricity usage. Estimated annual electricity usage is 500 to 1,000 kWh.

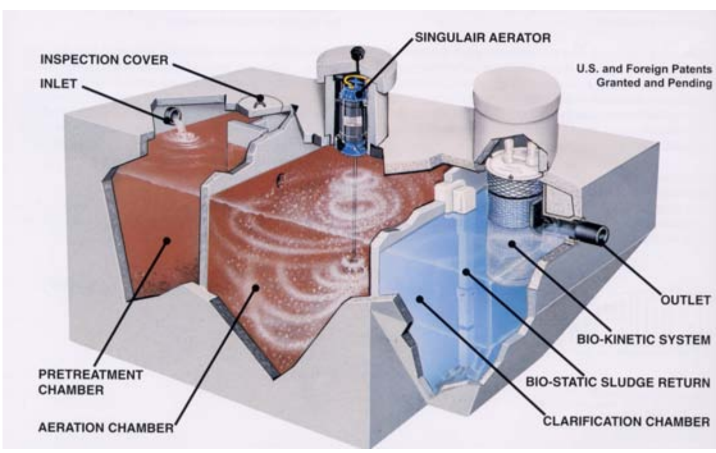


Figure 7-9

Diagram of the Singulair wastewater treatment system (Adapted from Norwalk Wastewater Equipment Company, Inc.)

Suppliers
Norwalk Wastewater Equipment Company, Inc.
220 Republic Street
Norwalk OH 44857-1196
Phone (419) 668-4471
Fax (419) 663-5440
Web www.norwweco.com

Model description

Model 960-500 (500 gal/d)
Model 960-750 (750 gal/d)
Model 960-1000 (1000 gal/d)
Model 960-1250 (1250 gal/d)
Model 960-1500 (1500 gal/d)

Manufacturer support

Treatment systems are sold, installed, and serviced by manufacturer trained distributors. Operation and maintenance are covered under a service contract for two years after installation (included with purchase price of the system). Norweco recommends renewal of the service contract after the introductory two year period. All system components are under warranty for this two year period and the system aerator is warranted under a 50 year replacement policy.

References and other resources

NSF (1995) *Final Report Norweco Inc., Singulair Model 960*, NSF International, Ann Arbor, MI.

7-1.17 Solar Air aerobic sewage treatment system

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background

Extended aeration package plant; not currently available in California.

Performance

NSF certified for production of secondary quality wastewater (NSF, 2000).

Contact

National Wastewater Systems Incorporated
6754 HWY. 90 East
Lake Charles, La. 70615
Phone (337) 439-0680
Fax (337) 439-0685
Web www.solarair.net/index.htm

Model description

SA - 500 GAL/D
SA - 800 GAL/D
SA-1000 GAL/D
SA-1200 GAL/D

References and other resources

NSF (2000) Final Report National Wastewater Systems, Inc., Solar Air Wastewater Treatment System, NSF International, Ann Arbor, MI.

7-1.18 USBF™

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, cluster systems, commercial, industrial

Background
The USBF process is a modification of conventional activated sludge process that incorporates an anoxic selector zone and an upflow sludge blanket clarifier.

Description of process
Wastewater is processed in anaerobic, anoxic, and aerobic treatment zones. Water is filtered thorough a sludge layer for improved clarification and nutrient removal.

Performance
The USBF process is capable of removal of BOD_5 to less than 5 mg/L, TSS removal to less than 10 mg/l without filtration, total nitrogen removal to less than 1.0 mg/L and total phosphorus removal to a range of 0.5 to 2.0 mg/L. Higher levels of phosphorus removal down to 0.2 to 0.5 mg/L can be achieved by metal salt addition to the aeration zone immediately prior to the mixed liquor entering the clarifier.

Operation and maintenance
Standard inspection and maintenance of mechanical devices (air pump).

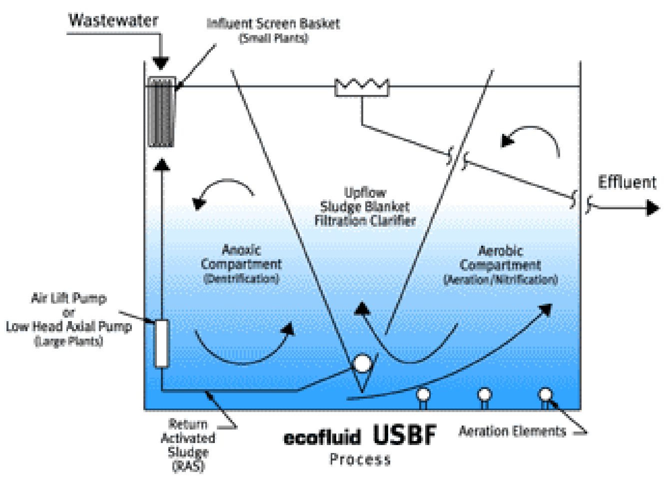


Figure 7-10

Diagram of the USBF reactor by Ecofluid Systems (left) and photograph of the USBF reactor before installation (right). (Adapted from Ecofluid Systems, Inc.)

Contact

Ecofluid Systems, Inc.
101-366 East Kent Ave. South
Vancouver, BC, V5X 4N6 Canada
Phone (604) 662-4544
Fax (640) 662-4564
E info@ecofluid.com
Web www.ecofluid.com

Clearwater, Inc.
3685 Stilesboro Rd
Kennesaw, GA 30144
Phone (770) 427-7091

7-1.18 Whitewater wastewater treatment systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems, cluster systems

Background
The Whitewater extended aeration treatment systems are modular treatment units with an internal cone shaped clarifier design.

Description of process
Wastewater enters the aeration chamber and is mixed with air which is pumped to the bottom of the tank and released through air diffusers. A portion of the water in the aeration chamber is directed into the internal cone clarifier and after settling flows out of the system. Settled sludge is returned into the aeration chamber.

Performance
NSF certified for production of secondary quality wastewater with an average effluent concentration of BOD_5 and TSS of 6 and 7 mg/L, respectively (NSF, 2000). The results from an independent study at a residential application in New Mexico are presented in Table 7-6. Additional treatment of effluent from the Whitewater system in a sand biofilter has resulted in a higher quality effluent, often with BOD_5 and TSS concentrations of less than 5 mg/L, and TN less than 10 mg/L.

Table 7-6
Selected representative studies of Whitewater system performance

Parameter	Unit	Location of study Bernalillo County, NM[a]
Description of system		Demonstration site
HLR	gal/d	161.8
System performance[b]		
BOD_5	mg/L	36.9 (89%)
COD	mg/L	181.9 (81%)
TSS	mg/L	8.4 (99%)
TN	mg/L	14.2 (77%)
Ortho-P	mg/L	1.5 (69%)
Fecal coliform	CFU/100 mL	2.7E4 (1.3)

[a] Hanson *et al*. (2002)
[b] Performance reported as average effluent concentration with average percent removal reported in parentheses. Fecal coliform removal is reported in log units.

Operation and maintenance
Standard inspection and maintenance of mechanical devices (air pump). Periodic sludge removal from the aeration tank will eventually be needed.

Contact
Delta Environmental Products
P.O. Box 969; 8275 Florida Blvd.
Denham Springs, LA 70726
Phone (800) 219-9183; (225) 665-166
Web www.deltaenvironmental.com

Model description

DF40 (400 gal/d)
DF50 (500 gal/d)
DF60 (600 gal/d)
DF40 (400 gal/d)
DF75 (750 gal/d)
DF100 (1000 gal/d)
DF150 (1500 gal/d)

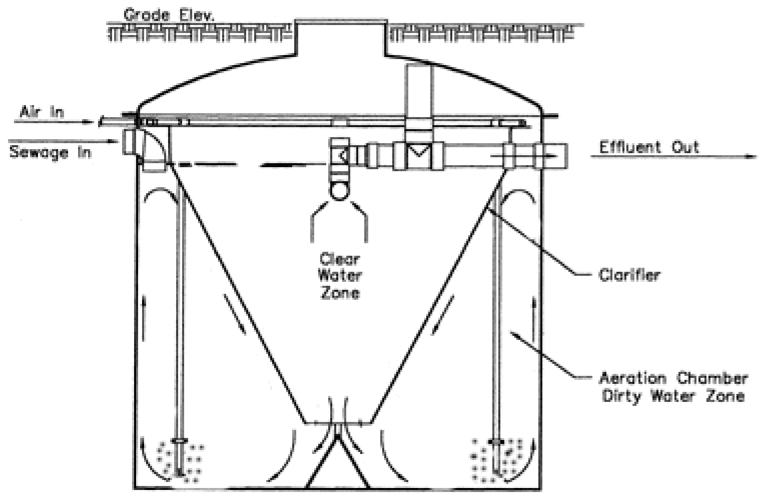


Figure 7-11

Diagram of the Whitewater treatment system. (Adapted from Delta Environmental Products, Inc.)

References and other resources

Hanson, A., W. Zachritz, R. Polka, Luz-Elna Y. Mimbela, and B. Thomson (2002) Alternative Small-Flow Wastewater Technologies in the Aird Southwest, *Small Flows Quarterly*, Vol. 3, No. 3, Morgantown, WV.

NSF (2000) *Final Report on the Whitewater Wastewater Treatment System*, NSF International, Ann Arbor, MI.

7-2 Sequencing batch reactors

Sequencing batch reactors (SBRs) utilize the activated sludge process for the treatment of wastewater. The basic process is composed of four steps, a volume of wastewater, i.e., batch, is (1) collected, (2) aerated/treated, (3) settled, and (4) discharged. Batch treatment processes typically use the same tank for aeration and clarification. Some systems take advantage of the fluctuating redox conditions to facilitate denitrification.

7-2.1 ABJ ICEAS™

Category	Primary and secondary treatment
Technology	Sequencing batch reactor, aerated suspended growth
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Community/municipal treatment systems.

Background
The ICEAS process is an intermittent decant process, not a true sequencing batch reactor. The intermittent decant process is believed to have several advantages over the conventional SBR. The ABJ ICEAS process is typically applied for the treatment of wastewater from communities.

Performance
Expected high levels of nitrogen and phosphorus removal.

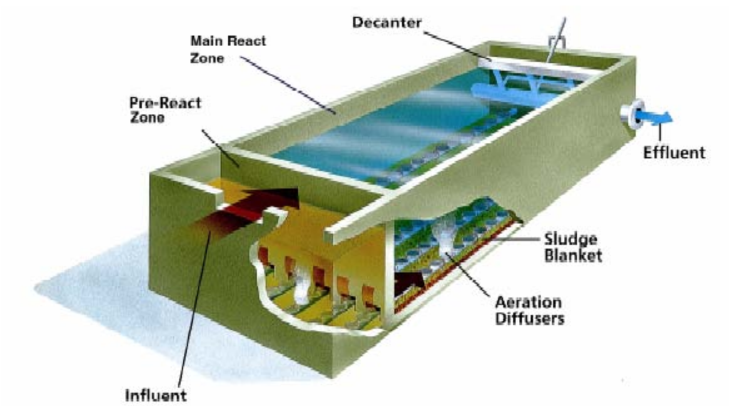


Figure 7-12

Diagram of the ABJ ICEAS wastewater treatment system.
(Adapted from Sanitaire, Inc.)

Contact
Sanitaire Inc.
9333 N. 49th Street
Brown Deer, WI 53223
Phone (414) 365-2200
Fax (414) 365-2210
E sanitaire@fluids.ittind.com
Web www.sanitaire.com

References and other resources
ABJ (2001) *Biological Treatment and the ICEAS Process*

7-2.2 Aquarobic International

Category	Primary and secondary treatment
Technology	Sequencing batch reactor, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential, cluster, community, and commercial systems

Background
Aquarobic International manufactures extended aeration SBRs and add-on attachments for the treatment of wastewater and enhanced nutrient removal from wastewater. Wastewater flows into the reactor and is aerated for a set amount of time. After aeration is complete, the aeration is stopped and the solids settle to the bottom of the reactor. After settling is finished, the supernatant is discharged from the system.

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000), additional performance

data reported in Table 7-7. Various add-ons are available from the manufacturer for enhanced nutrient removal.

Table 7-7
Selected representative studiesof Aquarobic Miniplant performance

Parameter	Unit	Location of study Virginia Tech[a]
Description of system		Demonstration site
HLR	gal/d	365
System performance[b]		
BOD_5	mg/L	8.5
TSS	mg/L	
TN	mg/L	43
NO_3-N	mg/L	43
NH_3-N	mg/L	0.2
TP	mg/L	6.6
Fecal coliform	CFU/100 mL	1820

[a] Reneau *et al*. (2001).
[b] Performance reported as average effluent concentration.

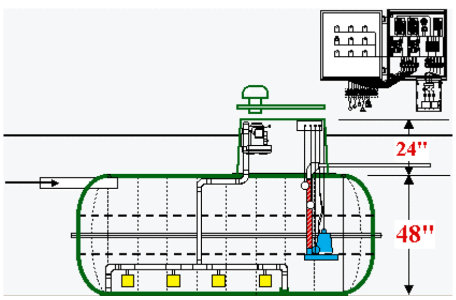


Figure 7-13
Diagram of the Aquarobic Mini Plant. (Adapted from Aquarobic International, Inc.)

Contact
Aquarobic International Inc.
508 Kendrick Lane
Front Royal, Virginia 22630
Phone   (540) 635-5200
Fax   (540) 635-2277
Web   aquarobicinternational.com
Model description
  Mini-plant (500 to 5000 gal/d)
  Maxi-plant (to 15,000 gal/d)

References and other resources

Reneau Jr. RB, C Hagedorn, AR Jantrania (2001) Performance Evaluation of Two Pre-Engineered Onsite Treatment and Effluent Dispersal Technologies, in *Proceedings of the 9th National Symposium of Individual and Small Community Sewage Systems* - 2001, Fort Worth, TX, American Society of Agricultural Engineers, pp. 271-280, St. Joseph, Michigan.

NSF (2000) Final Report Aquarobic International Miniplant, NSF International, Ann Arbor, MI.

7-2.3 Cromaglass wastewater treatment systems

Category	Primary and secondary treatment, optional disinfection
Technology	Sequencing batch reactor, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background

The Cromaglass batch treatment system has been installed in every state and in many other countries. The process is housed in a fiberglass tanks and available in various sizes depending on design flow rate and application. The Cromaglass system has been used in water recycling/reuse (irrigation and toilet flushing) situations and at sites with limiting conditions. Cromaglass also manufactures chlorine contact basins, equalization basins, and sludge processing facilities. Systems are installed and serviced by local representatives.

Description of process

Wastewater flows into a three chambered tank. The first section of the tank is for primary settling/grit removal. The wastewater flows through a screen into the aeration section. Aeration is accomplished with an aspirating pump. After aeration (based on process control/timer settings), the contents of the aeration tank are discharged to the clarifier for settling and discharge. Sludge is returned to the aeration tank.

System footprint

Unit has length of 7 ft 11 in and diameter of 5 ft 7 in. Effluent management depends on characteristics of receiving area. If acceptable, effluent may be discharged to soil treatment system such as drip irrigation. Cromaglass has experience with various configurations for wastewater reuse.

Advantages

Effective treatment process. Capable of high nitrogen removal. Process performance documented in multiple studies. Unit is modular and compact.

Disadvantages

Treatment systems requires electricity for proper operation. Periodic sludge removal may be needed. Service contract needed to insure long term operation.

Performance

Although not specifically NSF approved, treatment system has been evaluated independently under NSF guidelines. Typical effluent concentrations of BOD_5 and TSS less than 10 mg/L. System can also be operated in nitrogen reduction mode and often attains effluent nitrogen concentrations less than 5 mg/L.

Figure 7-14

Cromaglass treatment system using multiple units anchored to concrete pad to prevent flotation. (Adapted from Cromaglass Co.)

Operation and maintenance
Basic system operations are controlled through a logic controller and float switches. Using telemetry, Cromaglass is able to provide online (24 h) monitoring. Standard inspection and maintenance of mechanical devices (submerged pumps, control panel, float switches). Sludge removal will be needed on a periodic basis.

Power and control
System includes control panel, float switches, and submerged pumps. Estimated annual power usage is 3,000 kWh.

Cost
$5,000 to 6,000 includes capital costs for treatment unit and necessary components

Contact
Cromaglass Corporation
P.O. Box 3215; 2902 N. Reach Rd.
Williamsport, PA 17701
Phone (570) 326-3396
Fax (570) 326-6426
Web www.cromaglass.com
Model description

CA-5 to CA-150 for flow rates ranging from 500 to 150,000 gal/d. Can also be used in parallel for larger flow rates.

References and other resources
Cromaglass (2001) Company product brochure and materials package.

7-2.4 EnviroSBR™

Category	Primary and secondary treatment
Technology	Sequencing batch reactor, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Note: process description and data not available

Contact
Earthtek Environmental Systems, Inc.
204 South Street
Batesville IN 47006
Phone (800) 934-5044
Fax (812) 934-5018
Web www.earthtekonline.com

7-2.5 Nitro Raptor™

Category	Primary and/or secondary treatment
Technology	Sequencing batch reactor, aerated suspended growth
Input	Untreated wastewater (raw) or primary effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The Nitro Raptor is an extended aeration, sequencing batch reactor treatment process designed for nitrogen reduction. Limited information has been obtained on this system.

Performance
The 7-H treatment was evaluated at the Ventura Regional Sanitation District Demonstration Project, the results from this study are presented in Table 7-8.

Contact
7-H Technical Services Group
431 Crown Point Circle
Grass Valley
Phone (530) 271-1600 x106
Fax (530) 271-1840

Table 7-8
Selected representative studies of Nitro Raptor performance

Parameter	Unit	Location of study: Ventura, CA[a]
Description of system		Demonstration site[b]
HLR	gal/d	365
System performance[c]		
BOD_5	mg/L	27 (85%)
TSS	mg/L	42 (81%)
TN	mg/L	16 (47%)
NO_3-N	mg/L	11.1
NH_3-N	mg/L	1.0
TP	mg/L	2.6 (19%)
Total coliform	MPN/100 mL	>1600
Fecal coliform	MPN/100 mL	>1600

[a] Results may not be representative because system was evaluated without the use of a pretreatment (septic) tank
[b] Ventura Regional Sanitation District (2001) Septic Tank Nutrient Removal Project
[c] Performance reported as average effluent concentration with average removal in parentheses, where applicable

References and other resources
Ventura Regional Sanitation District (2001) Septic Tank Nutrient Removal Project, Advanced Onsite Sewage Disposal System Demonstration.

7-2.6 SYBR-AER™

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater (raw)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The SYBR-AER process is an extended aeration batch treatment process.

Description of process
Wastewater flows into the single compartment tank and a set aeration schedule is applied. After aeration is complete, mixing is stopped and the process water is settled. After the settling period, the supernatant is discharged from the process.

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000).

Contact
Alternative Wastewater Systems, Inc.
1240 Lyon Road
Batavia, IL 60510-1389
Phone (630) 761-8720
Model description
    500 to 1,500 gal/d

References and other resources
NSF (2000) *Final Report Alternative Wastewater Treatment System, SYBR-AER 500 (and SYBR 600 to 1,500 gal/d)*, NSF International, Ann Arbor, MI.

7-2.7 Thomas TRD1000

Category	Primary and secondary treatment, disinfection
Technology	Sequencing batch reactor, aerated suspended growth
Input	primary effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The TRD1000 is a computer controlled extended aeration treatment process.

Description of process
Primary effluent flows into the batch treatment reactor and is exposed to anaerobic and aerobic processing. A portion of the batch is returned to the anoxic tank for additional nitrogen removal. After settling, the clarified water is discharged to a filtration and UV disinfection process.

Performance
NSF certified for production of secondary quality wastewater (NSF, 2000).

Operation and maintenance
Systems are fitted with telemetry system for continuous monitoring in addition to standard 6 mo inspection.

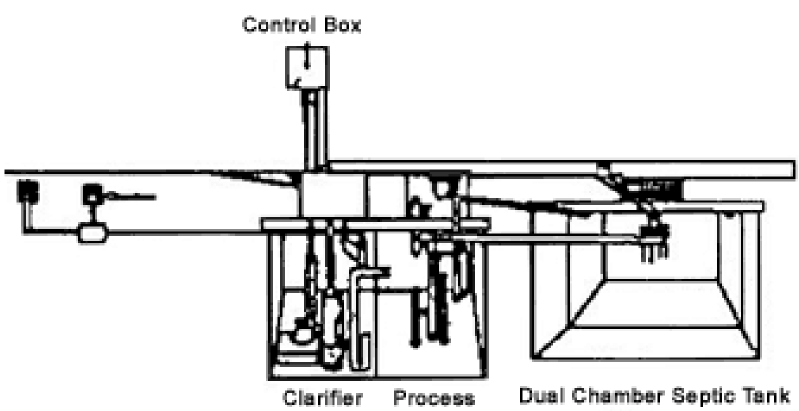


Figure 7-15
Diagram of the TRD1000 SBR. (Adapted from Thomas, Inc.)

Contact
Thomas, Inc.
8000 Parker Rd
Sedro Woolley, WA 98284
Phone (360) 856-0550
Fax (360) 856-0551
Web www.trd1000.com

References and other resources
NSF (2000) Final Report Wastewater Treatment System, NSF International, Ann Arbor, MI.

7-3 Membrane bioreactors

A membrane bioreactor is composed of a membrane filtration system submerged in an activated sludge tank. A vacuum applied to the membrane draws water through, excluding oversized wastewater particles and large molecules. Water that passes through the membrane is discharged as effluent from the system. Membrane bioreactors produce a high quality effluent that is often utilized for reuse applications, however, the cost of these systems may be restrictive.

7-3.1 Kubota

Category	Primary and secondary treatment
Technology	Membrane bioreactor, aerated suspended growth
Input	Settled wastewater, septic tank effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Note: process description and data not available.

Contact
Kubota
3401 Del Amo Blvd.
Torrance, CA 90503
Phone (310) 618-6932
Web www.kubota.co.jp/english/division/envi2.html

7-3.2 ZenoGem™ and Cycle-Let™

Category	Primary, secondary, tertiary treatment
Technology	Membrane bioreactor, aerated suspended growth
Input	Primary treated water
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems, water reuse/recycling

Background
The membrane bioreactor developed by Zenon offers are unique treatment process for the recovery and reuse of wastewater. Membrane modules (ZeeWeed) are submerged in a typical aerated processing tank. The influent primary treated wastewater is aerated and then drawn through the membrane. This permeate water is amenable to tertiary filtration, disinfection, and non-potable reuse.

Performance
Expected effluent concentrations of BOD_5, TSS, and TN less than 5 mg/L, TP less than 1 mg/L, and FC less than 2.2 CFU/100mL.

