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Decentralized Systems Technology Fact Sheet
Aerobic Treatment

DESCRIPTION

Natural treatment of biological waste has been practiced for centuries. However, engineered aerobic biological treatment of wastewater has been practiced in the United States, on a large scale, for only a few decades. In fact, in 1925, 80 percent of all cities in the United States with populations of over