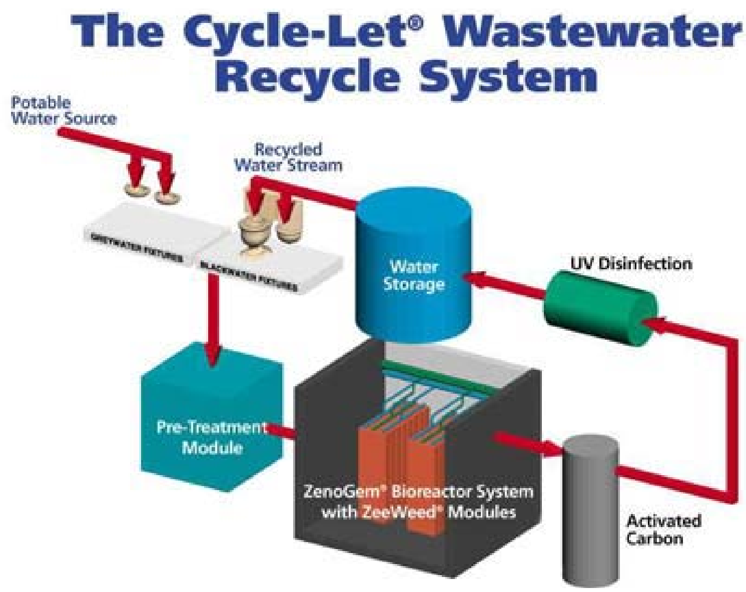


Figure 7-16

The Zenon Bioreactor system used for wastewater reuse applications.
(Adapted from Zenon Environemental, Inc.)

Contact

ZENON Environmental Inc.
3239 Dundas Street West
Oakville, Ontario L6M 4B2 Canada
Phone (905) 465-3030
Fax (905) 465-3050
Web www.zenonenv.com

Zenon West (Industrial WWT)
5051 Commercial Circle, Suite B
Concord, CA 94520
Phone (925) 246-8190; (858) 486-7555
Fax (925) 246-8199

References

Rosenberg, S., U. Kruger, R. Witzig, W. Manz, U. Szewzyk, and M. Kraume (2002) Performance of a bioreactor with submerged membranes for aerobic treatment of municipal wastewater, *Water Research*, Vol. 36, pp. 413-420.

CHAPTER 8
COMBINED SUSPENDED AND ATTACHED GROWTH AEROBIC TREATMENT SYSTEMS

Combined processes are a hybridization of the activated sludge and attached growth systems, including packed beds, suspended carrier materials, and rotating biological contactors. In general, having an fixed film component has a buffering effect in the event of a process disturbance. Process disturbances may include extreme hydraulic overloading, discharge of toxic compounds into the system, or aeration system malfunction.

Types of processes
The principle types of processes may be classified as (1) Continuous flow suspended growth with fixed internal packing, (2) Continuous flow suspended growth with suspended internal packing, (3) Sequencing batch reactors with internal packing, and (4) Rotating biological contactor.

Continuous flow suspended growth with fixed internal packing
Wastewater moves through the system by hydraulic displacement, i.e., as water is discharged into the system, an equal volume flows out of the system. The fixed internal packing is generally a plastic matrix material designed to maximize fixed film microbial growth and contact with wastewater to be treated. In many cases, the aeration system is integrated with the fixed packing to achieve unique flow patterns.

Continuous flow suspended growth with suspended internal packing
Suspended packing materials can be designed to float or sink, depending on the specific process material. The attached growth moves throughout the water column in the treatment process, increasing the overall contact with the wastewater. The suspended packing is generally circulated in the aeration tank by currents induced by the aeration device.

Sequencing batch reactors with internal packing
In the sequencing batch reactor, wastewater is stored in the reaction chamber of the treatment system until a sufficient volume (a batch) is collected, at which point the treatment process begins. The batch of wastewater is seeded with an active bacterial culture (affixed to the support medium) and aerated for the treatment period. After the reaction is complete, aeration and mixing are stopped, and the flocculated bacteria and other solid particles settle out. The clear layer (supernatant) is discharged from the reaction chamber, and the next batch of wastewater to be treated begins to flow into the reaction chamber. The fill, react, settle, discharge cycle is repeated continuously.

Rotating biological contactors
A rotating disk is partially submerged in a flow through reactor. The attached microbial community is exposed to the wastewater with each revolution of the disk. The process is optimized by adjusting the speed of rotation and the depth of submergence.

System components
Important components of combined aerobic suspended and attached growth treatment systems are the reactor (container), the aeration and mixing devices, the medium used for microbial attachment, the outlet structure, and the control system. Each of these components is discussed below.

Container
The process tank is generally divided into three compartments, the primary separation chamber, the aeration chamber, and the settling chamber. Some systems accomplish primary treatment in a standard septic tank, making them suitable for upgrading sites that already have an existing septic system. The primary separation chamber is designed to separate settable and floatable

substances from the influent wastewater. The primary separation compartment should be designed to have a capacity to retain materials that may interfere with downstream processes. The aeration chamber is designed to provide sufficient volume for contact between the wastewater and the microbial biomass. The distribution of the fixed film media, placement of the aeration device, and hydraulic flow paths are important criteria for effective treatment. Clarification is the separation of wastewater solids (particles and microbial cells) from the treated water. The secondary settling chamber is used for clarification of the wastewater and should be sized to provide adequate detention time for secondary separation before discharge of the treated water.

Attached growth media
The two basic types of configurations for the attachment of the microbial community are suspended packing and fixed packing. Suspended packing is generally made from a polymer that will remain buoyant in the treatment process. In case of a disruption in the aeration process, the buoyant packing will float to the surface of the liquid and remain partially aerobic. Fixed packing is typically a submerged bed of sand or synthetic media.

Aeration and mixing devices
Mixing and aeration are, in most cases, accomplished by the same device. Generally, air is delivered to the bottom of the aeration tank and released through a diffusing mechanism to increase the surface area and, thus, oxygen transfer efficiency, to the aerobic treatment process. As the air bubbles move up the water column, oxygen is consumed, and the contents of the tank are mixed. Important factors to be considered for the aeration mechanism are the (1) maintenance requirements, (2) expected lifespan and reliability, (3) noise generated during operation, (4) access to the device, and (5) durability under adverse conditions. The common types of aeration and mixing devices are presented in Table 8-1. Because these treatment processes are aerobic, the device or method used to compress and deliver air to the aeration tank is a critical element.

Table 8-1
Mixing and aeration devices used for onsite wastewater treatment systems

Device	Description
Air diffusers	Air diffusers are porous fixtures located in the aeration tank. Compressed air is pushed through the holes in the diffuser, causing the formation of discrete air bubbles. The compressed air may be supplied by a diaphragm, rotary vane, or piston pump (rated for continuous use).
Aspirators	Aspirators have a small impeller located below the end of a submerged hollow shaft (draft tube), when the impeller and shaft are rotated, a vacuum is created that draws air down the draft tube and into the aeration tank and is simultaneously disperses by the impeller into the water.
Air lift pumps	The air lift pump operates by injecting air into the bottom of a vertical submerged column (hollow shaft). The air that is released moves up the column and forces water to move upwards with it, accomplishing aeration and mixing.

Outlet structures
The outlet is designed to release clarified, treated water from the treatment system. The outlet structure should be designed to keep residual particles from exiting with the process effluent. Commonly used devices are baffled outlet structures, outlet (effluent) filters, and floating and fixed overflow weirs.

Control systems
Process control is generally accomplished by float switches to monitor the water level, pumps to transfer water between processes, and timers to regulate the treatment process. Many systems

are incorporating programmable logic controllers to make the treatment process more adaptable to the challenges of onsite treatment.

Operational parameters

Operational parameters are used to define the system application. Most treatment processes are rated based on the daily hydraulic capacity for wastewater with an assumed composition. In some of the processes, the solids retention time (SRT) is also used as a control parameter. Because onsite treatment systems are often exposed to highly variable loading, processes are often oversized. A robust treatment process should provide design performance under a range of adverse loading conditions. The parameters used to categorize system operation include the loading rate, retention time, surge capacity, aeration characteristics, flow configurations, and process failure.

Retention time

Each process within a treatment process has a liquid retention time based on the effective volume of the process and the expected hydraulic loading rate (HLR). The various treatment processes and the importance of proper retention time are presented in Table 8-2. Most aerated onsite treatment processes are based on the concept of extended aeration to reduce the overall sludge volume, due to the difficulty in regular removal this material.

Table 8-2

Treatment processes and the importance of design retention time

Treatment process	Importance
Primary	Primary treatment processes require liquid retention time to accomplish solids separation from the water to be treated. If hydraulic overload occurs, solids may be carried over into subsequent processes, reducing the overall effectiveness of the treatment process.
Aeration	Contact time in the aeration cycle is needed to ensure design oxidation of the process water. If the water is not in the aeration process for a sufficient length of time, the effluent discharged may have an increased BOD or ammonia concentration.
Secondary	Secondary processing is designed to separate the biomass and other suspended materials from the wastewater to be discharged. If not given enough time for settling, these solids will be discharged with the wastewater and may interfere with downstream processes. Outlet filters have reduced the possibility of inadvertent solids discharge.
Solids	The solids retention time (SRT) is related to the length of time that the microbial biomass is kept in the treatment process. Because it is not realistic to remove solids from onsite treatment systems on a regular basis, they are often recycled back to the primary treatment process or the aeration process for digestion. Solids recycling is accomplished by allowing the settled solids to flow back into the aeration process by gravity or with a submerged pump that periodically activates and discharges the solids to a specified location.
Disinfection	For systems that incorporate a disinfection step, adequate contact time with the disinfectant needs to be ensured to accomplish design performance.

Loading rate

The loading rate is the flow of a material, such as liquid or a specific constituent, through the system. The HLR is often defined as the daily volume of wastewater that the system is able to process. The organic loading rate (OLR) is defined as the daily BOD_5 input to the system. For residential applications, the constituent concentrations for typical domestic wastewater are used to estimate the OLR. Activities that can effect the loading rate include (1) variable loading, (2) over loading, (3) extended periods of non-operation, (4) electricity outage, and (5) equipment failure.

Process failure
Process failure occurs when the treatment system discharges water with constituent concentrations that are above the acceptable limit as determined by the effluent management system. The causes of failure in aerated treatment processes are often caused by (1) inadequate maintenance of the treatment system, (2) discharge of toxic substances (such as chlorine) to the biological treatment system, and (3) failure of a component (such as an aeration device) needed for proper operation. Of these, proper maintenance is believed to be the most important aspect of long-term success of onsite treatment systems.

Monitoring and maintenance
The ongoing monitoring and maintenance of aerated treatment systems is important for keeping these devices operating as designed. Monitoring and maintenance activities should be conducted regularly by a certified individual.

The system components that should be inspected include the aeration device, the packing materials (if applicable), the inlet and outlet structures, pumps, and the air diffusers. Additional components may also need servicing as determined by the manufacturer. The system components and standard maintenance needs are presented in Table 8-3.

Table 8-3
Recommended maintenance activities for aerated treatment systems

Component	Typical maintenance needs
Aeration device	Check air filters and clean if necessary. Also check oil seals, noise level, abnormal vibration, and heating output.
Packing	Check media for debris or solids accumulation. Check for ponding and clogging of any associated component and clean as necessary.
Inlet and outlet structures	Remove floating debris and scum that accumulates around outlet structures.
Process tanks	Check for excessive solids accumulation and remove as needed.
Pumps	Confirm that pumps are operating correctly.
Diffusers	Inspect diffusers for solids buildup and clean as necessary.
Timers	Check system timers and other control devices for correct settings as determined by manufacturer or system installer.
Float switches	Observe float switches to confirm proper operation.
Alarms	Confirm that alarms are functioning.
Effluent quality	Qualitative assessment of odor, color, and turbidity. Qualitative assessment may depend on the discharge location and can include BOD, TSS, nitrogen, phosphorus, and fecal coliform bacteria.

8-1 Continuous flow suspended growth with fixed internal packing
Submerged, aerated, packed beds that are used in aerated continuous flow systems. The stationary packed bed is available as a package system or as a supplement to the conventional septic tank.

8-1.1 Bio-fosse™

Category	Primary and secondary treatment
Technology	Continuous flow, aerated attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and instituational systems

Background

Treatment system utilizes a patented material (Biotex™) for attached growth.

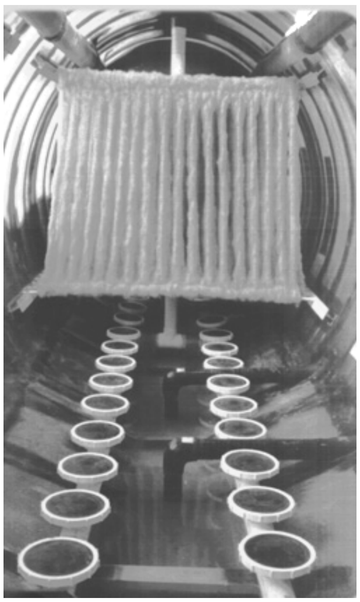


Figure 8-1

Biotex material placed inside Bio-fosse aeration chamber. (Adapted from Bioflo, Inc.)

Contact

Bioflo, Inc
2186 de la Province
Longueuil (Québec) Canada
Phone (450) 463-3388
Fax (450) 463-3711
E Info@bioflo.ca
Web www.bioflo.ca
Manufacturer support
10 year manufacturer warranty on Biotex material

8-1.2 Biomax

Category	Primary and secondary treatment
Technology	Continuous flow, aerated attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Background
The Biomax system is a self contained treatment unit that utilizes a proprietary suspended growth media known as Ringlace™. The units are approved for use in Washington; however, limited information has been obtained at this time.

Description of process
The Biomax treatment process makes use of anaerobic and aerobic chambers packed with media for attached biological growth and a clarifier for solids removal (chlorine disinfection unit optional).

Figure 8-2
The Biomax treatment unit prior to installation.
(Adapted from Biomax Systems, Inc.)

Contact
Brightwater Engineering Ltd.
Brightwater House, Unit 2, Business Centre East
Avenue One, Letchworth, Herts SG6 2HB
Phone 01462 485 005
Fax 01462 485 003
E enquiries@brightwater.uk.com
Web www.bordnamona.com/environmental/

8-1.3 BioSorb™ advanced wastewater treatment systems

Category	Secondary treatment, ozonation
Technology	Continuous flow, aerated attached growth
Input	Primary effluent (e.g., septic tank effluent)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Background
The BioSorb system is a prefabricated aerobic digester with an aerated attached growth medium. The process incorporates ozonation of effluent for water reuse (e.g., subsurface irrigation) purposes.

Operation and maintenance
Air compressor and ozone disinfection units both require maintenance.

Contact
RGF Environmental
3875 Fiscal Court
West Palm Beach, FL 33404
Phone   (800) 842-7771
Fax   (888) 848-0047
E   rgf@rgf.com
Web   www.rgf.com
Model description
Flow rates from 500 and larger.

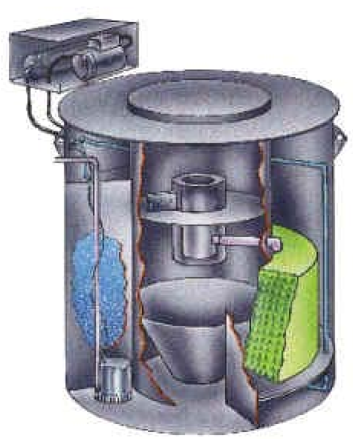


Figure 8-3
A cut-away illustration of the Biosorb treatment unit. (Adapted from RGF Environmental, Inc.)

8-1.4 BTX Biotreater™ systems

Category	Secondary treatment
Technology	Continuous flow, aerated
Input	Primary treated wastewater
Function	Oxidation, nutrient transformation
Applications	Community, commercial, and industrial

Background
The BTX Biotreater system is a biological reactor with a corrugated fixed internal packing for attached growth. The system is designed for treatment of wastewater and contaminated groundwater.

Contact
Bioscience, Inc.
1550 Valley Center Parkway
Bethlehem, PA 18017
Phone   (610) 974-9693
Fax   (610) 691-2170
E   bioscience@bioscience.com
Web   www.bioscience.com
Model description
Wastewater treatment systems for flow rates from 2,500 (7 lb BOD/d) to 225,000 gal/d (470 lb BOD/d).

8-1.5 EcoKasa wastewater treatment systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Background
The EcoKasa system is a fixed bed attached growth reactor. System sizes ranges from serving an individual house to a large community. The system incorporates a unique sand filtration mechanism to reduce effluent suspended solids.

Operation and maintenance
Includes an air compressor that will require maintenance. Accumulated sludge may need to be removed periodically.

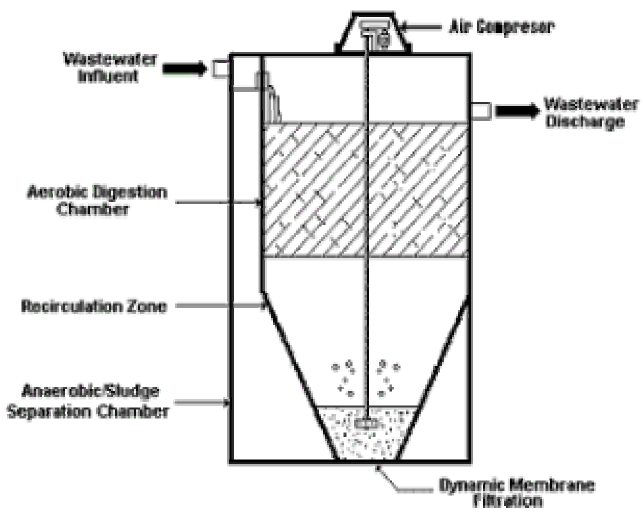


Figure 8-4
Diagram of the EcoKasa treatment system. (Adapted from EcoKasa, Inc.)

Contact
EcoKasa, Inc.
14910 Welcome Lane
Houston, Texas 77014
Phone (281) 580-7591
Fax (281) 880-9498
Web www.ecokasa.com
Model description
EcoKasa I
EcoKasa II
EcoKasa 1MP

8-1.6 FAST wastewater treatment systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended/attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Recommended for individual, small community, and commercial systems. Offer alternate systems for advanced nitrogen and phosphorus removal, lagoons, and retrofits to existing systems.

Background
Bio-Microbics Inc. offers wastewater treatment systems for single family residences. The units are composed of a septic tank, fixed film media, and an air supply. Bio-Microbics also provides systems for applications such as lagoon treatment (LagoonFAST), retrofitting existing septic systems (RetroFAST), enhanced nitrification (NitriFAST), enhanced clarification (ABC-C), advanced nitrogen removal (ABC-N), and advanced phosphorus removal (ABC-P). Smith & Loveless custom design systems using the FAST technology for larger applications.

Description of process
The basic residential FAST system consists of a fixed-film media which is submerged in the second compartment of a modified, two-compartment septic tank. Air is supplied to the fixed-film process by a remote blower. Alternate modes of operation include recirculation of nitrified wastewater to the primary settling chamber for denitrification and intermittent operation of the blower to reduce electricity usage and increase denitrification.

System footprint
The system is integrated into a standard septic tank and therefore does not require additional space. The blower is generally located above grade in an area that will not be flooded or below grade in a vault (2 ft x 2 ft x 2 ft). The effluent meets secondary quality requirements and can be distributed to soil treatment system or disinfected for surface irrigation.

Performance
The Bio-Microbics FAST system has been evaluated in numerous research studies, as reported in Table 8-4. Depending on the treatment objectives, various systems are available for advanced nitrogen and phosphorus removal using chemical addition.

Advantages
The treatment unit can be installed in a standard septic tank. The space requirements are not greater than a standard septic tank. Performance data for the FAST system is available from multiple studies.

Disadvantages
Requires the use of a blower to supply air to the treatment process.

Operation and maintenance
The FAST systems incorporate a blower that will need periodic monitoring. The air intake filter for the blower will need to be cleaned. The blower is equipped with an alarm to signal in the event that the blower malfunctions. Sludge removal will also be needed on a periodic basis, approximately every one to three years.

Power and control
Annual electrical needs expected to be 2,000 to 3,000 kWh.

Cost

Basic system (MicroFAST 0.5) costs $3,000, and includes the capital cost for the FAST system, blower, blower housing, and control panel.

Table 8-4

Selected representative studies of Bio-Microbics FAST system performance

		Location of study			
Parameter	Unit	Ventura CA[a]	Mass[b]	Florida[c]	Rhode Island[d]
Description of system		Demonstration	Demonstration	Test facility	Home system
HLR	gal/d	365	330	307	214
System performance[e]					
BOD_5	mg/L	13 (93%)	18 (90%)	3.7 (97%)	15
TSS	mg/L	5.9 (97%)	12 (92%)	3.9 (96%)	9
TN	mg/L	20.4 (34%)	15.5 (55%)	11.5 (76%)	20
NO_3-N	mg/L	15		10.34	
NH_3-N	mg/L	1.2			
P	mg/L	2.7 (16%)		6.62 (24%)	
Fecal coliform	MPN/100 mL	>1600	5E4 (1.6)		2E4

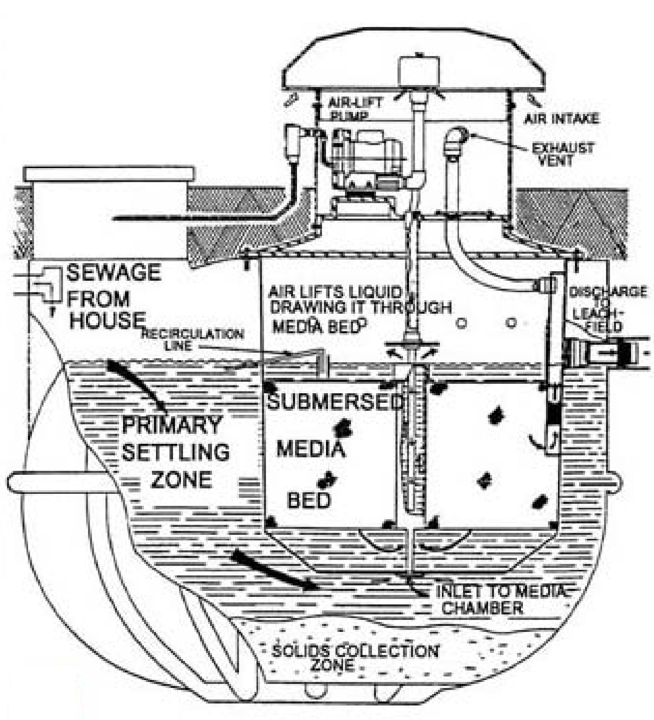
[a] Loomis *et al*. (2001); note operation was modified to evaluate reduced blower operation, resulting in higher effluent concentrations than under normal operating conditions.

[b] Ventura County Sanitation District (2001)

[c] Massachusetts Alternative Septic System Test Center (2001)

[d] Florida Department of Health (2000)

e Performance reported as average effluent concentration with average removal in parentheses, except microorganism removal, which has logs of removal reported in parentheses.



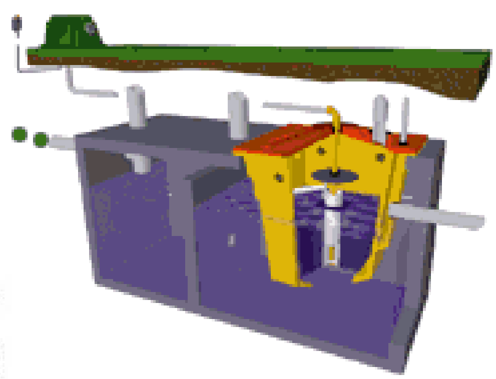


Figure 8-5

Cut-away illustration (left) and diagram (right) of the BioMicrobics MicroFAST 0.5. (Adapted from BioMicrobics, Inc.)

Contact

Bio-Microbics, Inc.
8450 Cole Parkway
Shawnee, KS 66227
Phone (913) 422-0707; (800) 753-FAST
Fax (913) 422-0808
E onsite@biomicrobics.com
Web www.biomicrobics.com

Model description

- MicroFAST 0.5, 0.9, 1.5, 3.0, 4.5, 9.0 (for domestic wastewater flows from 500 to 9000 gal/d)
- HighStregnthFAST 1.0, 1.5, 3.0, 4.5, 9.0 (for commercial wastewater flows from 1000 to 9000 gal/d)
- RetroFast 0.25, 0.375 (for existing standard septic systems with wastewater flows from 250 to 375 gal/d)
- LagoonFast 1.5, 3.0, 4.5, 9.0 (for lagoon treatment systems with flows from 1500 to 9000 gal/d)
- NitriFAST 0.5, 1.0, 1.5, 3.0, 4.5, 9.0 (for nitrification of high nitrogen wastewater with flows from 500 to 9000 gal/d)
- ABC-C 0.5, 1.0, 1.5, 3.0, 4.5, 9.0 (for clarification of wastewater with flows from 500 to 9000 gal/d)
- ABC-N 0.5, 1.0, 1.5, 3.0, 4.5, 9.0 (chemical addition for advanced removal of nitrogen from wastewater with flows from 500 to 9000 gal/d)
- ABC-P 0.5, 1.0, 1.5, 3.0, 4.5, 9.0 (chemical addition for advanced precipitation of phosphorus from wastewater with flows from 500 to 9000 gal/d)

Manufacturer support

Bio-Microbics manufactures an assortment of systems that are based on a patented process for wastewater treatment. The systems are distributed and installed by approved organizations. Bio-Microbics provides equipment and controls for the gravity based systems, additional pumps and components for other configurations obtained locally. Company covers materials and workmanship for two years from date of installation or three years from date of shipment.

Smith & Loveless, Inc.
14040 Santa Fe Trail Drive
Lenexa, KS 66215-1284
Phone 913-888-5201
Fax 913-888-2173
E answers@smithandloveless.com
Web www.smithandloveless.com
Model description

Smith & Loveless offer the Modular FAST system for larger flows (>10,000 gal/d), serving domestic, commercial, and industrial needs.

References and other resources

Anderson, D.L., M.B. Tyl, R.J. Otis, T.G. Mayer, and K.M. Sherman (1998) Onsite Wastewater Nutrient Reduction Systems (OWNRS) for Nutrient Sensitive Environments, *Proceedings of the Eight National Symposium on Individual and Small Community Sewage Systems*, Orlando, FL.

Bio-Microbics (2001) Manufacturer information.

Loomis, G.W., D.B. Dow, M.H. Stolt, L.T. Green, and A.J. Gold (2001) Evaluation of Innovative Onsite Wastewater Treatment Systems in the Green Hill Pond Watershed, Rhode Island – A

NODP II Project Update, *Proceedings of the Ninth National Symposium on Individual and Small Community Sewage Systems*, Fort Worth TX.

Massachusettes Alternative Septic System Test Center (2001) Technology Fact Sheet Interim Findings, MicroFAST Model 0.5.

Florida Department of Health (2000) *Florida Keys Onsite Wastewater Nutrient Reduction Systems Demonstration Project – Phase II Addendum*, Florida Department of Health.

NSF International (1997) Report on Evaluation of Scienco/FAST Model 23-001-750, NSF International, Ann Arbor, MI.

Ventura Regional Sanitation District (2001) Septic Tank Nutrient Removal Project, Advanced Onsite Sewage Disposal System Demonstration.

U.S. EPA (2001) *CEIT Virtual Trade Show: Fast Wastewater Treatment Systems (available at www.epa.gov/region1/steward/ceitts/wastewater/techs/fast.html).*

8-1.7 JET BAT™

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Background

The JET 1500 Series treatment system is available in 5 models (500, 750, 1000, 1250, and 1500) serving flow rates from 500 to 1,500 gal/d. The J-500 and J-750 systems are single reactors divided into three sections. The J-1000, J-1250, and J-1500 models are composed or two separate tanks, a pretreatment tank (divided into two sections) and a treatment unit (divided into three sections. The J-500 model is described below.

Description of process

Household wastewater flows into the primary treatment section. As new water enters the system, an equal amount of water is displaced through the system. After sedimentation the liquid is aerated and exposed to the fixed packing and associated microbial community. The water is then settled in the clarification chamber and a fixed surface baffle keeps surface particles from flowing out in the effluent.

System footprint

The unit has a length of 10 ft, width of 5 ft, and depth of 5.75 ft. A standard soil treatment system is used for subsequent effluent management.

Advantages

All treatment occurs in single tank (for models J-500 and J-750). The fixed film media prevents washout of bacterial culture. There is only one mechanical component (aeration device).

Disadvantages

Limited performance data is available. Backup of wastewater into the unit (due to soil clogging or high water event) may damage the aeration device.

Performance

The Jet treatments systems J-500 through J-1500 have been certified under the NSF program. Additional performance data are provided in Table 8-5.

Operation and maintenance
The unit will need to have sludge removed periodically. The aeration device will need to be replaced upon failure (manufacturer offers a 20 year factory exchange on aeration unit). Other potential maintenance activities include media and tank cleaning, testing the circuit breaker, and checking the various system components.

Power and control
The only mechanical/electrical component is the aerator. Expected annual power usage is estimated to be 1,000 to 1,500 kWh.

Table 8-5
Reported performance of JET Model 500

		Location of study[b]
Parameter	Unit	Mass
Description of system		Pilot testing
BOD_5	mg/L	23 (88%)
TSS	mg/L	24 (88%)
TN	mg/L	25.6 (35%)
TP	mg/L	7.6 (17.4%)

[a] Performance reported as average effluent concentration with average removal in parentheses.
[b] U.S. EPA (2001).

Cost
The estimated cost for the model J-500 is $6,000 (residential application). An additional cost will be required for installation, shipping, and electrical work.

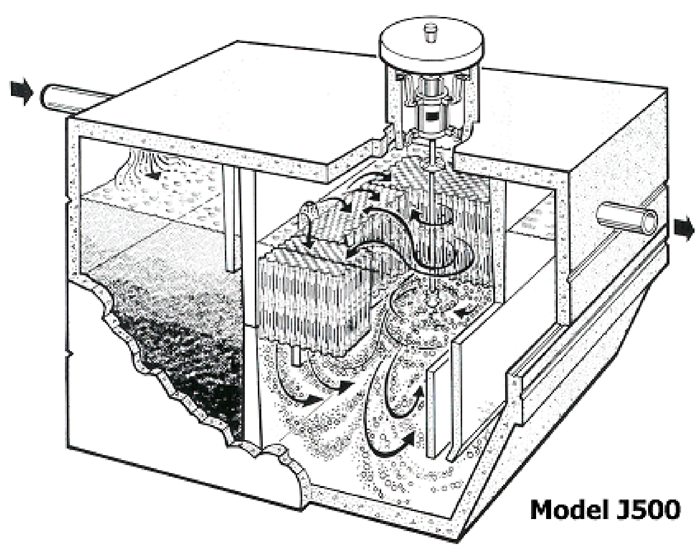


Figure 8-6
Cut-away illustration of the JET Model J-500 wastewat treatment system. (Adapted from Jet, Inc.)

Contact
JET, Inc.
750 Alpha Dr.
Cleveland, OH 44143
Phone (440) 461-2000
Fax (440) 442-9008

Model description
J-500 (500 gal/d)
J-750 (750 gal/d)
J-1000 (1000 gal/d)
J-1250 (1250 gal/d)
J-1500 (1500 gal/d)

Manufacturer support
JET recommends regular maintenance every six months. After installation, the JET distributor provides inspection and servicing for the treatment system for two years (included in the purchase price of unit) on a six month basis. Inspection includes confirming operation, cleaning, and effluent analysis. However, the service policy does not include sludge removal. JET recommends maintaining a service contract after the initial two-year agreement expires.

References and other resources
JET (2002) *Owner's Manual: 1500 Series Media Plants and All Other Models*, JET Inc., Cleveland, OH.

U.S. EPA (2001) *CEIT Virtual Trade Show: JET Aerobic Treatment System (available at www.epa.gov/region1/steward/ceitts/wastewater/techs/jetaerobic.html).*

8-1.8 Pirana

Category	Secondary treatment
Technology	Continuous flow, aerated attached growth
Input	Primary effluent
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual septic systems, failed systems

Background
The Pirana system is an aerated fixed film reactor that is submerged into the first or second chamber of an existing septic tank. In addition, the treatment system utilizes a bacterial culture to promote advanced digestion of wastewater solids.

Description of process
The fixed film reactor, submerged in a standard septic tank, receives air from a remote air pump. The system is inoculated with a microbial community that attaches to the medium and is suspended in the septic tank. Direct aerobic denitrification activity has been identified as resulting in exceptionally low effluent nitrogen. An outlet filter further protects the soil treatment system from high solids loading.

System footprint
A small watertight basin is used to house the air pump; otherwise the system does not require any additional space beyond a standard septic tank. The effluent can be distributed to a standard soil treatment system.

Advantages
The system fits into a standard septic tank with minimal site disturbance. Expected high level of treatment and manufacturers claims that sludge removal from the septic tank will not be needed.

Disadvantages
Operation requires the use of an air pump to supply air. Bacterial culture will need to be regenerated periodically (typically every 6 to 12 months).

Operation and maintenance
The air compressor will require standard maintenance. The specialty bacterial culture requires addition on regular basis (6 months). The manufacturer claims septic tank will not require sludge removal due to complete solids digestion in septic tank. The system should be inspected periodically to make sure all components are functioning correctly.

Power and control
Estimated annual power usage for air pump is 400 to 500 kWh.

Cost
System cost ranges from $3,000 to 4,000 for the Pirana unit and septic tank.

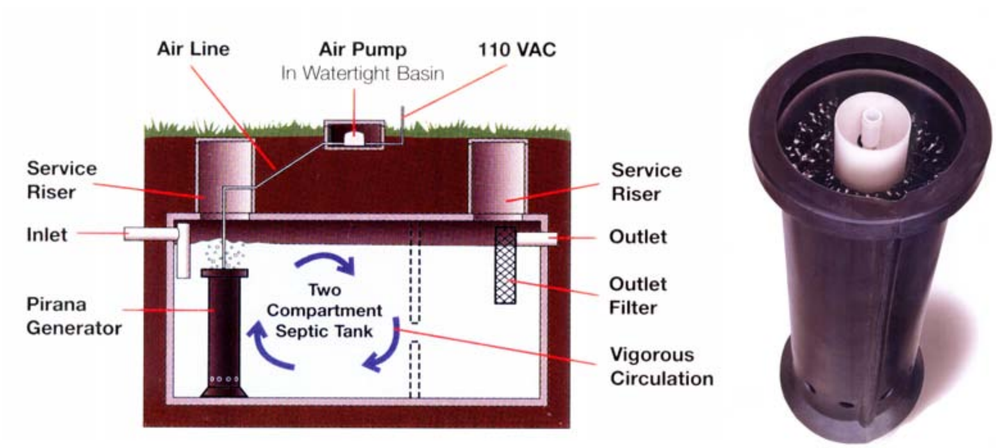


Figure 8-7

Diagram of the Pirana wastewater treatment system (left) and a photo of the Pirana generator (right). (Adapted from Pirana, Inc.)

Contact
Piranaco Company
Phone (707) 824-1170
Fax (707) 824-8154
E Pirana@monitor.net

8-2 Continuous flow with internal suspended packing
The continuous flow reactor can be equipped with a suspended packing. The suspended packing is used as a carrier for treatment organisms. The typical configuration is composed of a tank with two or more chambers. In the aeration chamber the suspended packing circulates with the water current. Many packing materials are designed to float to the surface when the water is not circulating, which may protect the aerobic organisms in the event of a power outage.

8-2.1 BioGreen™ wastewater treatment systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated fixed-film suspended growth
Input	Primary effluent (septic tank effluent)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual and cluster residential

Background
The BioGreen system was developed in Japan and has been used there for many years. The basis of the system is a series of aerated, fixed-film reactors. The treatment process uses air lift pumps to aerate and transfer the water between the various processes.

Description of process
After passing through the septic tank, wastewater passes through an upflow attached growth anaerobic (fermentation) reactor. After passing through the anaerobic reactor, the wastewater is exposed to a series of aerated suspended packing reactors. The effluent from the aeration chambers enters a secondary settling process and is then discharged to a soil treatment or alternate effluent management system.

System footprint
The treatment system requires an area of 50 ft^2 in addition to a standard septic system.

Advantages
The BioGreen system has provided effective treatment in long term performance studies.

Disadvantages
Operations requires an air compressor.

Performance
The BioGreen units have provided effective treatment as determined from effluent samples drawn at actual installations. Typical effluent characteristics are summarized in Table 8-6.

Table 8-6
Effluent quality from BioGreen unit after
4 years of operation (Enviroaccess, 1996)

Parameter	Unit	Influent	Effluent	Removal
BOD5	mg/L	152	3.9	97%
TN	mg/L	54.7	27.3	50%
TP	mg/L	7.32	4.83	34%

Operation and maintenance
Maintenance is recommended every six months, including quantitative effluent analysis and blower inspection. If needed, system can be backwashed to flush out accumulated solids. Air supply and effluent pumps inspected for proper operation. Sludge removal as needed.

Power and control
The air compressor (with low pressure alarm), level control and high water level switches, and systems alarms have an estimated annual electricity usage of 2,000 to 2,500 kWh.

Cost
The estimated cost for a residential system is $14,000 to 17,000. The cost includes septic system, air compressor, float switches, control panel, one year service contract, and chlorine

disinfection unit. The cost does not include installation, electrical needs, soil treatment system, taxes, engineering and permitting fees, or shipping.

Contact
BioGreen Systems (Pacific) Ltd.
11443 Kingston St
Maple Ridge BC V2X 0Y6 Canada
Phone (604) 460-0203
Fax (604) 460-0263
E biogreen@lynx.bc.ca
Model description
BG-2000 (400 gal/d)
BG-3000 (600 gal/d)
BG-4000 (800 gal/d)
Manufacturer support
The BioGreen systems includes the first year of maintenance in the purchase price of the unit, with an option to extend the service agreement after the first year.

References and other resources
Enviroaccess (1996) Environmental Technologies Fact Sheets: BioGreen, Center for Environmental Technologies, (available at www.enviroaccess.ca/fiches_3/FA3-01-96a.html).

8-2.2 Eco-Kleen™

Category	Primary and secondary treatment
Technology	Continuous flow, aerated attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Background/description of process
The Eco-Kleen process includes anaerobic and aerobic chambers packed with media for attached biological growth, a clarifier for solids removal, and a sand filter for effluent polishing.

Contact
Eco-Kleen Systems Inc.
6-12444 Harris Road; Pitt Meadows, BC
Belfair, WA 98528
Phone (604) 465-5911
Fax (604) 465-4380

8-2.3 EnviroServer™

Category	Primary and secondary treatment, disinfection, sludge processing
Technology	Continuous flow, aerated suspended and attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Residential, commercial, light industrial

Background
The EnviroServer system is a continuous flow system that includes features for sludge elimination, remote monitoring, and disinfection. The treatment units have been evaluated in several studies with excellent results. MicroSepTec ensures system operation by requiring a monitoring and management agreement for all systems.

Description of process

The EnviroServer unit is divided into four sections. The first compartment is for primary treatment and flow equalization. The second and third compartments contain a suspended packing material for attached growth. Aeration to the second and third compartments results in oxidation and nitrification of the process wastewater. The last compartment of the unit is for secondary clarification. Sludge from the secondary clarification compartment is returned to the primary treatment chamber with an intermittent recirculation pump. Secondary effluent flows through a tablet chlorinator and into a chlorine contact/pump basin.

System footprint

The standard household system is 14 ft long and 5 ft in diameter. Effluent is suitable for discharge to most soil based treatment/adsorption systems. Effluent may require dechlorination in some areas.

Performance

The performance of the EnviroServer system has been characterized through evaluation by NSF (2000), at UC Riverside by Wistrom and Matsumoto (1999), and by the Ventura Regional Sanitation District (2001). Performance specifications of representative research findings are presented in Table 8-7.

Table 8-7

Selected representative studies of MicroSepTec EnviroServer system performance

		Location of study		
Parameter	Unit	Ventura CA[a]	UC Riverside[b]	Manufacturer claim[c]
Description of system		Demonstration	10 week performance evaluation	Product brochure
HLR	gal/d	365	156	
pH	unitless		8	7.5
System performance[d]				
COD	mg/L		54 (93%)	
BOD_5	mg/L	4.6 (97%)	5.7 (97%)	<10 (95%)
TSS	mg/L	10 (96%)	5.9 (98%)	<10 (97%)
TN	mg/L	16 (47%)	9.1 (79.4)	<10 (75%)
NO_3-N	mg/L	10	2.1	
NH_3-N	mg/L	1	0.1	
TP	mg/L	3.1 (3%)	2 (89%)	
Fecal coliform	CFU/100 mL	220	<2 (5.4)	<2.2 (9.6)
Total coliform	CFU/100 mL	358	<2 (5.6)	

[a] Manufacturer supplied information (2002).
[b] Ventura County Sanitation District (2001).
[c] Wistrom and Matsumoto (1999).
[d] Performance reported as average effluent concentration with average removal in parentheses, coliform data reported as effluent concentration and log removal in parentheses.

Advantages

Systems produces a high quality effluent. The EnviroServer is a complete treatment system, including disinfection and sludge removal. All systems include a telemetry monitoring and management contract and enhanced manufacturer support.

Disadvantages
Residual chlorine in effluent may not be suitable for discharge in some areas. The system utilizes more mechanical and electrical components than most other systems.

Operation and maintenance
Electrical components include two blower units, three pumps (sludge, recirculation, and effluent), a thermal sludge processing unit, and a process control/monitoring system. See description of management and monitoring specification below. No O&M for homeowner besides proper usage. Two-year system monitoring and management is included in the purchase price. Long term management and monitoring required.

Power and control
System includes a sludge pump, a recirculation pump, an effluent pump, two air compressor units, a thermal sludge processing unit, and a monitoring and control system. The estimated annual electrical usage for the EnviroServer 600 is 2160 kWh.

The monitoring system includes detection for high water level, pump failure, air compressor failure, sludge processing unit failure or high temperature, thermocouple failure, chlorine residual (disinfection failure), and overall monitoring system failure (by not responding at required interval).

Cost
The estimated cost for the EnviroServer 600 (600 gal/d) system is $10,900, and includes the capital cost of all system components sold as a complete unit.

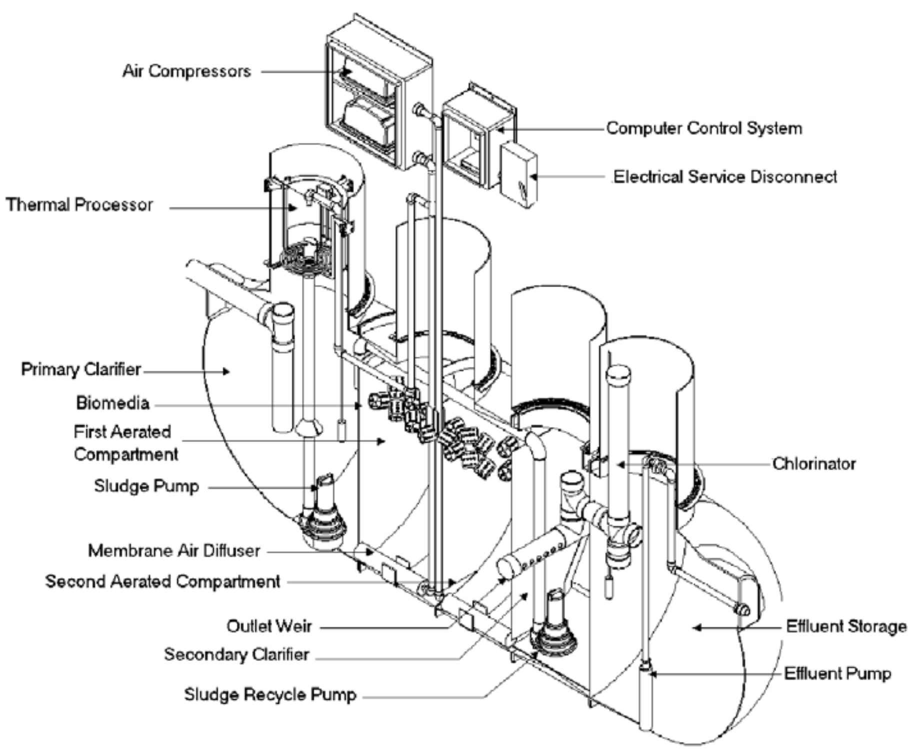


Figure 8-8
Diagram of the EnviroServer by MicroSepTec. (Adapted from MicroSepTec, Inc.)

Contact

MicroSepTec
23112 Alcalde Dr, Suite C
Laguna Hills, CA 92653
Phone (949) 855-3500
Fax (949) 855-3515
Web www.microseptec.com

Model description

MicroSepTec offers three complete units:
EnviroServer 600 (600 gal/d)
EnviroServer 1200 (1200 gal/d)
EnviroServer 1500 (1500 gal/d)

Manufacturer support

Each system is sold with a mandatory maintenance and monitoring contract. The maintenance and monitoring contract is held as a permanent agreement against the property. The first two years of maintenance, monitoring, and complete parts warranty are included in the purchase price of the unit. After the first two years, the owner is required to pay a $28/month service fee, covering maintenance and monitoring. MicroSepTec uses a telemetry system for continuous (24 hour) monitoring.

References and other resources

Edvardsson, C.M., and T.G. Edvardsson (2001) E-connected Onsite Management for Advanced Treatment Units, National Onsite Wastewater Recycling Association (NOWRA) Conference.

NSF (1999) Final Report: EnviroServer 600 Wastewater Treatment System, NSF International, Ann Arbor, MI.

Wistrom, A.O., and M.R. Matsumoto (1999) Evaluation of MicroSepTec EnviroServer Residential Wastewater Treatment System, University of California, Riverside.

Ventura Regional Sanitation District (2001) Septic Tank Nutrient Removal Project, Advanced Onsite Sewage Disposal System Demonstration.

8-2.4 Nibbler™ Wastewater Treatment Systems

Category	Primary and secondary treatment
Technology	Continuous flow, aerated suspended growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual and cluster residential, commercial

Background

The Nibbler wastewater treatment system was developed for the treatment of wastewaters with higher oxygen demand than typical residential wastewaters, such as commercial facilities. The Nibbler technology is the basis for three wastewater treatment systems:

Nibbler Jr.	For residential and light commercial applications, pretreatment and renovation of failed systems.
Nibbler Lite,	For high strength waste treatment and flow rates in the range of 500 to 1,200 gal/d.
Nibbler.	For the pretreatment of high strength waste with flows ranging from 1,000 to 25,000 gal/d

Description of process
The Nibbler Jr. system is a standard septic tank with an aerated attached growth process in the second chamber. The basis of the Nibbler process is an aerated fixed film suspended packing. Wastewater flows into the treatment reactor and is drawn through the packing material with an air lift pump. A portion of the lifted water is discharged from the system and a portion is returned to the anoxic chamber (first chamber of septic tank) for denitrification.

System footprint
Space requirements approximately equal to that needed for a standard septic tank.

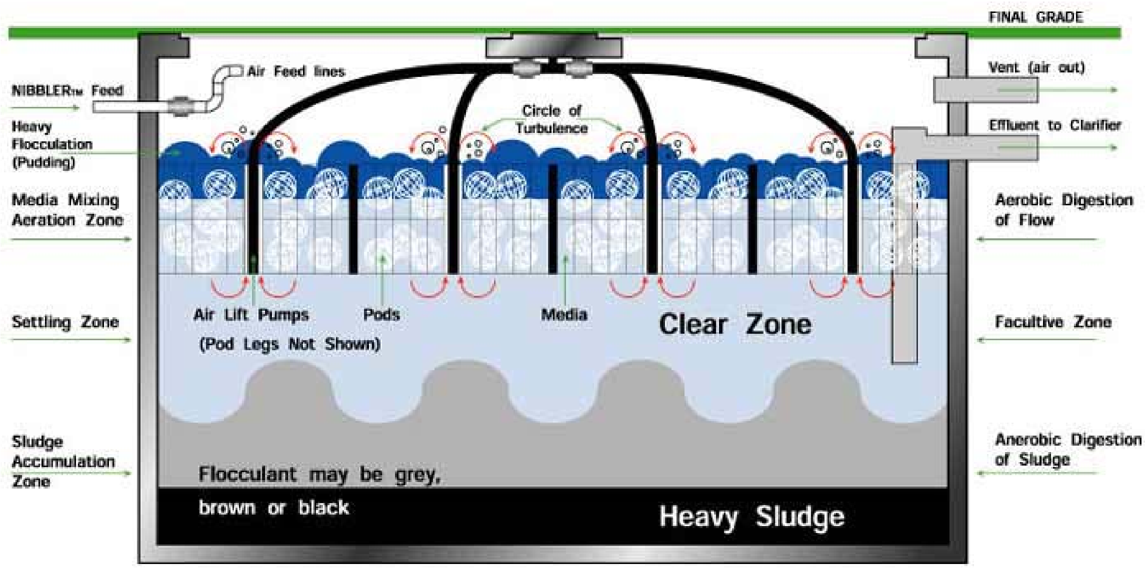


Figure 8-9
Diagram of the Nibbler wastewater treatment systems. (Adapted from NCS wastewater solutions/Northwest Cascade-Stuth.)

Advantages
All operations occur in a single basin, and it can be installed in an existing septic tank, resulting in relatively small space requirements. In case of air lift pump (blower) failure, the system can gravity discharge.

Disadvantages
The Nibbler system requires a blower for aerobic operation.

Performance
The data reported in Table 8-8 have been obtained for the Nibbler Jr. wastewater treatment unit, based on 15 samples from the Anne Arundel County National Onsite Demonstration Project.

Table 8-8
Performance of the Nibbler Jr. treatment system (Anne Arundel NODP, 2001)

Parameter	Unit	Influent	Effluent	Removal
BOD	mg/L	236	34	86%
TSS	mg/L	109	24	64%
TN	mg/L	58	28	52%
Fecal Coliform	MPN/100 mL	3.2E6	1E4	2.5 log

Operation and maintenance
Required management contract, inspection every six months (including sampling for high strength applications, sludge removal when needed, and blower maintenance), 3 year warranty on parts and labor.

Power and control
The estimated annual power usage for the aeration system, alarm, and controls is 1,000 to 2,000 kWh.

Contact
NCS wastewater solutions/Northwest Cascade-Stuth
16207 Meridian East; PO Box 73399
Puyallup, WA 98373
Phone (800) 444-2371; (253) 848-2371
Fax (253) 840-0877
Web www.ncswastewater.com

References and other resources
Anne Arundel County National Onsite Demonstration Project (2001) Nibbler Jr. wastewater treatment system performance.

Stuth WL and MM Lee (2001) Recovery of Failing Drainfields and a Sand Mound Using Aerobic Effluent, in *Proceeding of the Ninth National Symposium on Individual and Small Community Sewage Systems, Fort Worth, TX,* American Society of Agricultural Engineering, St Joseph, MI.

8-3 Rotating Biological Contactor (RBC)

The RBC system consists of rotating disks, partially submerged in the water to be treated. The disks are designed to maximize biomass attachment for biological wastewater treatment. Organisms suspended in the water and attached to the rotating disks provided treatment to the wastewater.

8-3.1 Biokreisel™

Category	Secondary treatment
Technology	Continuous flow, aerated attached growth
Input	Primary (settled) wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual residential systems

Background
The Biokreisel unit was developed in Germany and has been certified by NSF and is currently being evaluated in the La Pine Onsite Demonstration Project in Oregon. The unit is composed of two chambers, a treatment chamber (375 gal) and a settling chamber (199 gal).

Description of process
Primary effluent from the septic tank flows into the treatment side of the Biokreisel. In the treatment section, a partially submerged attached growth packing rotates continuously. As the packing rotates, the attached microbial community is intermittently exposed to the wastewater. With each rotation, cups attached to the packing material lift a portion of the wastewater and sloughed biofilm and then deposit it into a pipe for return to the septic tank (recirculation flow). The treated water is lifted into a settling chamber with the screw auger in the center of the rotating packing. Sludge that accumulates in the settling chamber is also sent back to the septic tank.

System footprint
The Biokreisel unit has a diameter of 8.75 ft and a depth of 5.8 ft. A primary treatment device, such as a septic tank, and a soil adsorption system are also needed.

Advantages
The Biokreisel system provides effective wastewater treatment. The recirculation feature buffers the system when there is no household wastewater output. An alarm system for monitoring the process will alert the system owner in the event of a manlfunction.

Disadvantages
The process requires electricity to power the motor.

Performance
Effluent concentrations of BOD_5 and TSS less than 10 mg/L are expected from the Biokreisel system; there is also potential for total nitrogen removal in range of 70% (NSF 1997).

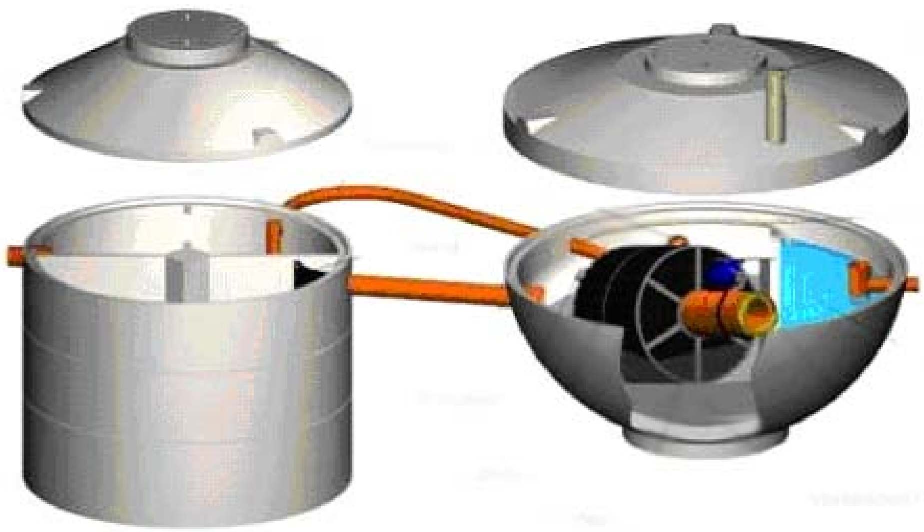


Figure 8-10

Illustration of the Biokreisel wastewater treatment system. (Adapted from Nordbeton North America, Inc.)

Operation and maintenance
The manufacturer recommends shutting the unit off if the system is not to be used for more than 8 weeks (i.e., vacation). The septic tank requires solids removal as needed. The system owner needs to confirm system is running (especially after power outage), check for alarm messages, watch for signs of malfunction (water backup, odors), and schedule regular service. On a six month basis, the service company checks for proper operation, sludge accumulation, excess biomass growth, and performs a qualitative effluent check. A control system monitors for high water conditions in the treatment unit, alarm interruption, operation of pump, and operation of the motor.

Power and control
The system components that require electricity include a control panel, alarms, drive motor, and sludge return pump. The estimated annual electricity usage for the Biokreisel system is 1,000 kWh.

Cost
The estimated cost for a single unit ranges from $5,000 to $6,000 (based on Models BK-250NA and BK-252NA), and includes capital cost for Biokreisel only (delivery, installation, etc. not included).

Contact
BIOKREISEL; Nordbeton North America, Inc.
P.O. Box 470858
Lake Monroe, Fl 32747
Phone (407) 322-8122
Fax (407) 322-8159
Web www.nordbeton.com
Model description
BK-250NA (400 gal/d)
BK-251NA (500 gal/d)
BK-252NA (600 gal/d)
Manufacturer support
Manufacturer provides a limited warranty on system and service contract for first two years after installation included in purchase price. After two years service contract expires, owner is given opportunity to renew service agreement.

References and other resources
NSF (1997) Performance Evaluation Report: Nordbeton GmbH Model BK-252NA Wastewater Treatment System, NSF International, Ann Arbor, MI.

8-3.2 Biorotor™

Category	Primary and secondary treatment
Technology	Continuous flow, attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Community systems

Background
The Biorotor system is composed of a primary treatment system (such as a septic tank), an RBC aeration unit, and a secondary clarification system.

Figure 8-11

The Biorotor treatment system shown with a fiberglass septic tank. (Adapted from NPS Wastewater Treatment Systems Limited.)

Operation and maintenance
Typical operation and maintenance includes sludge removal, bearing lubrication, and process monitoring. Monthly service is provided by a manufacturer certified technician.

Contact
NPS Wastewater Treatment Systems Limited
Unit 3, 1974 Spicer Rd
N Vancouver, BC V7H 1A2
Phone (604) 924-1085; (877) 712-2233
Fax (604) 924-1785
E info@npswastewater.com
Web www.npswastewater.com
Model description
Units available for treatment of flow rates from 3,000 to 30,000 gal/d.
Manufacturer support
Telemetry systems available for process monitoring.

8-3.3 CMS Rotordisk™

Category	Primary and secondary treatment
Technology	Continuous flow, attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Community systems

Background
The Rotordisk unit combines primary settling, biological oxidation, final settling, and sludge storage in one integrated system. The system is entirely enclosed, and therefore ideal for situations where odor control, noise reduction, and visual impact must be considered. If required, advanced wastewater treatment options can be added to the standard Rotordisk to provide tertiary filtration, nitrification, disinfection or phosphorus reduction (CMS Group Inc., 2001).

Figure 8-12
The Rotordisk treatment system installed at a residential location. (Adapted from CMS Group Inc.)

Contact
CMS Group Inc.
185 Snow Blvd. Suite 200
Concord, Ontario, Canada L4K 4N9
Phone (905) 660-7580
Fax (905) 660-0243
E cms@rotordisk.com
Web www.rotordisk.com
Model description
Units available for treatment of flow rates from 500 to 100,000 gal/d.

8-3.4 Five Star Environmental KR505

Category	Primary and secondary treatment
Technology	Continuous flow, attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual systems

Background
The Five Star RBC unit (Model 505-KR) is an integrated primary and secondary treatment system. Primary effluent flows into the second compartment which houses a series of partially submerged rotating disks. Organisms attached to the disk are alternately exposed to the wastewater and the atmosphere as the disks rotate.

Operation and maintenance
Typical operation and maintenance includes sludge removal and confirmation of alarm operation.

Performance
The Five Star 505-KR is certified under the NSF standard 40 to provide secondary quality effluent.

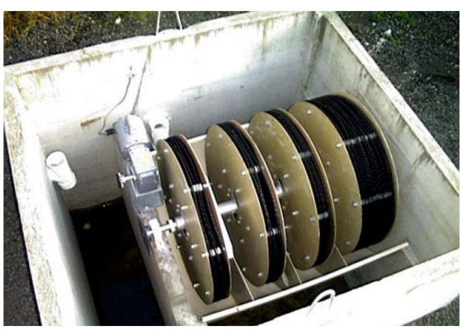


Figure 8-13
The Five Star Model 505-KR treatment system. (Adapted from Five Star Environmental Systems, Inc.)

Contact
Five Star Environmental Systems, Inc.
P.O. Box 1768
Kingston, WA 98346
Phone 360.297.3633
Fax 360.297.3636
Web www.fivestarenviro.com

8-3.5 Klargester Biodisk™

Category	Primary and secondary treatment
Technology	Continuous flow, rotating biological contactor
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Individual, community, and larger systems

Background

The Klargester Biodisk is an integrated primary and secondary treatment system.

Performance

The Klagester Biodisk has been evaluated at the Florida Keys Onsite Wastewater Nutrient Reduction Systems (OWNRS) Demonstration Project. The results from Phase I and II of the OWNRS project are presented in Table 8-9. Note that the performance values provided for the Florida Keys OWNRS Project are for a coupled Klargester Biodisk and anoxic upflow biofilter.

Table 8-9

Results from Phase I and II of the Florida Keys OWNRS Project

		Location of study	
Parameter	Unit	Florida[a]	Florida[b]
Description of system		Test facility	Test facility
HLR	gal/d	307	
System performance[c]			
BOD_5	mg/L	2.42 (99%)	2.42 (99%)
TSS	mg/L	5.75 (95%)	14 (85%)
TN	mg/L	12.52 (67%)	14.9 (69%)
NO_3-N	mg/L	9.77	13
TP	mg/L	4.67 (44%)	6.8 (22%)

[a] Florida Department of Health (2000).
[b] Anderson *et al.* (1998).
[c] Performance reported as average effluent concentration with average removal in parentheses, where applicable.

Figure 8-14

Cut-away illustrations of two types of Klargester RBC units (left) and a system prior to installation (right). (Adapted from Klagerster Environmental Ltd.)

Contact
Klargester Biodisk; Klargester Environmental Ltd.
College Road, Aston Clinton
Aylesbury, Bucks. HP22 5EW
Phone
Web www.klargester.co.uk

Local Contact
Waste Water Solutions International Inc.
3238 Old Fence Road
Ellicott City, MD 21042
Phone (410) 480-0272
Fax (410) 480-0282
E wwsi@worldnet.att.net

References and other resources
Anderson DL, MB Tyl, RJ Otis, TG Mayer, KM Sherman (1998) Onsite Wastewater Nutrient Reduction Systems (OWNRS) for Nutrient Sensitive Environments, in *Proceeding of the Eighth National Symposium on Individual and Small Community Sewage Systems, Orlando, FL,* American Society of Agricultural Engineering, St Joseph, MI.

8-3.6 RotoFix™

Category	Primary and secondary treatment
Technology	Continuous flow, attached growth
Input	Untreated wastewater
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Community, commercial, institutional

Background
The RotoFix rotating biological contactor is an aerobic, semi-submerged fixed culture biological treatment system for domestic wastewater in commercial, institutional, community, and municipal applications (Premier Tech Environment, 2001).

Description of process
The RotoFix consists of a patented, tubular PVC medium with multiple internal blades offering a large contact surface per unit of volume of liquid. Numerous media channels are radially arranged around a horizontal, stainless steel shaft and secured by end plates and a central plate of polymer to from the RotoFix rotor assembly (Premier Tech Environment, 2001).

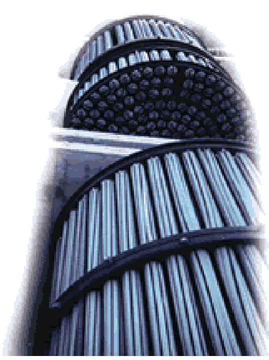


Figure 8-15
View of the Premier Tech RotoFix RBC medium used for biological attached growth. (Adapted from Premier Tech Environment.)

Contact
Premier Tech Environment
6021 Terrace Hills Dr
Birmingham, AL 35242
Phone (205) 408-969;1(877) 295-5763
Fax (205) 408-8783
E ecoflo@premiertech.com
Web www.premiertech.com

8-4 Sequencing batch reactor

The SBR process discussed below is identical to the SBR process described in Chap. 7, with the addition of an attached growth material for the biological treatment stage of the process.

8-4.1 Amphidrome™

Category	Primary and secondary treatment
Technology	Continuous flow, submerged fixed film sequencing reactor
Input	Primary effluent (septic tank)
Function	Oxidation, nutrient transformation/removal, and pathogen reduction
Applications	Single family homes, cluster and commercial systems from 5,000 to 36,000 gal/d

Background

The Amphidrome process is an advanced biological wastewater treatment system that utilizes a fixed film, sequencing batch biofilter. The system consists of a deep bed filter that alternates between aerobic and anoxic treatment. The design allows for the nitrification and denitrification of the waste stream to be carried out in a single reactor.

Description of process

The process consists of aerobic, anoxic, recirculation, and discharge cycles. In the aerobic portion of the cycle, primary effluent flows down through a fixed film media as air is supplied from below by an air blower. The media is an attached growth media in a bed of silica sand supported by a layer of gravel. As the air flows up through the media, the air bubbles are sheared by the sand, thus producing a fine even pattern throughout the bed. The cyclical action of the system is created by allowing a batch of wastewater to pass from the anoxic/equalization tank through the aerated granular biological filter into the clear well, and then reversing the flow back through the biofilter through the use of a pump. The reverse flow passes from the clear well up through the filter, where it overflows into a trough that carries it back to the anoxic/ equalization tank. The aerobic/anoxic cycles are repeated multiple times. Once sufficient cycles have been repeated to insure the degree of treatment required, a batch of effluent is discharged. Periodically, the deep bed filter in the reactor has to be backwashed. This is accomplished by simultaneously pumping water, back from the clearwell, and blowing air, at a high volume, into the Amphidrome Reactor.

System footprint

Requires two basins in addition to a standard septic tank. High quality effluent may be discharged to soil treatment systems or alternate effluent management system.

Advantages

The use of a septic tank buffers the system by providing flow and constituent equalization.

Disadvantages

Mechanically and energy intensive process. Operation and maintenance intensive and reliant on SCADA controls for adjusting process controls.

Performance

Performance specifications of representative research findings are presented in Table 8-10.

Operation and maintenance

Quarterly inspection of pumps, control devices, and blowers is recommended. Sludge removal from the septic tank may be needed periodically.

Power and control

Process uses four float alarm/switches, two pumps, an air blower, and process control panel. The annual electrical usage is estimated to be 800 to 1,000 kWh.

Cost

Capital cost for Amphidrome components are estimated to be $10,000, (does not include septic tank). The total installed cost ranges from $12,000 to 14,000 for an individual residence.

Table 8-10

Reported results from Buzzards Bay Project for the Amphidrome treatment process[a]

		Location of study
Parameter	Unit	Massachusetts[b]
Description of system		Test facility
HLR	gal/d	330
System performance		
BOD_5	mg/L	17 (90%)
TSS	mg/L	8 (95%)
TN	mg/L	14.9 (47%)
NO_3-N	mg/L	3
Fecal coliform	No./100 mL	4E5 (1)

[a] Massachusetts Alternative Septic System Test Center (2001).

[b] Performance reported as average effluent concentration with average removal in parentheses, except fecal coliform removal which is reported as logs of removal.

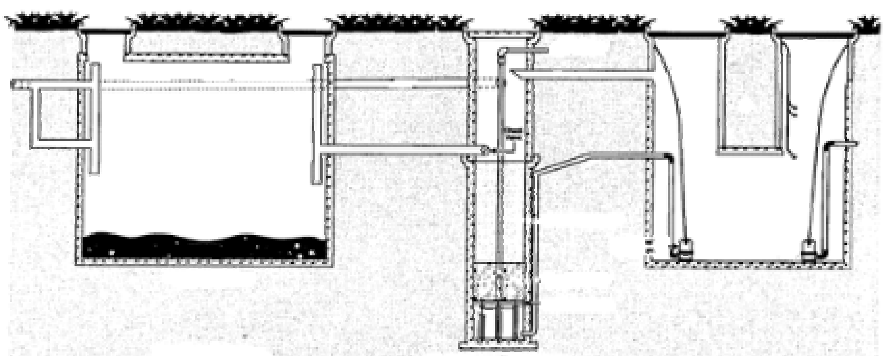


Figure 8-16

Diagram of the Amphidrome process (top) and installation of the Amphidrome at the Massachusetts Alternative Septic System Test Center (bottom). (Adapted from F.R. Mahony & Associates.)

Contact

F.R. Mahony & Associates
131 Weymouth St., Rockland, MA 02370
Phone (781)982-9300
Fax (781)982-1056
Web www.frmahony.com

Model description

The basic residential model is designed for a single family home with a flow rate of 330 to 440 gal/d, the process has been expanded to treat up to 36,000 gal/d.

References and other resources

Massachusetts Alternative Septic Test Center (2001) Technology Fact Sheet Interim Findings: Amphidrome, Buzzards Bay Project.

U.S. EPA (2001) *CEIT Virtual Trade Show: Amphidrome Wastewater Treatment Systems (available at www.epa.gov/region1/steward/ceitts/wastewater/techs/amphidrome.html).*

Natural systems for onsite treatment are an alternative to mechanized treatment systems. Natural systems have the advantage of minimized operation and maintenance costs, but are often more difficult to control. Solar, aquatic, and plant based treatment systems depend primarily on their natural components to achieve the intended purpose. The types of systems to be discussed in this chapter are (1) surface flow constructed wetlands, (2) subsurface flow constructed wetlands, (3) ecological systems, (4) evapotranspiration systems, and (5) lagoons.

9-1 Constructed wetlands (surface flow)

Category	Secondary and tertiary treatment
Technology	Solar/aquatic treatment system
Input	Stormwater and secondary treated wastewater
Function	Removal of particulates, BOD, nutrients, and pathogens; effluent polishing
Applications	Agricultural, industrial, and domestic systems

Background
A wetland refers to land in which the water table is at, or above, the ground surface to maintain saturated soil conditions and growth of related vegetation. The use of constructed wetlands for the treatment of wastewater is becoming more common in urban and rural areas. These systems have been used for the treatment of wastewater from agricultural, industrial, municipal, and storm runoff wastewaters. The need to meet more stringent discharge requirements in the future may limit their application.

Description of process
A surface flow (SF) constructed wetland, also known as a free water surface (FWS) wetland, has a water level above the ground surface. It is a shallow natural treatment process that performs a combination of unit processes. Typical vegetation for SF systems includes cattails, reeds, sedges, and rushes. Native wetland vegetation can be found in all regions of the country and has the advantage of being well adapted to the climate. The vegetation is flooded with an effluent, normally pretreated in a septic tank. Seasonal patterns are of concern, due to the variability in primary productivity with changing climatic conditions. Design criteria for constructed wetland systems can be found in Crites and Tchobanoglous (1998), U.S. EPA (2000), and U.S. EPA (2002).

System footprint
The size of surface flow wetlands depends on the quality of the influent wastewater and the degree of treatment to be accomplished. Surface flow wetland systems typically require a large land area and should be designed by a qualified organization. Depending on the type of soil, depth to groundwater, and other site specific conditions, a clay or synthetic liner may be needed.

Advantages
Can be used to improve water quality and provide wildlife habitat. Relatively low technology systems that utilize a long hydraulic residence time (HRT) and passive solar energy to achieve treatment.

Disadvantages
If improperly designed or maintained, nuisance conditions may result. Surface flow wetlands are a potential vector for mosquito propagation. In summer months, algae in the effluent can result in high TSS concentrations.

Performance
Expected effluent quality from surface flow constructed wetlands are presented in Table 9-1. In addition to the water quality parameters listed in Table 9-1, wetland systems have also been found to sequester metals and reduce pathogens in wastewater.

Table 9-1
Typical performance of surface flow wetlands[a]

Parameter	Effluent value
BOD_5	<20 mg/L
TSS	<20 mg/L
TN	<10 mg/L
TP	<5 mg/L
Fecal coliform	2 to 3 log removal

[a] Adapted from Crites and Tchobanoglous (1998).

Operation and maintenance
Minimal maintenance is needed for wetland systems and, in many cases, maintenance may be performed by non-skilled personnel or the system owner. Periodic removal and thinning of vegetation may enhance hydraulic performance. A fence around the facility may be needed to meet safety concerns.

Power and control
Power and control systems are not needed unless water will be pumped to an elevated location.

Cost
A surface flow wetland system for an individual home will typically cost from $2,000 to 5,000, depending on the degree of pretreatment and site conditions.

Figure 9-1
A surface flow wetland for stormwater runoff treatment in an urban area. Note walkway and signs located around facility to educate community about non-point source pollution and treatment system. (Photo of Tollgate wetlands by CR MacCluer.)

References and other resources
Crites, R., and G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems*, WCB/McGraw-Hill, New York.

U.S. EPA (2000) *Constructed Wetlands Treatment of Municipal Wastewaters*, EPA/625/R-99/010, Office of Research and Development, United States Environmental Protection Agency, Wachington, DC.

U.S. EPA (2002) *Onsite Wastewater Treatment Systems Manual*, EPA/625/R-00/008, Office of Water, Office of Research and Development, United States Environmental Protection Agency, Wachington, DC.

9-2 Constructed wetlands (subsurface flow)

Category	Primary and secondary treatment
Technology	Solar/aquatic treatment system
Input	Primary and secondary effluent
Function	Removal of particulates, BOD, nutrients, pathogens
Applications	Agricultural, industrial, and domestic systems

Background
The subsurface flow (SSF) constructed wetland system is composed of a bed of gravel or other aggregate packing material contained in a lined bed. Subsurface flow systems are often used for the treatment of wastewater that has a high concentration of biodegradable organic material because the treatment process is primarily anaerobic. Subsurface flow wetlands offer several advantages over other surface flow wetlands; however, the need to import packing material significantly increases the cost of subsurface flow constructed wetlands.

Description of process
In a subsurface constructed system, the water to be treated flows through a porous packing material. The packing material has sufficient depth so that the water is not seen from the surface. The vegetation of the wetland provides some oxygen to the root zone and provides surface area for biological growth. The vegetation also stabilizes the bed surface, prevents the bed from freezing, and improves the wetland aesthetics. Mixed cultures of wetland vegetation typically provide a more stable and effective wastewater treatment process. An outlet device is used to control the depth of water in the wetland.

System footprint
The typical constructed subsurface wetland system has a slope of approximately 0 to 0.5%, and an impermeable liner membrane on the bottom to prevent leakage to the groundwater. The depth of the bed ranges from 1.5 to 3.3 ft. The typical size for a single household system is 300 to 400 ft^2. The treatment system is temperature dependent and requires a larger area for a colder climate. The expected effluent concentrations of BOD_5 and TSS are 5 to 10 mg/L and 10 to 20 mg/L, respectively.

Advantages
Subsurface flow wetlands are able to treat wastewater with high concentrations of COD, such as that from food processing facilities, breweries, and wineries. Subsurface flow wetlands typically have a higher removal rate of BOD_5, TSS, and nitrogen than surface flow systems. Because the water is contained within the gravel media, there is reduced chance for public exposure to wastewater and mosquito breeding. Vegetation can be integrated into landscape and add aesthetic appeal. In addition, the subsurface flow wetland is a relatively passive process that does not require forced aeration.

Disadvantages
The aggregate packing material used may be expensive to acquire in some areas. There is limited process control relative to other types of treatment processes once the system is installed. The potential for the periodic release of adsorbed constituents is also of concern.

Performance
Expected performance of subsurface flow constructed wetlands is presented in Table 9-2. In addition to the parameters and values listed in Table 9-2, wetlands are also known to sequester metals. Low effluent phosphorus concentrations can be obtained when a phosphorus adsorbing medium is used.

Table 9-2
Typical performance of subsurface flow wetlands[a]

Parameter	Effluent value
BOD_5	<20 mg/L
TSS	<20 mg/L
TN	<10 mg/L
TP	<5 mg/L
Fecal coliform	2 to 3 log removal

[a] Adapted from Crites and Tchobanoglous (1998).

Operation and maintenance
Operation and maintenance for a subsurface system are minimal, although the surface growth may need to be cut back. The system should not be a source of odors, while the effluent is introduced below the surface. A small observation tube should be installed in each cell so the homeowner can periodically check the water level to ensure that it is not too low or too high. Plant care may also be needed, such as removing dead plants and any weeds or saplings that have taken root.

Power and control
Subsurface flow constructed wetlands generally do not require power or control systems to operate.

Cost
Subsurface flow systems cost significantly more than surface flow systems because they are more difficult to design and they often require the importation of a suitable gravel substrate. The costs for a subsurface system, including a septic tank pretreatment system can range from $10,000 to 15,000 for an individual home. Each wetland design and cost will differ based on soil conditions, usage requirements, and local and state laws.

Figure 9-2
Onsite treatment of septic tank effluent in a subsurface flow constructed wetland. (Adapted from IEES, 2001.)

References and other resources

Crites, R., and G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems*, WCB/McGraw-Hill, New York.

IEES (2002) EcoEng Newsletter 1, April 2002, *International Ecological Engineering Society*.

U.S. EPA (1993) *Subsurface Flow Constructed Wetlands for Wastewater Treatment: A Technology Assessment*, EPA/832/R-93/001, Office of Research and Development, United States Environmental Protection Agency, Washington, DC.

U.S. EPA (2000) *Constructed Wetlands Treatment of Municipal Wastewaters*, EPA/625/R-99/010, Office of Research and Development, United States Environmental Protection Agency, Washington, DC.

U.S. EPA (2002) *Onsite Wastewater Treatment Systems Manual*, EPA/625/R-00/008, Office of Water, Office of Research and Development, United States Environmental Protection Agency, Washington, DC.

9-3 Ecological systems

Category	Secondary and tertiary treatment
Technology	Aquatic treatment systems
Input	Primary treated wastewater
Function	Organic, nutrient, and pathogen removal, effluent polishing
Applications	Small community, institutional, commercial, and industrial systems

Background/description of process

Ecological or solar aquatic systems are greenhouse based wastewater treatment systems. The entire treatment system is contained in a greenhouse to sustain year-round operation. The water to be treated flows through different biosystems (anaerobic, anoxic, aerobic, vegetated, etc.), where plants, algae, and other organisms remove BOD, TSS, nutrients, and pathogenic organisms.

System footprint

Ecological wastewater treatment systems are typically contained in greenhouse or atrium structures. The size requirements depend on the wastewater quality and quantity to be treated. In milder climates, the treatment reactors may not require a greenhouse.

Advantages

Ecological systems are an aesthetically pleasing and effective treatment system that is often used to educate people about waste and wastewater.

Disadvantages

Ecological systems are typically more expensive than other treatment processes because of the custom design for each application and additional space and structural needs.

Performance

The performance of ecological treatment systems is presented in Table 9-3.

Operation and maintenance

Ecological wastewater treatment systems require regular inspection and maintenance of the treatment process and the vegetation; however, because these systems are typically more visible than other underground treatment processes, monitoring activities may be easier.

Power and control
Systems can employ passive or active aeration. The power requirements will depend on the amount of aeration and pumping utilized in the treatment process.

Table 9-3
Expected performance of
ecological wastewater treatment systems[a]

Parameter	Effluent concentration, mg/L
BOD	<5
TSS	<5
TN	<10
TP	<5

[a] Adapted from Crites and Tchobanoglous (1998).

Figure 9-3
Ecological wastewater treatment systems contained in greenhouse structures and treating domestic wastewater. (Adapted from Ocean Arks International and EcoWerks Technologies.)

Contact
The following organizations can provide engineering and design consulting on ecological wastewater treatment systems.

9-3.1 EcoWerks Technologies
100 Arbors Lane, Unit A
Woodbridge, ON L4L 7G4 Canada
Phone (905) 856-5225 x33
Fax (905) 856-9017
E living@ecowerks.ca
Web www.ecowerks.ca

9-3.2 Living Technologies

125 La Posta Rd., 8018 NDBCU
Taos, New Mexica 87571
Phone (505) 751-4448
Fax (505) 751-9483
E info@livingmachines.com
Web www.livingtechnologies.com

9-3.3 Ocean Arks International

176 Battery Street
Burlington, VT 05401
Phone (802) 860-0011
Fax (802) 860-0022
E info@oceanarks.org
Web www.oceanarks.org

9-3.4 Solar Aquatics Systems

508 Boston Post Rd.
Weston, MA 02493
Phone (781) 891-5085
Fax (781) 891-8654
E eea@solaraquatics.com
Web www.solaraquatics.com

9-4 Evapotranspiration (ET) systems

Category	Soil treatment/atmospheric discharge
Technology	Evapotranspiration
Input	Primary or secondary treated wastewater
Function	Wastewater evaporation
Applications	Residential systems

Background

Evaporation and evapotranspiration (ET) systems dispose of wastewater to the atmosphere through evaporation from the soil or transpiration from plants. The system is an option for arid and semi-arid areas where the annual evaporation is higher than the precipitation, for sites where protection of the surface water and groundwater is essential, or where other limiting site conditions will not allow soil discharge of wastewater.

Description of process

Wastewater pretreated in a septic tank or secondary treatment device flows into a bed lined with an impermeable membrane and filled with sand. Vegetation planted on the surface of the bed enhances the transpiration process. The water rises up to the surface by capillary forces in the sand and evaporates. The vegetation transports the water from the root zone to the leaves, where it also evaporates. When the water evaporates, salts, minerals and solids accumulate in the bed. The evapotranspiration bed surface area is often divided into two parts to make it possible to switch between them to avoid overloading.

System footprint

A liner and/or clay layer is placed in the bottom of an excavated bed. A layer of gravel or rock with a diameter of 0.75 to 2 in and a depth of 12 in, depending on the bed's total depth, is placed within the liner. A crown of topsoil may be placed on the sand bed to enhance plant growth and the rate of evaporation. Systems are sized according to local climatic conditions and the quantity of wastewater to be evaporated. The typical surface area required for an ET system is 1,000 to 2,000 ft^2.

Advantages
The risk of groundwater contamination is minimized with an ET system that has an impermeable liner. An ET system is ideal for seasonal applications, especially for summer homes or recreational parks with high evaporation and transpiration rates, such as in the southwestern U.S. Landscaping enhances the aesthetics of an ET system.

Disadvantages
The ET system is not suitable in areas with land limitations due to the space requirements for these systems. They have a limited storage capacity, and are generally not designed to store winter wastewater for evaporation in the summer. The transpiration and evaporation rate is somewhat dependent on the vegetation. Salt accumulation and other elements can have a negative effect on vegetation. The system may be affected by excess precipitation.

Performance
The amplitude for the ET cycle is latitude dependent with larger variations for larger latitudes. While the evapotranspiration is solar driven, the system is also dependent on a diurnal cycle, in which the maximum water loss is at mid-day and the minimum is almost zero in the middle of the night. The performance of an ET system is largely affected by climate factors, such as precipitation, temperature, and wind speed. Other factors that determine the performance are water usage, potential for capillary rise, and the ability of cover soil and vegetation to withstand fluctuating precipitation.

Operation and maintenance
To maintain the system it is important to mow the grass regularly and have a yearly cover. A small slope will help the rain run off the bed, and avoid overloading. The bed should be designed to eliminate the possibility of clogging.

Power and control
Evapotranspiration systems are solar powered and do not require supplemental power or control systems to operate.

Cost
The construction cost of an ET system depends on the surface area and the characteristics of the wastewater. Other cost considerations are availability of sand, thickness of liner and type of vegetation. Estimated costs range from $6,000 to $10,000 for design and installation of the ET bed, in addition to the cost of pretreatment devices.

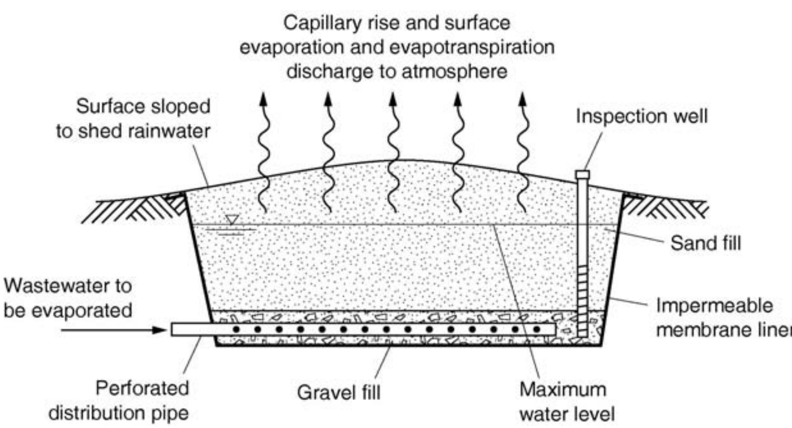


Figure 9-4

Diagram of an ET system for wastewater evaporation.

References and other resources

U.S. EPA (2000) *Decentralized Systems Technology Fact Sheet: Evapotranspiration*, EPA/832/F-00/033, Office of Water, United States Environmental Protection Agency, Wachington, DC.

9-5 Lagoons

Category	Secondary and tertiary treatment
Technology	Solar/aquatic treatment system
Input	Stormwater and primary or secondary treated wastewater
Function	Removal of particulates, BOD, nutrients, and pathogens
Applications	Agricultural, industrial, and domestic systems

Background/description of process

Lagoons are artificial ponds built into the ground, or above the ground with earthen dikes, to treat wastewater. There are four basic types of systems: *anaerobic, facultative, aerated lagoons*, and *stabilization ponds*. The type of lagoon varies according to the amount of dissolved oxygen typically present in the water, which is dependent on the loading rate and other design parameters. The purpose of treatment lagoons is to receive, retain, and treat wastewater for an extended period of time.

Anaerobic lagoons

In an anaerobic system, the bacteria responsible for the breakdown of organics are able to operate in the absence of both free oxygen and oxygen contained in inorganic compounds. Anaerobic ponds serve as sedimentation basins and anaerobic treatment systems. The two major steps in the process are the conversion of complex organic compounds to organic acids and the breakdown of the acids to carbon dioxide and methane. The anaerobic reactions take place in the sludge layer of the ponds. Intermediate organic acids are released to the water column and gas rises to the surface and is released to the air. Anaerobic lagoons are typically deep systems, up to 20 feet with steep sidewalls. Anaerobic lagoons develop a thick crust on the surface, which inhibits oxidization and serves to trap in heat, making anaerobic lagoons suitable for colder climates. Anaerobic lagoons can be expected to remove 60 percent of particulate material and 35 percent of the BOD; however, at low environmental temperatures anaerobic activity is significantly reduced.

Facultative lagoons

Facultative lagoons have an aerobic top layer and an anaerobic bottom layer. They tend to be large and shallow (3-8 feet) to allow for maximum diffusion of oxygen, which occurs at the surface, and to maximize algae growth. Algae help the treatment process by supplying oxygen through photosynthesis and by using nutrients in the wastewater. Facultative lagoons cause fewer odor problems than anaerobic systems, but may have problems functioning during prolonged cold periods when ice forms on the surface.

Aerobic lagoons (oxidation ponds)

Aerobic ponds have dissolved oxygen throughout most of the water column. Aerobic lagoons are shallow to allow oxygen and solar radiation to move through the water column. The ponds need to be mixed to prevent algae from forming a layer that blocks out the air and sun. The algae can be harvested and used as a component of animal food, as a soil conditioner, or for aquaculture projects. Aerated lagoons create aerobic conditions through mechanical means. Mechanical aeration allows these lagoons to use 60 to 90 percent less land area than non aerated stabilization ponds. Mechanical aeration can reduce the land area needed and initial construction costs, but will ultimately be more costly to operate and maintain.

Stabilization ponds

Stabilization ponds are the shallowest of all lagoon systems, typically only 2 feet deep. Stabilization ponds are passive systems that rely on the surface diffusion of oxygen and algae growth to oxygenate the wastewater. Stabilization ponds require a large area of land, typically about 1 acre for every two hundred people, and are usually located in areas where the climate permits year round algae growth. Stabilization ponds are frequently used to treat dairy farm wastewater. Waste stabilization ponds achieve high removal of BOD and suspended solids, but the effluent quality is variable both between different systems and over time. The limiting factor for treatment of dairy wastewater is the low rate of nitrification.

System footprint
The system requires a large area compared to other treatment systems, especially in colder climate when the treatment process is less efficient and need a longer detention time.

Advantages
Pond systems can be cost effective where land is inexpensive. They are easy to operate and maintain and handle shock loadings better than many other systems. Because of a high nutrient level the effluent can be suitable for irrigation.

Disadvantages
Odor production may be a problem if the system is close to a populated area. The ponds can provide a breeding area for mosquitoes.

Performance
Effluent constituent concentrations are highly variable depending on the type of treatment systems, environmental conditions, and the influent water quality. Typical effluent BOD and TSS concentrations are in the range of 15 to 40 mg/L and 30 to 100 mg/L, respectively.

Operation and maintenance
Sludge accumulation will occur on the bottom and should be measured each year and removed as needed. A weed and vector control program should also be implemented to control nuisance conditions.

Power and control
Systems with mechanical aeration and mixing require power and control systems, significantly increasing the operational costs of these systems.

Figure 9-5

A stabilization pond treating wastewater from a cannery operation.

References and other resources
Crites, R., and G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems*, WCB/McGraw-Hill, New York.

U.S. EPA (1983) *Municipal Wastewater Stabilization Ponds - Design Manual*, EPA-625/1-83-015, Office of Water, United States Environmental Protection Agency, Washington, DC.

CHAPTER 10
DISINFECTION SYSTEMS

Wastewater disinfection can be used to reduce the possibility of pathogenic organisms entering the environment. The most common types of onsite disinfection units use chlorine tablets, ultraviolet radiation, and ozone gas. Depending on the pretreatment process, disinfection may be required for some reuse systems such as drip irrigation.

It should be noted that many of the wastewater treatment systems outlined in other chapters of this report also provide disinfection. However, the systems described in the following discussion are differentiated from other systems because they attempt to provide reliable and predictable disinfection as their primary function.

10-1 Chlorination

Category	Disinfection
Technology	Tablet chlorinator
Input	Secondary treated water
Function	Pathogen reduction/removal
Applications	Single home and small community residential systems

Background

For small onsite wastewater treatment systems, the most common type of disinfection equipment is the tablet chlorinator. The tablet chlorinator is the most common disinfection system because it does not require electricity, is easy to operate and maintain, and is relatively inexpensive.

Description of process

The tablet chlorinator consists of the following components:

> A pretreatment system (e.g., primary and secondary treatment)
> Chlorine tablets specially designed for this application (typically calcium hypochlorite, tablets designed for swimming pools and other applications may not be appropriate)
> A reservoir for the chlorine tablets
> An access cap for refilling the chlorine tablet reservoir
> A device for contacting the chlorine tablets with the wastewater
> A basin for providing sufficient contact time between the chlorine and the wastewater

In the tablet chlorination system, a solid chlorine tablet (specifically designed for this application) is partially submerged in the wastewater flow. As the water to be treated flows through the chlorination device, the chlorine tablet slowly dissolves and releases chlorine into the water. As the chorine tablet dissolves, another chlorine tablet slides down into the wastewater flow.

Chlorinated water may inhibit the performance of subsequent soil treatment systems. In some cases, chlorination has been used to inhibit biological growth in trickling filter systems. In areas where water is distributed for irrigation, chlorine is used to ensure the prevention of disease transmission through wastewater.

System footprint

Typical surface area of a tablet chlorination system is about 2 to 4 ft^2. Tablet chlorination systems are usually located at grade following a secondary treatment process. A chlorine contact tank will also require 2 to 4 ft^2.

Advantages

Units are inexpensive and do not require energy to operate. Easy to operate and maintain.

Disadvantages
Require periodic chemical addition. Chlorine tablet feeder may jam and cause system to not work properly. Requires the handling of chemicals.

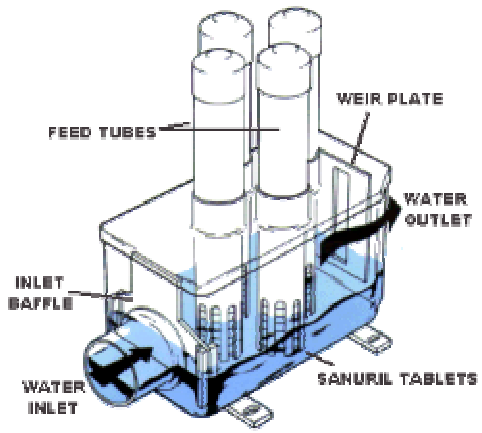


Fig 10-1

Device for contacting chlorine tablets with treated wastewater. (Adapted from Severn Trent De Nora.)

Performance
When applied correctly, chlorination is an effective method to control disease causing organisms in wastewater. Sufficient contact time and the presence of chlorine residual can ensure that the system performs as stated in manufacturer claims. Chlorinated water must be collected in a holding (chlorine contact) tank to provide sufficient holding time to accomplish disinfection, typically 20 to 40 mintues. Water may also require dechlorination depending on characteristics of receiving area.

Operation and maintenance
For this system, the operational parameters include the rate at which the chlorine tablets dissolve, the amount of chlorine transferred into solution, the capacity of the chorine tablet reservoir, and the time required between servicing. Systems should be inspected monthly to ensure operation. For a typical system, tablets may need to be added every 4 to 6 months.

Power and control
None needed.

Cost
Tablet chlorinators for individual homes can range from $250 to 300. Annual operation chemical costs can range from $200 to 300. If a dechlorination system is also used the cost will be about double.

References and other resources
Texas Agricultural Extension Service (2000) Tablet Chlorination; http://texaserc.tamu.edu

10-1.1 American Manufacturing Company, Inc.
PO Box 549
Manassas, VA 20108-0549
Phone (800) 345-3132
Fax (703) 754-0058
Web www.americanonsite.com

10-1.2 Hammonds
15760 West Hardy Road, Suite 400
Houston, TX 77060
Phone (281) 999-2900
Fax (281) 847-1857
Web www.hammondscos.com

10-1.3 JET, Inc.
750 Alpha Dr.
Cleveland OH 44143
Phone (440) 461-2000
Fax (440) 442-9008
Web www.jetincorp.com
Model description

Jet Inc. offers the JET-CHLOR systems

10-1.4 Norweco
Norwalk Wastewater Equipment Company, Inc.
220 Republic Street
Norwalk OH 44857-1196
Phone (419) 668-4471
Fax (419) 663-5440
Model description

Norweco manufactures the Bio-dynamic chlorination and dechlorination systems for flow rates in the range of 200 to 200,000 gpd. Norweco also provides aerated wastewater treatment, flow equalization, and effluent filtration.

10-1.5 Sanuril
Severn Trent De Nora
1110 Industrial Blvd
Sugar Land, TX 77478
Phone (281) 240-6770
Fax (281) 670-6762
E customer_service@severntrentdenora.com
Web www.severntrentdenora.com

10-2 Ozonation

Category	Disinfection
Technology	Ozone
Input	Secondary treated water
Function	Pathogen reduction/removal
Applications	Community, industrial, municipal, and commercial systems

Background

Ozone is a strong oxidant that has been used for the disinfection of water and wastewater. Because ozone is not chemically stable, it must be generated onsite near the point of use, making the system more complex than tablet chlorinators. Ozone has also been used in combination with other compounds for advanced oxidation treatment of wastewater. Ozone is used primarily for medium and large treatment facilities; however, ozone disinfection may become feasible for small systems in the future.

Description of process

The ozonation process is composed of several steps, including the generation of ozone gas, the transfer of ozone gas into the water to be treated, and the mixing and contact between ozone and the water to obtain treatment results. The components of the ozone disinfection system are as follows (Aqua-flo Inc., Baltimore, MD):

- Ozone generator to produce sufficient ozone from air or oxygen feed source
- Air dryer or oxygen feed gas source (oxygen generators require compressed air)
- Ozone delivery line and check valve for transport of ozone gas
- Venture injector or diffusion stone to distribute ozone into water
- Mixing and contact tank to provide adequate contact time between ozone and water
- Pump to push water through venture injector or to push ozone through diffusion stone
- Flow gauges and pressure gauges for process monitoring

System footprint
For larger scale applications, systems are relatively small when compared to other disinfection technologies.

Advantages
Very effective disinfectant, especially for resistant organisms such as viruses. Increases amount of dissolved oxygen in water. Disinfectant is generated onsite. No residual effect.

Disadvantages
High operation and maintenance costs. Relatively expensive. No residual effect.

Performance
The process performance depends on factors such as the ozone concentration and contact time, the characteristics of the water to be treated, and the characteristics of the organisms to be destroyed. Under normal operating conditions, for high quality effluents, ozone can be an effective disinfection method.

Operation and maintenance
Ozonation systems require regular monitoring due to the relative complexity of the system. Important monitoring points include the concentration of ozone in the water, checking for system leaks, and testing and calibration of electrical components. Electrical and mechanical components will need to be serviced as recommended by the manufacturer. If water is to be reused for fixtures, it will be necessary to account for the precipitation of iron due to oxidation during ozonation treatment.

Suppliers / Patents
In addition to the manufacturers listed below, many pool and spa companies sell reasonably prices ozonation equipment that may be adaptable to the disinfection of treated wastewater.

10-2.1 Aqua-flo Inc.
6244 Frankford Ave
Baltimore, MD 21206
Phone (800) 368-2513
Fax (410) 488-2030
E aquaflo@erols.com
Web www.aquafloinc.com
Model description

Manufactures ozonation equipment for various domestic, commercial, and industrial applications, including water and wastewater disinfection and treatment, odor control, and air treatment.

10-2.2 Ozonia

P.O. Box 455
491 Edward H. Ross Drive
Elmwood Park, NJ 07407
Phone (201) 794-3100
Fax (201) 794-3358
Web www.ozonia.com
Model description

Manufactures advanced ozone and UV treatment process. Applications include water and wastewater treatment as well as commercial and industrial uses.

10-2.3 RGF Environmental

3875 Fiscal Court
West Palm Beach, FL 33404
Phone (800) 842-7771
Fax (888) 848-0047
Web www.rgf.com
Model description

Manufactures complete line of wastewater products including ozonation systems and aerobic treatment systems.

References and other resources

Gross MA and SW Jones (1999) Stratified Sand Filter and Ozonation for Wastewater Reuse, in *Proceedings NOWRA Conference*, 8th Annual Conference and Exhibit, Jekyll Island, GA.

Townshend AR, EC Jowett, RA LeCraw, DH Walter, R Paloheimo, C Ives, P Russell, and M Liefhebber (1997) Potable Water Treatment and Reuse of Domestic Wastewater in the CMHC Toronto Healthy House, *Site Characterization and Design of Onsite Septic Systems*, ASTM STP 1324, MS Bedinger, JS Fleming, and AI Johnson, American Society for Testing and Materials, West Conshohoken, PA.

U.S. EPA (1999) Wastewater Technology Fact Sheet: Ozone Fact Sheet.

10-3 Ultraviolet radiation (UV)

Category	Disinfection
Technology	Ultraviolet radiation
Input	Secondary treated water
Function	Pathogen reduction/removal
Applications	Individual, community, commercial, industrial, and municipal wastewater systems

Background

Ultraviolet light is an effective disinfectant for water and wastewater. For small systems, UV light has been used most commonly as a disinfectant before wastewater reuse for irrigation. This technology is widely available and well characterized.

Description of process

A common configuration of a UV disinfection system is composed of one or more lamps that are encased in a quartz sleeve and submerged in a tubular reactor. Water to be treated enters one end of the reactor and is exposed to the UV radiation for a required amount of time. After sufficient exposure, the water exits the system and is discharged. In some applications the water is recirculated through the UV system to improve overall removal.

Fig 10-2

A sand filter pump control and alarm system and ultraviolet disinfection system (steel cylinder to the right of the control box) used to treat sand filter effluent before landscape irrigation.

System footprint
Systems are relatively small, occupying several square feet for an individual or cluster system.

Advantages
An effective disinfectant. Does not leave residual chemical or toxicity in the water. Not space intensive.

Disadvantages
No residual effect. Capital and maintenance (lamp replacement) costs may be relatively high.

Performance
The effectiveness of UV systems is highly dependent on the quality of the water to be treated. Because of the ability of wastewater particles to absorb the UV radiation that would otherwise be used for organism inactivation, lower levels of turbidity and suspended solids in the water results in improved treatment. UV disinfection systems do not leave a residual in the water and do not require additional tankage to accomplish contact time as with chlorine and ozone.

Operation and maintenance
UV disinfection systems require that the lamps be cleaned and/or changed periodically to maintain a high level of treatment. Because the system uses electrical power it will need regular inspection to ensure correct operation.

Power and control
Annual power requirements can range from 200 to 400 kWh.

Cost
Single bulb disinfection units (for the disinfection of wastewater from an individual residence) cost in the range of $750 to 1000. Replacement bulbs cost about $100 per year.

10-3.1 International Water-Guard Industries Inc.
3133 Sumner Ave.
Burnaby, BC, Canada, V5G 3E3
Phone (604) 255-5555
Fax (604) 255-5685
www.waterknowledge.com

10-3.2 Ozonia

P.O. Box 455
491 Edward H. Ross Drive
Elmwood Park, NJ 07407
Phone (201) 794-3100
Fax (201) 794-3358
Web www.ozonia.com
Model description

Manufactures advanced ozone and UV treatment process. Applications include water and wastewater treatment as well as commercial and industrial uses.

10-3.3 Salcor Engineering

P.O. Box 1090
Fallbrook, CA 92088-1090
Phone (760) 731-0745
Fax (760) 731-2405
E jscruver@aol.com
Model description

Manufactures UV disinfection systems for small wastewater treatment systems. Systems have performed well even under conditions of high suspended particles in the water.

10-3.4 Trojan Technologies, Inc.

1380 East Vocell Blvd., Suite B
Davis, CA 95616
Phone (530) 759-7600
Fax (530) 759-7620
E trojanca@trojanuv.com
Web www.trojanuv.com

References and other resources

U.S. EPA (1999) Wastewater Technology Fact Sheet: Ultraviolet Disinfection Fact Sheet. EPA-832/F/99/064.

10-4 Peracetic Acid

Category	Disinfection
Technology	Chemical disinfectant
Input	Secondary treated water
Function	Pathogen reduction/removal
Applications	Individual, community, commercial, industrial, municipal

Background

Peracetic acid based disinfectants have been developed for the control of pathogenic microorganisms in sewage effluent and sludge. Solvay Interox manufactures an equilibrium mixture of peracetic acid, hydrogen peroxide, acetic acid and water. In surface water peracetic acid will be hydrolysed. The degradation products formed by hydrolysis are acetic acid and hydrogen peroxide, both of which are easily biodegradable substances.

During the field trials it was found that, within the application concentrations required for disinfection, peracetic acid also reduced sludge odor. In addition, peracetic acid was rapidly utilized in the sludge and gave rise to safe, readily biodegradable, non-toxic decomposition products. At optimum concentrations required for disinfection of sludge, these trials proved peracetic acid was not harmful to pasture plants, invertebrates, or to the beneficial organisms occurring in the soil. The fertilizer and soil conditioning values of the sludge were undiminished. Peracetic acid was also found to be effective against E. coli.

Advantages
> Effective against a broad spectrum of microorganisms
> Operates over a wide temperature range
> Controls odors
> Removes sulfides
> Non-foaming
> No toxic residues
> Safe decomposition products
> No disposal problems
> Easy to use
> Limited investment cost

Disadvantages
> Difficult to obtain
> Very expensive relative to other disinfectants

10-4.1 Solvay Interox
3333 Richmond Avenue
Houston, TX 77098-3099
Phone (800) INT-EROX; (713) 525-6500
Fax (713) 524-9032
Web www.solvay.com

The objective of the soil treatment/adsorption system is to provide final treatment to wastewater effluent before release to the groundwater. In many ways, these systems can be thought of as groundwater recharge systems. Under non-ideal conditions, such as in course soils, high groundwater events, and subsurface channeling, wastewater may reach the groundwater or surface water before receiving adequate treatment. These conditions may lead to health impacts for persons who ingest or come into contact with the inadequately treated wastewater.

Many configurations of soil treatment systems have been used, including deep and shallow trenches, at-grade and above-grade (mound) systems, and spray irrigation. In addition, wastewater can be distributed in gravel filled trenches, without gravel (gravelless), or using drip irrigation to distribute wastewater to the root zone of plants. It is generally accepted that releasing wastewater in the upper soil horizons (where soil carbon and gas exchange are available) results in more effective wastewater polishing than wastewater release deeper in the soil environment.

The topics discussed in this section include (1) soil adsorption systems, (2) drip irrigation systems, (3) gravelless distribution systems, and (4) products for flow distribution.

11-1 Soil adsorption systems

Depending on the local hydraulic conditions, primarily the depth to the high groundwater, a number of options are available for selecting a location to release wastewater to the terrestrial environment. The three classifications for releasing wastewater are above [original] grade, at-grade or shallow, and below grade. Above grade systems are used in areas that have a seasonal or permanent high groundwater or other limiting soil condition, with the most common types being the mound system and the bottomless packed bed filter. At grade systems are less expensive because they do not require the import of soil or site excavation, but instead make use of the soil environment in a relatively undisturbed state. The below grade system is the most common. Soil adsorption systems and their applications are summarized in Table 11-1.

Table 11-1
Summary table of characteristics and applications of soil adsorption systems

		Applications		
System[a]	Provides treatment	High groundwater	Shallow limiting condition	Poor soils
At-grade		X	X	
Bed and trench				
Bottomless packed bed	X	X	X	X
Glendon biofilter	X	X	X	X
Mound	X	X	X	X
No-Mound	X	X		
Shallow		X		
Spray irrigation		X	X	X

[a] Designation of a system with an ‘X’ for a particular category indicates possible consideration for the corresponding application

11-1.1 At-grade systems

Category	Soil discharge/treatment system
Technology	Below grade discharge
Input	Primary and secondary wastewater
Function	Soil adsorption system
Applications	Discharge of effluent

Background
The at-grade system is an intermediate stage between the traditional trench leachfield and the mound type system. This system was developed in Wisconsin for areas with high groundwater, but without the limiting conditions which would require a mound system. The at-grade system resembles a mound type system without the sand layer.

Description of process
The area that will serve as the leachfield is tilled and covered with a layer of drainrock. The distribution pipe is placed in the drain rock, covered with a synthetic fabric, and covered with a final soil layer. Effluent is discharged by gravity or under pressure through the distribution piping and then infiltrated into the soil. Gravelless at-grade systems may eliminate the need to import aggregate drainrock.

System footprint
The area required for any distribution system will depend on the soils present at the site. In addition, this system requires a shallow soil mound to cover the distribution piping. The mound is often planted with ornamental landscaping plants.

Advantages
Makes use of the upper soil horizon for treatment and does not require the excavation of trenches. At-grade systems are compatible with areas that have limiting conditions where a trench would not be recommended.

Disadvantages
Soil clogging may result in surfacing wastewater earlier than it would in a comparably sized trench system. A shallow mound of soil will be visible where the system is located.

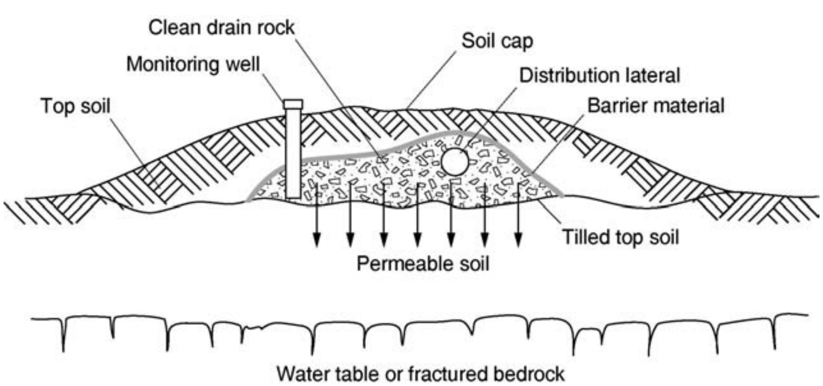


Figure 11-1
Diagram of a typical at-grade distribution system.

Operation and maintenance
Observation and sampling wells should be installed for monitoring of system.

Power and control
Effluent can be discharged under pressure or by gravity if appropriate.

Cost
Installation and construction of an at-grade soil adsorption system is expected to cost from $2,500 to 3,500, not including the septic tank. Overall cost will vary according to the availability of imported aggregate and soil.

References and other resources
Converse, J.C., M.E. Kean, E.J. Tyler, and J.O. Peterson (1991) Bacterial and nutrient removal in Wisconsin at-grade onsite systems, *Proceedings of the Sixth National Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural Engineers, St Joseph, MI.

Converse, J.C., E.J. Tyler, and J.O. Peterson (1990) Wisconsin at-grade soil adsorption system: siting, design, and construction manual, *Small Scale Waste Management Project*, University of Wisconsin, Madison.

11-1.2 Below-grade (trench and bed) systems

Category	Soil discharge/treatment system
Technology	Below grade discharge
Input	Primary and secondary wastewater
Function	Soil adsorption system
Applications	Discharge of effluent

Background
The trench system is the most common form of wastewater discharge to the soil. Trenches have been constructed at depths ranging from less than 1 ft (shallow) to 5 ft, with a width typically between 1 and 3 ft. The bed system is similar to the trench system; however, a large area is excavated for the wastewater distribution system instead of discrete trenches. Infiltration beds are not as effective as trenches on sloped sites. The discharge of wastewater in the upper soil horizons can potentially make use of soil carbon and increased microbial activity for the transformation of wastewater constituents. Shallow distribution systems may utilize aggregate for wastewater distribution; however, gravelless systems are also common. Gravelless systems use large diameter corrugated drain pipe or sections of half pipe to drain water into the soil (see Sec. 11-3).

Description of process
Trenches are generally filled with an aggregate support material, although chamber systems and other alternate systems are becoming more common. Wastewater is discharged to the trench by gravity or under pressure. The wastewater infiltrates through the bottom and sides of the trench, gradually forming a clogging/treatment layer of biological solids. For the bed system, a large, usually continuous, area is excavated and partially backfilled with aggregate. A system of perforated pipes is placed on the aggregate, followed by a geotextile fabric or similar material and covered with soil. Wastewater is discharged through the perforated pipes and infiltrated through the bottom of the trench or bed.

System footprint
Systems are generally sized according to the soil type and specific site conditions. A typical system may be between 500 and 2,500 ft^2, depending on site conditions and wastewater quality.

Advantages
Relatively low maintenance systems, typically gravity flow. Design criteria are well established

due to long history of use. Gravelless systems may be used, eliminating the need to import aggregate.

Disadvantages
Systems that are buried deep in soil are less effective at providing treatment to wastewater, potentially resulting in negative groundwater impacts. The area for infiltration is reduced for bed systems due to the presence of additional side area for trenches. Bed systems should not be used on sloped sites. Limited by soil characteristics at site, low permeability soils or high groundwater conditions may require a modified or alternative soil discharge system.

Operation and maintenance
Observation ports should be installed for periodic inspection of the infiltrative surface.

Power and control
Pressure distribution not required, but may be used to obtain more uniform distribution or for a remote soil adsorption field.

Cost
Typical installation and construction costs between $1,000 and 2,000 not including the septic tank or treatment system. The cost to import drainrock will influence the overall cost of an aggregate based system. The cost of a bed systems is typically less than the cost of trenches. Shallow systems are also less costly to install than deep systems.

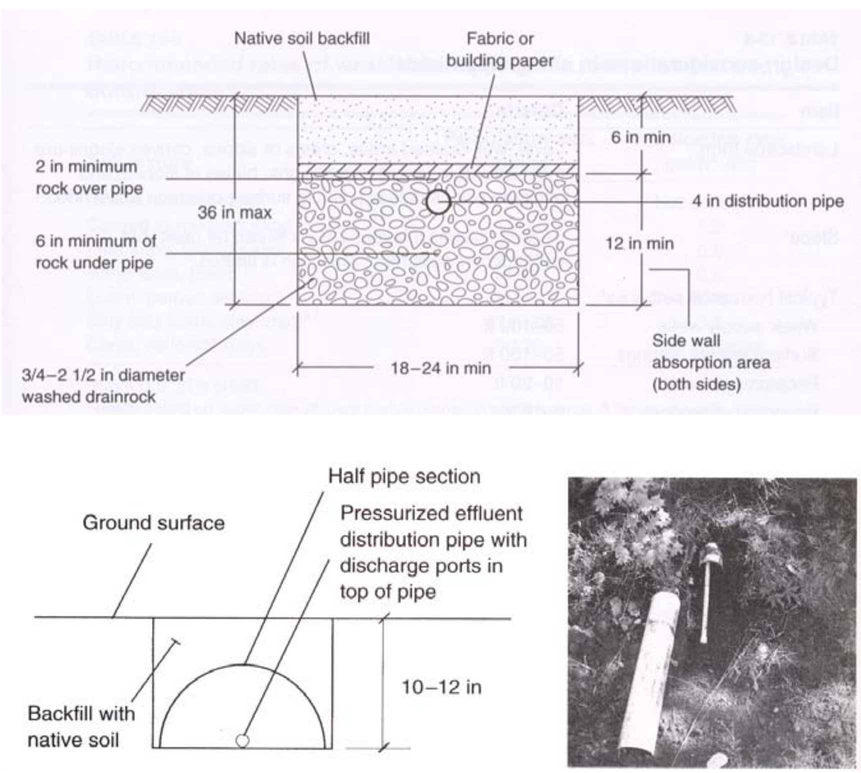


Figure 11-2

Diagrams of typical below-grade soil adsorption systems typical trench system (top) and shallow gravelless distribution system (bottom left) and a shallow gravelless distribution system with half pipe section removed. (Adapted from Crites and Tchobanoglous, 1998).

References and other resources

U.S. EPA (1980) Design Manual: Onsite Wastewater Treatment and Disposal Systems, EPA/625/1-80-012, Office of Water, Office of Research Development, United States Environmental Protection Agency, Washington DC.

U.S. EPA (2002) Onsite Wastewater Treatment Systems Manual, EPA/625/R-00/008, Office of Water, Office of Research Development, United States Environmental Protection Agency, Washington DC.

11-1.3   Bottomless packed bed filters

Category	Soil discharge/treatment system
Technology	Aerobic biofilter
Input	Effluent from septic tank or other primary treatment
Function	Treatment/distribution
Applications	Discharge of effluent

Background

Packed bed filters (such as the biofilter systems discussed in Chap. 6) can be constructed without a bottom and allowed to discharge the treated wastewater directly into the soil below the unit.

Description of process

Effluent from a septic tank or other primary treatment process is distributed to the surface of an intermittently dosed packed bed (biofilter) treatment process. After passing through the biofilter media, the water flows directly into the soil below.

System footprint

The area required for the discharge system is equivalent to the area of the bottomless packed bed filter system (see Chap. 6).

Advantages

Does not require construction of separate soil discharge area. Wastewater receives treatment before release into the environment.

Disadvantages

Clogging of the soil infiltration system (located below the packed bed filter) may be difficult to repair.

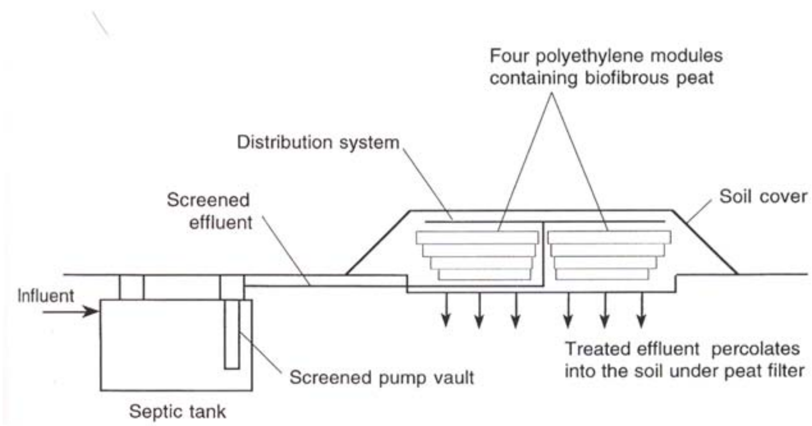


Figure 11-3

Diagram of a bottomless trickling biofilter system utilizing peat biofilter modules. (Adapted from Crites and Tchobanoglous, 1998.)

Performance
The bottomless packed bed filter provides (single-pass) treatment to wastewater before discharge to the soil. The performance before infiltration can be expected to be similar to that for the biofilter systems described in Chap. 6.

Operation and maintenance
Requirements for operation and maintenance will depend on the specific system, however, will be similar to the operation and maintenance outlined in Chap. 6.

Power and control
Pressure distribution will require a pump vault and the operation of a pump for wastewater delivery to the filter system.

Cost
The cost of the soil component of the bottomless packed bed system will no minimal compared to the biofilter treatment component.

References and other resources
Crites, R., and G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems*, WCB/McGraw-Hill, New York.

11-1.4 Glendon Biofilter®

Category	Soil discharge/treatment system
Technology	Anaerobic/aerobic biofilter
Input	Effluent from septic tank or other primary treatment
Function	Treatment/distribution
Applications	Treatment/discharge of effluent from septic tank

Background
The Glendon Biofilter system is a unique and effective treatment and distribution system. Wastewater is discharged from a septic tank or other primary treatment process to an anaerobic upflow biofilter system. After passing through the anaerobic stage, the water flows through a soil berm and into the natural soil. For additional details on the Glendon Biofilter, see Sec. 5-2.1.

Glendon BioFilter Technologies, Inc.
25448 Port Gamble Road N.E.
Poulsbo, WA 98370
E info@glendon.com

11-1.5 Mound systems

Category	Soil discharge/treatment system
Technology	Aerobic biofilter
Input	Effluent from septic tank or other primary treatment
Function	Treatment/distribution
Applications	Discharge of effluent

Background
Mounds were developed at the North Dakota Agricultural College in the 1940s. The mound systems were designed to overcome the limitations of soil discharge in areas with high groundwater, low permeability soils, and shallow soils over fractured or porous bedrock. Mounds have also been used in areas with steep slopes.

Description of process

The mound system is composed of a bed of sand and an effluent distribution system. The area to receive the mound system is tilled to break up the surface layer of the soil. A wastewater distribution system and an underlying bed of sand are placed on top of the tilled soil for treatment of the wastewater. The distribution system is covered with a geotextile fabric or similar material and a low permeability cap soil for cold weather protection. The system is then covered with soil and landscaped. Wastewater is then discharged (by gravity or under pressure) to the mound system for aerobic treatment before infiltration into the soil.

System footprint

Mounds typically range from 300 to 500 ft^2, with a height of 2 to 3 ft.

Advantages

The mound system makes it possible to provide treatment to wastewater before release into non-ideal soils, such as areas with high ground water, low permeability soils, and areas with highly porous bedrock at shallow depths. Design and use is well established.

Disadvantages

May be expensive to procure all materials needed for implementation (sand and gravel). Clogging may result in odors and wastewater surfacing. In flat areas, wastewater will need to be pumped because of elevated nature of mound. Large mounded area may require integration into landscape to avoid aesthetic concerns.

Performance

Effluent from mound systems (infiltrated into soil) expected to be comparable to single-pass sand filters of similar depth.

Operation and maintenance

Observation ports necessary for inspection of system operation. Any pumps and/or control systems will need periodic maintenance as determined by manufacturer.

Power and control

Low pressure pumps often used to deliver wastewater to mound system. Standard mound system does not utilize any internal power and control facilities.

Cost

The estimated cost to construct a mound system (not including the septic tank) is in the range of $10,000 to 15,000. Operation of a low head pump can be expected to use about 100 to 300 kWh per year.

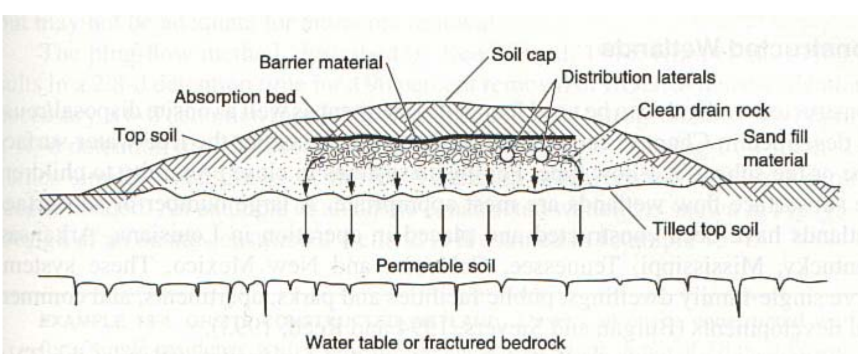


Figure 11-4

Diagram of a mound system for wastewater treatment and dispersal.
(Adapted from Crites and Tchobanoglous, 1998.)

11-1.6 NoMound® Systems

Category	Soil discharge/treatment system
Technology	High groundwater soil adsorption system
Input	Effluent from septic tank or secondary/advanced treatment
Function	Treatment/distribution
Applications	Discharge of effluent

Background
The basic NoMound onsite system is an alternative to the elevated sand mound for any location with a seasonal or regional high water table.

Description of process
A geomembrane enclosure is installed around the sides and top of the drainfield or trenches leaving the bottom open. The sidewalls of the geomembrane enclosure are installed deep enough so that the lowered groundwater level inside the NoMound forms a water seal which prevents air from flowing out of the bottom of the enclosure. Air is introduced inside of the geomembrane cap, lowering the groundwater table and creating an unsaturated zone for aerobic wastewater treatment.

System footprint
The space required for the NoMound system is the same as that needed for a conventional soil adsorption system.

Advantages
In areas with high groundwater, the NoMound system can be used as an alternative to imported aggregate/sand mounds. Because the system is installed completely underground, above ground mounds are not needed. The air supply to control the water level may also improve the treatment process in the soil.

Disadvantages
Requires an air compressor to control water level. If the geomembrane becomes punctured it will need to be repaired for proper system operation.

Figure 11-5

The complete NoMound system before the final soil cover is applied. (Adapted from the Oak Hill Company, Ltd.)

Operation and maintenance
Standard operation and maintenance is needed, similar to that for a typical soil adsorption system. In addition, the system requires periodic (6 month) inspection of the air compressor (cleaning or replacement of the air filter and check valve. The water level monitoring system should also be checked for proper operation.

Power and control
An air compressor operating half time is expected to use about 100 kWh annually. A water level monitoring device and alarm are used in case of system malfunction.

Cost
System will cost $1,000 to 2,000 in addition to the cost of the standard soil adsorption system and installation of the system.

Contact
The Oak Hill Company, Ltd.
Great Valley Corporate Center
5 Great Valley Parkway Suite 239
Malvern PA 19355
Phone (610) 648-6270
Fax (610) 644-7048
Web www.nomound.com

References and other resources
NoMound Product Brochure (2001).

11-1.7 Spray irrigation

Category	Soil discharge/treatment system
Technology	High groundwater soil adsorption system
Input	Disinfected effluent from secondary/advanced treatment system
Function	Distribution, irrigation
Applications	Residential, commercial, institutional

Background
The use of spray irrigation for the discharge of wastewater is somewhat limited due to the potential for human contact. Because the system is suited for areas with high year round water demands, it is not appropriate for all areas.

Description of process
Wastewater that has been treated in a secondary or advanced treatment process and disinfected is collected in a holding tank and periodically pumped from the holding tank to surface spray nozzles. The irrigation system is designed to apply water evenly to the landscape, similar to a conventional lawn irrigation system.

System footprint
The size of the system needed depends on the wet weather irrigation needs, so will vary by climatic zone and amount of wastewater to be discharged.

Advantages
Spray irrigation is a form of beneficial water reuse. In appropriate climates, spray irrigation can be used independent of soils provided that the soil can support vegetation, even in soils not suitable for soil adsorption systems. Studies have concluded that there is a minimized possibility for groundwater impacts when using spray irrigation with onsite treatment systems. More of the available land area can be utilized.

Disadvantages
Increased potential for human contact will necessitate frequent system monitoring/maintenance to ensure safety. In dry weather, additional water will be needed to meet irrigation demands. May be more energy intensive than some other alternatives due to the need to secondary/advanced treatment and pressure distribution. Requires minimum lot size.

Performance
Spray irrigation systems have been found to have negligible impacts on groundwater and surface water from runoff. Plant uptake has been identified as a significant removal mechanism of nitrogen.

Operation and maintenance
Spray irrigation systems require a maintenance contract to ensure the protection of human health and environmental safety. Servicing several times a year, including monitoring of onsite treatments systems, disinfection facilities, and spray irrigation systems is needed. Monitoring of subsurface and runoff water should be conducted.

Power and control
In addition to treatment system needs, the spray irrigation system will require a collection sump and pump to distribute the water to the spray nozzles.

Cost
In addition to the costs for secondary/advanced treatment and disinfection, installation of a spray irrigation system will typically cost about $1,500. Operation and maintenance costs will range from $300 to 600 a year.

Figure 11-6

A spray irrigation system installed at a home, systems can also be installed with low trajectory spray nozzles installed at ground level. (Adapted from the Virginia Department of Health.)

Contact
K-Rain Manufacturing Corporation
1640 Australian Avenue
Riviera Beach, Florida 33404
Phone   (561) 844-1002; (800) 73k-Rain
Fax   (561) 842-9493
E   Krain@K-Rain.Com
Web   www.k-rain.com/

Figure 11-7
Pop-up style spray irrigation emitters for wastewater. (Adapted from K-Rain Manufacturing Corporation.)

References and other resources

Lesikar, B. (1999) Onsite Wastewater Treatment Systems: Spray Irrigation, Texas Agricultural Extension Service, Texas A&M University System. (this and other onsite fact sheets available at texaserc.tamu.edu/catalog/topics/Waste_Management.html).

McIntyre, C., C. D'Amico, and J.H. Willenbrock (1994) Residential Wastewater Treatment and Disposal: On-Site Spray Irrigation Systems, *Proceedings of the Seventh International Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural Engineers, St. Joseph, MI.

Monnett, G.T., R.B. Reneau, and C. Hagedorn (1991) Evaluation of onsite sewage spray irrigation on marginal soils, *Proceedings of the Sixth International Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural Engineers, St. Joseph, MI.

Rubin, A.R., and B.L. Carlile (1991) Slow rate spray irrigation treatment facilities for individual homes, *Proceedings of the Sixth International Symposium on Individual and Small Community Sewage Systems*, American Society of Agricultural Engineers, St. Joseph, MI.

11-2 Drip irrigation systems

A subsurface drip irrigation system is used to apply wastewater to soil in a way that allows plants to utilize the water. Drip irrigation can be a reliable and effective method for the distribution of wastewater from onsite wastewater treatment systems to the surrounding environment.

Description of process

Drip irrigation systems for wastewater discharge typically consist of a treatment process, a pump, and the drip tubing with emitters. The treatment process needed depends on manufacturer of the drip system, but typically consists of a secondary/advanced treatment system. However, some drip systems are designed for use with screened septic tank effluent. The wastewater is collected in a sump and pumped through the drip tubing. Anti-siphon valves are placed at the high points in the drip irrigation network to prevent backflow of soil particles into the emitters.

System footprint

The size of a drip irrigation system is dependent on the amount of wastewater to be discharged and the characteristics of the soil; however, these systems are adaptable to almost all landscapes.

Advantages

Wastewater is distributed uniformly around landscape. Shallow placement of drip emitters (typically 6 in) allows for improved treatment and plant uptake of wastewater. Drip irrigation systems are an established technology.

Disadvantages

Drip irrigation systems are somewhat mechanically intensive and often use filtration devices that require periodic maintenance for proper operation. Drip emitters are small and can become clogged with particles in wastewater. Root intrusion may also be a concern for systems that do not incorporate a pesticide into the design.

Performance

Performance is expected to be better than deep trenches and comparable to shallow pipe soil adsorption systems. Because wastewater is often treated in a secondary/advanced treatment process prior to drip distribution, the wastewater discharged is typically of higher quality than septic tank effluent.

Operation and maintenance

Proper and regular maintenance is critical for drip irrigation systems. Particle filter devices need to be checked for proper operation and cleaned or replaced as necessary. Drip lines should be flushed periodically. Many systems incorporate timers and controls for automated operation, for these systems the controls and timers should be checked for proper operation.

Power and control

Typical system components include pumps and process control devices. System manufacturers and designers should be contacted for specific design details. Annual energy needs for drip irrigation controls and pumping expected to be from 500 to 1,000 kWh.

Cost

The cost to install a drip irrigation systems at a residential site can range from $2,000 to more than $10,000, in addition to primary and secondary treatment systems. The cost is a function of market variables and the degree of sophistication involved.

11-2.1 AQUA DRIP

Hydro-Action, Inc.
8645 Broussard Rd.
Beaumont, TX 77713
Phone (409) 892-3600
Fax (409) 892-0005
Web www.hydro-action.com
Model description

Wastewater from a secondary treatment process is filtered through a backwashing sand filter before discharge to the drip irrigation system.

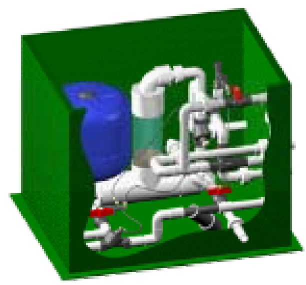


Figure 11-8

The AQUA DRIP Wastewater Effluent Management System. (Adapted from Hydro-action, Inc.)

11-2.2 BioLine

Netafim Irrigation, Inc.
5470 E. Home Avenue
Fresno, CA 93727
Phone (559) 453-6800
Fax (800) 695-4753
Web www.netafim-usa-wastewater.com
Description

Drip irrigations systems with pressure compensating emitters and self-flushing feature to provide uniform flow and resist clogging

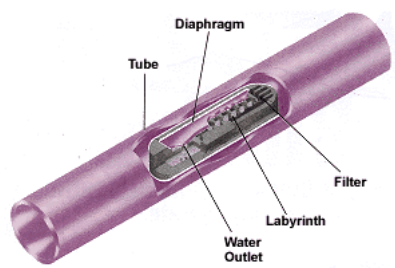


Figure 11-9

A cross-section of the BioLine drip line showing the pressure compensating emitter. (Adapted from Netafim Irrigation, Inc.)

11-2.3 Drip-Tech

P. 0. Box 5814
Austin Texas 78763
Phone (512) 329-0066
E goldberg@io.com
Web www.drip-tech.com
Description

Drip-Tech designs utilize Bioline and automatic backwashing disk filters.

Figure 11-10

A typical side trench shown during installation of a drip irrigation system. (Adapted from Drip-Tech.)

11-2.4 Perc-rite

Waste Water Systems, Inc.
P.O. Box 1023; 64 Sailors Drive, Suite 114
Ellijay, GA 30540
Phone (706) 276-3139
Fax (706) 276-6535
E info@wastewatersystems.com
Web www.wastewatersystems.com;
Description

Process for drip irrigation of septic tank effluent or secondary/advanced treatment process effluent

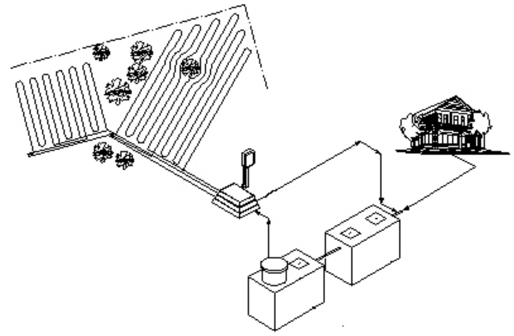


Figure 11-11

The Perc-rite system for drip irrigation of septic tank effluent (Adapted from American Manufacturing, Inc.)

11-2.5 Wasteflow

Geoflow, Inc.
200 Gate 5 Road #103
Sausalito CA 94966
Phone (415) 331-0166
Fax (415) 331-0167
Web www.geoflow.com
Description

Drip systems incorporating large orifice, biocide to inhibit biofilm growth in dripline, and herbicide to prevent root growth into emitters.

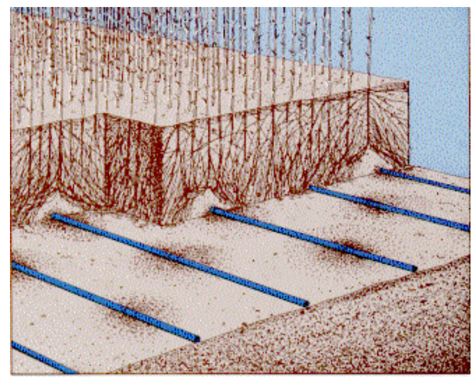


Figure 11-12

Diagram showing effects of Treflan herbicide on root growth around drip emitters. (Adapted from Geoflow, Inc.)

11-3 Gravelless distribution products

In addition to drip irrigation systems, a variety of products are available for the distribution of wastewater without gravel or other aggregate fill materials. The most common types of products are chambers (large half-pipe sections buried underground to form a cavern for wastewater infiltration) and drainpipe wrapped with a geotextile or alternate material.

Background

Gravelless systems are used as a replacement for the gravel adsorption system for the subsurface infiltration of treated effluents into the soil. The primary use for gravel in conventional systems is to provide structural support to the trench sidewalls and pipe, however, gravel is believed to decrease the overall infiltrative surface area and wastewater storage volume in the trench.

Description of process

The two basic types of gravelless systems are leaching chambers and drainage pipe. The process water is typically distributed by gravity (without lateral pipes), but may be dosed under pressure in pipe with drilled orifices. The water then infiltrates into the surrounding soil. Chamber systems have also been used as distribution systems for trickling (packed-bed) biofilters and above-grade (mound) effluent distribution systems. Technical guidelines for installation and use are available from the manufacturer.

System footprint
The system size needed depends on the soil properties at the site as well as the quantity and quality of wastewater generated. The overall area required for a gravelless systems should be equal to or less than the area needed for an aggregate based trench systems.

Advantages
Potential for reduction in the overall area required for soil dispersal of wastewater compared to gravel based systems. Installation requires less time and expense than gravel based systems. Inspection ports should be included to allow for monitoring of infiltration process. Products typically manufactured from recovered plastic. May be favorable in areas where it is expensive to import aggregate.

Disadvantages
Use of gravelless system does not eliminate possibility of soil clogging. Impact of increased infiltration rate on soil treatment systems requires additional research.

Performance
Gravelless systems have been installed at many locations in all parts of the country. The performance is typically dependent on the upstream treatment processes and the site specific factors, such as soil type and water table depth. A review of the field performance of chamber leaching systems by third parties and Infiltrator Systems staff reported the following results (Dix and May, 1998):
> Over 550,000 chamber leaching systems are in use (Infiltrator Systems, Inc., 2001).
> Properly designed systems could be operated with reduced adsorption area.
> Of the chamber systems evaluated for the study, most of the systems were found to be utilizing only 50% of the available surface area for adsorption, when sized according to specifications for gravel systems.
> In addition, it was noted that system failures were due to site conditions including (1) high ground water table, (2) surface flooding and infiltration, and (3) poor soils.

Operation and maintenance
Systems are generally installed below ground and should not require maintenance except in the event of soil clogging. Access ports should be installed to allow for monitoring of system hydraulic performance. Gravelless systems do not require regular maintenance, and thus are not typically installed with inspection facilities; however, the presence of inspection ports would facilitate monitoring activity.

Power and control
Gravelless systems may be used with gravity flow systems or pressure distribution systems.

Cost
The installation and construction costs for a gravelless system are typically range from $1,000 to 2,000, not including the septic system or other treatment devices.

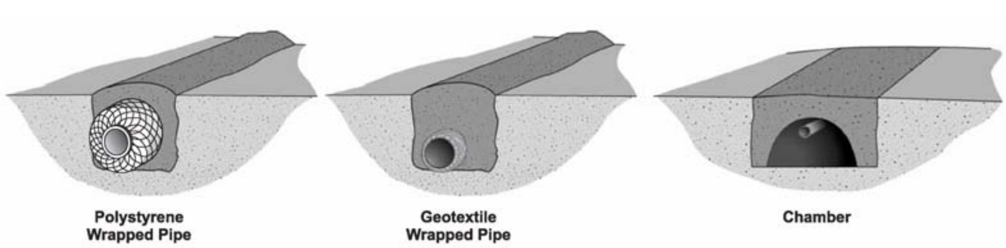


Figure 11-13
Three types of gravelless soil adsorption systems. (Adapted from U.S. EPA, 2001.)

11-3.1 Biodiffuser

ADS, Inc. (Advanced Drainage Systems)
4640 Trueman Boulevard
Hillard, OH 43026
Phone (800) 821-6710
E info@ads-pipe.com
Web www.ads-pipe.com
Model description

Manufactures standard and high capacity leaching chamber systems

Figure 11-14

Installation of the Biodiffuser chamber system. (Adapted from ADS, Inc.)

11-3.2 Cultec Contactor and Recharger

Cultec, Inc.
PO Box 280; 878 Federal Road
Brookfield, CT 06804
Phone (203) 775-4416; (800) 4CULTEC
Fax (203) 775-1462; (203) 775-5887
E custservice@cultec.com
Web www.cultec.com
Model description

A variety of leaching chamber sizes for storm water storage and wastewater infiltration.

Figure 11-15

Several models of Cultec chambers. (Adapted from Cultec, Inc.)

11-3.3 Enviro-Septic®

Presby Environmental
PO Box 617 Route 117
Sugar Hill, NH 03585
Phone 800-473-5298
Fax 603-823-8114
Web www.PresbyEnvironmental.com
Model description

Corrugated drainage pipe with a 12 in diameter wrapped with a polypropylene mat and polypropylene fabric.

Figure 11-16

The Presby Enviro-Septic and Simple-Septic. (Adapted from Presby Environmental, Inc.)

11-3.4 Envirochambers

Hancor, Inc.
Phone (888) 367-7473
Fax (888) 329-7473
E drainage@hancor.com
Web www.hancor.com
Model description

Chamber systems and corrugated drainage pipe wrapped with filter fabric.

Figure 11-17

Drainage and infiltration products from Hancor. (Adapted from Hancor, Inc.)

11-3.5 EZFlow

EZflow, LP
65 Industrial Park
Oakland, TN 38060
Phone (877) 368-8294
Fax (901) 465-1181
E tinac@ezflowlp.com
Web www.ezflowlp.com
Description

The EZflow drain basic unit is a 10 ft length of 4 in perforated corrugated plastic pipe surrounded by a geo-synthetic aggregate, held together by polyethylene netting 6, 10 and 12 in in diameter.

Figure 11-18

Installation of an EZFlow drainage system. (Adapted from EZflow, LP.)

11-3.6 Goldline GLP

Prinsco, Inc.
108 West Highway 7, PO Box 265
Prinsburg, MN 56281
Phone (320) 978-8602; (800) 992-1725
Fax (320) 978-8602
E info@prinsco.com
Web www.prinsco.com
Description

Corrugated polyethylene tubing covered in geotextile fabric

Figure 11-19

Goldline drainage pipe used for gravelless wastewater infiltration systems. (Adapted from Prinsco, Inc.)

11-3.7 In-Drains®

Eljen Corporation
125 McKee St
East Hartford, CT 06108
Phone (800) 444-1359
(860) 610-0426
Fax (860) 610-0427
E questions@eljen.com
Web www.eljen.com
Model description

The In-Drain system is composed of a cuspated plastic and geotextile fabric bundled together with an effluent distribution pipe. The system provides single-pass treatment to wastewater before infiltration into the soil. In addition to its use in soil adsorption systems, similar products are available for storm water runoff storage capacity and for curtain drain application.

Figure 11-20

The In-Drains system for the treatment and infiltration of wastewater. (Adapted from Eljen Corporation)

11-3.8 Infiltrator

Infiltrator Systems Inc.
P.O. Box 768; 6 Business Park Road
Old Saybrook, CT 06475
Phone 800-221-4436
860-577-7000
Fax 860-577-7001
E info@infiltratorsystems.com
Web www.infiltratorsystems.com
Description

Infiltrator Systems provides product technical information, reference library, design review, and testing. Company representatives are available throughout North America to provide training, education, and maintenance of local product distribution outlets. A standard one year limited warranty is included on chambers and endplates, offering product replacement in the event of defective products. Infiltrator Systems, Inc. also manufactures endplates and products to accommodate angled connecting joints and side by side chamber orientation.

Figure 11-21
Installation of Infiltrator chamber systems. (Adapted from Infiltrator Systems Inc.)

References and other resources

Dix, S., and R. May (1998) A review of field performance of chamber leaching systems, Infiltrator Systems, Inc.

U.S. EPA (2002) EPA Municipal Technology Branch: Decentralized Systems Technology Fact Sheet on Septic Tank Leaching Chamber, EPA 832-F-00-04, U.S. Environmental Protection Agency, Washington, DC.

11-4 Flow distribution products

A variety of products are available to provide flow balancing and flow dosing. Flow balancing ensures that a section of the soil adsorption system is not overloaded or can alternate dosing between two or more zones. Flow dosing discharges wastewater in discreet doses, allowing for aeration between doses and the potential for flow metering. The devices outlined in this section do not require electrical components for operation.

System footprint

Flow distribution devices are typically housed inside of a pump tank or distribution box.

Advantages

Improved distribution of wastewater may enhance the ability of the soil adsorption system to provide treatment. The systems below do not require electricity.

Disadvantages

Adding distribution components will increase the maintenance needs of an onsite treatment system.

Operation and maintenance

Depending on the specific component, typical maintenance consists of periodic inspection to confirm proper operation according to manufacturer instructions. Some valves are manually operated.

Cost

Flow distribution devices are typically less than $100.

11-4.1   Bull Run Valve

American Manufacturing Company, Inc.
P.O. Box 549
Manassas, Va. 20108-0549
Phone   (800) 345-3132
Fax   (703) 754-0058
E   info@americanonsite.com
Web   www.americanonsite.com
Product description

The Bull Run Valve is used to divert flow between two soil adsorption systems. Valve operation does not require exposure to wastewater.

Figure 11-22

The Bull Run Valve for flow control in distribution systems. (Adapted from American Manufacturing Company, Inc.)

11-4.2   Dial-A-Flow

American Manufacturing Company, Inc.
P.O. Box 549
Manassas, Va. 20108-0549
Phone   (800) 345-3132
Fax   (703) 754-0058
E   info@americanonsite.com
Web   www.americanonsite.com
Product description

Typically placed inside of the distribution box over a pipe inlet. Rotating the Dial-A-Flow increases or decreases flow rate.

Figure 11-23
The Dial-A-Flow valve. (Adapted from American Manufacturing Company, Inc.)

11-4.4   Dosing siphons

American Manufacturing Company, Inc.
PO Box 549, Manassas, Va. 20108-0549
Phone   (800) 345-3132
Fax   (703) 754-0058
E   info@americanonsite.com
Web   www.americanonsite.com

Fluid Dynamic Siphons, Inc.
PO Box 882019, Steamboat Sprgs, CO 80488
Phone   (303) 879-2494
Fax   (303) 879-4948
E   fluiddyn@cmn.net

Orenco Systems, Inc.
814 Airway Avenue, Sutherlin, OR 97479
Phone   (800) 348-9843; (541) 459-4449
Fax   (541) 459-2884
Web   www.orenco.com

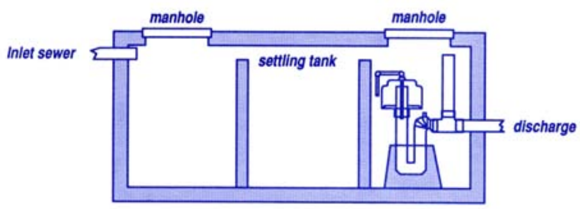


Figure 11-24
Diagram of an automatic dosing siphon used to provide discreet dosing in gravity flow systems. (Adapted from Fluid Dynamics Siphons, Inc.)

11-4.5   Hydrotek valve

K-Rain Manufacturing Corp.
1640 Australian Avenue
Riviera Beach, FL 33404
Phone   (561) 844-1002
Fax   (561) 842-9493
Web   www.k-rain.com
Description

Automatically advances to the next zone (4 to 6 zone models) each time the pump is activated.

Fig 11-25

The Hydrotek valve for flow distribution. (Adapted from K-Rain Manufacturing Corp.)

11-4.6   Polylok Dipper

PolyLok, Incorporated
173 Church Street
Yalesville, CT 06492
Phone   (203) 269-3119x20
Fax   (203) 265-4941x20
Web   www.polylok.com
Product description

Fill and empty cycle provides discreet dosing in gravity flow systems.

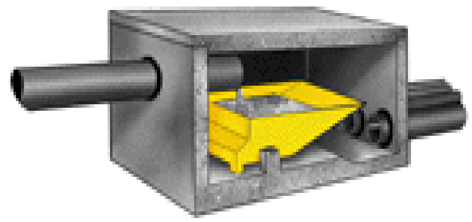


Figure 11-26

Illustration of the Polylok Dipper. (Adapted from Polylok, Inc.)

11-4.6   Polylok Equalizer

PolyLok, Incorporated
173 Church Street
Yalesville, CT 06492
Phone   (203) 269-3119x20
Fax   (203) 265-4941x20
Web   www.polylok.com
Product description

Equalizer provides adjustable flow rate control from distribution boxes.

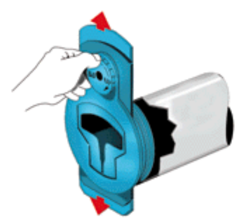


Figure 11-27

Illustration of the Polylok Equalizer. (Adapted from Polylok, Inc.)

1-4.7   Tuff-tite

Tuff-Tite Corporation
500 Capital Drive
Lake Zurich, IL 60047
Phone   (847) 550-1011; (800) 382-7009
Fax   (847) 550-8004
E   sales@tuf-tite.com
Web   www.tuf-tite.com
Product description

An assortment of distribution boxes and gas baffles

Figure 11-28

Tuf-tite drainage and septic products. (Adapted from Tuf-Tite Corporation, Inc.)

11-4.8   Zabel

Zabel Environmental Technology
PO Box 1520
Crestwood KY 40014
Phone   (502) 992-8200; (800) 221-5742
Fax   (502) 992-8201
Web   www.zabelzone.com

Product description

Pre-plumbed zone distribution systems.

Figure 11-29

Valve automatically advances to distribute wastewater to different zones. (Adapted from Zabel Environmental Technology.)

To manage onsite wastewater treatment systems properly, monitoring of process operation and performance is necessary. Because of the increasing number and complexity of onsite wastewater treatment systems, automated monitoring and control systems have become a key component to onsite treatment process management. System controls are necessary for controlling pumps, alarms, and other process equipment.

Most manufacturers of onsite wastewater treatment systems also provide basic control and alarm systems to alert the system owner of a malfunction. However, remote monitoring using telemetry systems is becoming a more feasible option for onsite applications. Telemetry is the science and technology of automatic measurement and transmission of data by wire, radio, or other means from remote sources to receiving stations for recording and analysis. The centralized management of onsite treatment systems is possible through the use of these automated monitoring and control devices.

The basic components of telemetry systems are described in this chapter. In addition to the systems listed below, most manufacturers of onsite treatment systems provide a control panel and alarm system specific for their system.

12-1 Sensors, alarms, and control devices

Sensors can be digital or analog type output devices. Sensors are used to make a measurement of a physical activity and provide a signal to a monitoring or control device. Float switches that are used for monitoring water levels are the most common digital sensors used in onsite treatment systems. Analog sensors can be used for measuring water level (using a pressure transducer), pump run time, sludge and scum depth, and constituent concentrations.

12-1.1 Conery Mfg., Inc.

1380 Enterprise Parkway
Ashland, OH 44805
Phone (419) 289-1444
Fax (419) 281-0366
E conmfg@bright.net
Web www.conerymfg.com
Description

Conery Mfg. provides a range of float switches and alarms for onsite wastewater treatment systems.

Figure 12-1

A typical float switch and alarm for high water notification and pump control. (Adapted from Conery, Mfg, Inc.)

12-1.2 Premier Tech Environment

7051 Meadow Lark Dr, Building 200, Suite 208
Birmingham Al 35242
Phone 877.295.5763
Fax 205.408.8783
Web www.premiertech.com
Model description

Control panels and float switches for monitoring liquid levels and pump control.

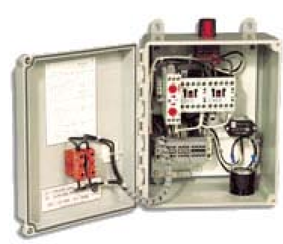


Figure 12-2

The Premier Tech control panel. (Adapted from Premier Tech Environment, Inc.)

12-1.3   Orenco Systems, Inc.

814 Airway Avenue
Sutherlin, OR 97479
Phone   (541) 459-4449
Fax   (541) 459-2884
Web   www.orenco.com
Description

Orenco manufactures control systems for all types on onsite wastewater management systems.

Figure 12-3

An Orenco control panel for pump operation and float alarms. (Adapted from Orenco Systems, Inc.)

12-1.4   SEPTICwatch™

Worldstone, Inc.
376 Route 130; PO Box 660
Sandwich, MA 02563
Phone   (508) 888-6161; (866) 279-2824
Fax   (218) 847-4617
Web   www.worldstoneinc.com
Description

The SEPTICwatch™ and GREASEwatch™ monitors provides continuous monitoring of the sludge, scum, temperature and liquid levels.

Figure 12-4

The SEPTICwatch from Wolrdstone Inc., provides continuous monitoring of sludge and scum levels in the septic tank for accurate determination of tank pumping intervals. (Adapted from Worldstone, Inc.)

12-1.5   SJE-Rhombus

22650 County Highway 6; PO Box 1708
Detroit Lakes, MN 56502
Phone   (888) 342-5753; (218) 847-1317
Fax   (218) 847-4617
E   SJE@SJERHOMBUS.COM
Web   www.sjerhombus.com
Description

A complete line of float switches, control panels, and alarms. Some control panels that interface with personal data assistants are also available.

Figure 12-5

The Data Minder control panel with PDA interface for downloading operational data. (Adapted from SJE Rhombus, Inc.)

12-2 Programmable Logic Controller (PLC)

A digital control device that receives input from system devices such as float switches and pumps. Programmable logic controllers also have output capability for controlling systems devices. For onsite wastewater treatment systems, PLCs are often used for controlling pump on and off time and can also perform advanced features, such as adjusting dosing frequency to remediate high and low water conditions.

12-2.1 Orenco Systems, Inc.

814 Airway Avenue
Sutherlin, OR 97479
Phone (541) 459-4449
Fax (541) 459-2884
Web www.orenco.com
Description

Orenco manufactures control systems for all types of onsite wastewater management systems.

Figure 12-6

A programmable logic controller manufactured by Orenco. (Adapted from Orenco Systems, Inc.)

12-2.2 Tesco Controls, Inc.

3434 52nd Avenue
Sacramento, CA 95823-9012
Phone (916) 395-8800
Fax (916) 429-2817
E sales@tescocontrols.com
Web www.tescocontrols.com
Description

Manufacturers PLCs for many water and wastewater applications.

Figure 12-7

One of the programmable logic controllers manufactured by Tesco for controlling pumps. (Adapted from Tesco Controls, Inc.)

12-3 Data loggers

Data loggers are devices used to measure and record data from an analog or digital sensor. Data loggers only record data measurements and do not transmit to remote locations. In most cases, data loggers are only able to process one type of signal, requiring additional units for more complex data input. The data is either recorded and printed on paper output or stored in a memory device and downloaded periodically. The remote monitoring systems discussed below incorporate data loggers.

12-3.1 Onset Computer

PO Box 3450
Pocasset, MA 02559-3450
Phone (800) 564-4377
Fax (508) 759-9100
E sales@onsetcomp.com
Web www.onsetcomp.com
Description

Products include a full range of data acquisition instrumentation, data loggers, and data transfer devices.

12-4 Auto dialer

The auto dialer is a relatively simple device that is programmed to call a number in the event of an alarm condition. These systems do not log or transmit data, except for the alarm condition notification. Auto dialers are useful for alerting a management organization of a high water alarm; however, more complex systems may be used to monitor multiple parameters.

12-4.1 Zabel Environmental Technology

PO Box 1520
Crestwood KY 40014
Phone (800) 221-5742
Fax (502) 992-8201
E zabel@zabelzone.com
Web www.zabelzone.com
Description

Float switches, control panels, alarms, and auto-dialers for onsite systems.

Figure 12-8

The Zabel alarm and auto dialer system. (Adapted from Zabel Environmental Technology, Inc.)

12-5 SCADA (Supervisory Control And Data Acquisition) systems

A basic SCADA system consists of a central computer that communicates with remote control points such as pumps and metering stations. At these control points, remote terminal units (RTUs) gather and manage data. The central computer is used to acquire data from the RTUs and provide control functions.

12-5.1 Bristol Babcock

1100 Buckingham Street
Watertown, CT 06795
Phone (800) 395-5497; (860) 945-2200
Fax (860) 945-2213
Web www.bristolbabcock.com
Description

Bristol Babcock supplies process control and measurement products, SCADA systems, transmitters, and services to the water and wastewater industry.

12-5.2 Industrial Control Links

12840 Earhart Avenue
Auburn, CA 95602
Phone 530-888-1800
Fax 530-888-7017
E icl@iclinks.com
Web www.iclinks.com
Description

Industrial Control Links, Inc. (ICL) designs and manufactures hardware and software solutions to collect, record, and transport information for SCADA systems, process control and industrial automation applications.

Figure 12-9

A wireless RTU from Industrial Control Links for remote process monitoring. (Adapted from Industrial Control Links, Inc.)

12-5.3 Quad Tech, LLC.

PO Box 907
Norcross, GA 30091
Phone (770) 932-0250
Fax (770) 271-8361
E mktg@quadtechllc.com
Web www.quadtechllc.com
Description
Control panels and remote communications equipment and software for SCADA systems.

12-5-4 Tesco Controls, Inc.

3434 52nd Avenue
Sacramento, CA 95823-9012
Phone (916) 395-8800
Fax (916) 429-2817
E sales@tescocontrols.com
Web www.tescocontrols.com
Description
Complete remote telemetry and SCADA systems for water and wastewater applications.

12-5.5 Zetron

PO Box 97004
Redmond, WA 98073-9704
Phone (425) 820-6363
Fax (425) 820-7031
E zetron@zetron.com
Web www.zetron.com
Description
Complete remote telemetry and SCADA systems for water and wastewater applications.

12-6 Telemetry systems

Telemetry systems make remote data acquisition and control possible and greatly extend that range of options for management of onsite treatment systems. Data is acquired from system devices and sensors and transmitted by radio or modem to a specified location. Web based telemetry systems transmit data to a server, where the data is put into a database that is accessible from any computer with internet access capabilities. In addition, logic controllers can be used to diagnose and correct system problems before a failure occurs.

12-6.1 In-Situ, Inc.

210 S. Third Street
Laramie, WY 82073-0920
Phone (800) 446-7488; (307) 742-8213
Fax (307) 721-7598
Web www.in-situ.com
Description
Water quality sensors and wireless, solar powered telemetry systems.

12-6.2 TEI/US

P.O. Box 200122
Austin, TX, 78720-0122
Phone (512) 259-2977
Fax (512) 259-1979
E tew@teicontrols.com
Web www.teicontrols.com
Description

TEI Controls can provide control and monitoring systems for many onsite applications.

Figure 12-10

TEI Controls radio telemetry systems can transmit data by radio within a 14 mile range. (Adapted from TEI/US, Inc.)

12-6.3 Telog Instruments, Inc.

830 Canning Pkwy
Victor, NY 14564
Phone (716) 742-3000
Fax (716) 742-3006
E telogsales@telog.com
Web www.telog.com
Description

Data loggers, monitoring equipment, and telemetry systems.

Figure 12-11

A remote telemetry system by Telog. (Adapted from Telog Instruments, Inc.)

12-6.4 VeriComm® by Orenco Systems, Inc.

814 Airway Avenue
Sutherlin, OR 97479
Phone (541) 459-4449
Fax (541) 459-2884
Web www.orenco.com
Description

Orenco manufactures control systems for all types on onsite wastewater management systems. The VeriComm control panel utilizes web-based communication of system operation data and online control.

Figure 12-12

The Vericomm control panel. (Adapted from Orenco Systems, Inc.)

Table A-1

Factors for the conversion of U.S. Customary Units to the International System (SI) of Units[a]

Multiply the U.S. customary unit		By	To obtain the corresponding SI unit	
Name	Abbreviation		Name	Symbol
acre	ac	40476.8564	square meter	m^2
acre	ac	0.4047	hectare	ha
atmosphere	atm	1.0133×10^5	pascals	Pa (N/m^2)
British thermal unit	Btu	1.0551	kilojoule	kJ
British thermal unit	Btu	0.2931	kilowatt per hour	kW•h
British thermal units per cubic foot	Btu/ft^3	37.259	kilojoules per cubic meter	kJ/m^3
British thermal units per hour per square foot	Btu/h•ft	23.158	joules per second per square meter	$J/s{\bullet}m^2$
British thermal units per square foot per hour	$Btu/ft^2{\bullet}h$	3.1525	kilowatt per meter square per second	$kW/m^2{\bullet}s$
British thermal units per kilowatt-hour	Btu/kWh	1.0551	kilojoules per kilowatt-hour	kJ/kWh
British thermal units per pound	Btu/lb	2.326	kilojoules per kilogram	kJ/kg
British thermal units per pound mass per degree fahrenheit	$Btu/lb_m{\bullet}°F$	4.187	joules per kilogram per kelvin	J/kg•K
British thermal units per ton	Btu/ton	1.16×10^{-3}	kilojoules per kilogram	kJ/kg
degree Celsius	°C	plus 273	Kelvin	K
calorie	C	4.187	joule	J (W•s)
cubic foot	ft^3	0.0283	cubic meter	m^3
cubic foot	ft^3	28.3168	liter	L
cubic feet per minute	ft^3/min	4.7190×10^{-4}	cubic meters per second	m^3/s
cubic feet per minute	ft^3/min	0.4719	liters per second	L/s
cubic feet per second	ft^3/s	2.8317×10^{-4}	cubic meters per second	m^3/s
cubic yard	yd^3	0.7646	cubic meter	m^3
day	d	86.4000	kilosecond	ks
degree Fahrenheit	°F	0.555(°F - 32)	degree Celsius	°C
foot	ft	0.3048	meter	m
feet per minute	ft/min	5.0800×10^{-3}	meters per second	m/s
feet per second	ft/s	0.3048	meters per second	m/s
feet of water	ft H_2O	2.989×10^{-2}	pascal	Pa (N/m^2)
gallon	gal	3.7854×10^{-3}	cubic meter	m^3
gallon	gal	3.7854	liter	L
gallons per minute	gal/min	6.3090×10^{-2}	liters per second	L/s

Multiply the U.S. customary unit		By	To obtain the corresponding SI unit	
Name	Abbreviation		Name	Symbol
grain	gr	0.0648	gram	g
horsepower	hp	0.7457	kilowatt	kW
horsepower-hour	hp-h	2.6845	megajoule	MJ
inch	in	2.5400	centimeter	cm
inch	in	2.5400×10^{-2}	meter	m
Inches of mercury	in Hg	3.367	pascal	Pa (N/m^2)
kilowatt-hour	kWh	3.600	megajoule	MJ
pound force	lb_f	4.448	newton	N
pound mass	lb_m	0.4536	kilogram	kg
pound mass per hour	lb_m/h	0.4536	kilogram per second	kg/s
pounds per capita per day	lb/capita•d	0.4536	kilograms per capita per day	kg/capita•d
Pounds per cubic foot	lb/ft^3	16.0181	kilograms per cubic meter	kg/m^3
pounds per cubic yard	lb/yd^3	0.5933	kilograms per cubic meter	kg/m^3
pounds per square foot	lb/ft^2	47.8803	newtons per square meter	N/m^2
pounds per square inch	lb/in^2	6.8948	kilonewtons per square meter	kN/m^2
million gallons per day	Mgal/d	4.3813×10^{-2}	cubic meters per second	m^3/s
miles	mi	1.6093	kilometer	km
miles per hour	mi/h	1.6093	kilometers per hour	km/h
miles per hour	mi/h	0.4470	meters per second	m/s
miles per gallon	mpg	0.425	kilometers per liter	km/L
ounce	oz	28.3495	gram	g
square foot	ft^2	9.2903×10^{-2}	square meter	m^2
square inch	in^2	6.452×10^{-4}		
square mile	mi^2	2.5900	square kilometer	km^2
square yard	yd^2	0.8361	square meter	m^2
ton (2000 pounds mass)	ton (2000 lb_m)	907.2	kilogram	kg
watt-hour	Wh	3.6000	kilojoule	kJ
yard	yd	0.9144	meter	m

[a] Adapted from Crites and Tchobanoglous (1998).

Table A-2

Conversion factors for commonly used wastewater treatment plant design parameters[a]

To convert multiply in direction shown by arrows			
U.S. units	→	←	SI units
Btu	1.0551	0.9478	kJ
Btu/lb	2.3241	0.4303	kJ/kg
Btu/ft^2•°F•h	5.6735	0.1763	W/m^2•°C
bu/ac•yr	2.4711	0.4047	bu/ha•yr
ft/h	0.3048	3.2808	m/h
ft/min	18.2880	0.0547	m/h
ft^3/capita	0.0283	35.3147	m^3/capita
ft^3/gal	7.4805	0.1337	m^3/m^3
ft^3/ft•min	0.0929	10.7639	m^3/m•min
ft^3/lb	0.0624	16.0185	m^3/kg
ft^3/Mgal	7.04805×10^{-3}	133.6805	$m^3/10^3\ m^3$
ft^2/Mgal•d	407.4611	0.0025	$m^{2/}10^3 m^3$•d
ft^3/ft^2•h	0.3048	3.2808	m^3/m^2•h
$ft^3/10^3$ gal•min	7.04805×10^{-3}	133.6805	m^3/m^3•min
ft^3/min	1.6990	0.5886	m^3/h
$ft^3/10^3\ ft^3$•min	0.001	1,000.0	m^3/m^3•min
gal	3.7854	0.2642	L
gal/ac•d	0.0094	106.9064	m^3/ha•d
gal/ft•d	0.0124	80.5196	m^3/m•d
gal/ft^2•d	0.0407	24.5424	m^3/m^2•d
gal/ft^2•d	0.0017	589.0173	m^3/m^2•h
gal/ft^2•d	0.0283	35.3420	L/m^2•min
gal/ft^2•d	40.7458	2.4542×10^{-2}	L/m^2•d
gal/ft^2•min	2.4448	0.4090	m/h
gal/ft^2•min	40.7458	0.0245	L/m^2•min
gal/ft^2•min	58.6740	0.0170	m^3/m^2•d
$hp/10^3$ gal	0.197	5.0763	kW/m^3
$hp/10^3\ ft^3$	26.3342	0.0380	$kW/10^3\ m^3$
in	25.4	3.9370×10^{-2}	mm
in Hg (60 °F)	3.3768	0.2961	kPa Hg (60 °F)
Mgal/ac•d	0.9354	1.0691	m^3/m^2•d
lb/ac	1.1209	0.8922	kg/ha
lb	0.4536	2.2046	kg
lb/hp•h	0.6083	1.6440	kg/kW•h
lb/Mgal	0.1198	8.3454	g/m^3

To convert multiply in direction shown by arrows			
U.S. units	→	←	SI units
lb/Mgal	1.1983×10^{-4}	8345.4	kg/m^3
lb/ft^2	4.8824	0.2048	kg/m^2
lb_f/in^2 (gage)	6.8948	0.1450	kPa (gage)
$lb/ft^3 \cdot h$	16.0185	0.0624	$kg/m^3 \cdot h$
$lb/10^3\ ft^3 \cdot d$	0.0160	62.4280	$kg/m^3 \cdot d$
ton/ac	2.2417	0.4461	Mg/ha
yd^3	0.7646	1.3079	m^3

[a] Adapted from Crites and Tchobanoglous (1998).

References

Crites, R., and G. Tchobanoglous (1998) *Small and Decentralized Wastewater Management Systems*, WCB/McGraw-Hill, New York.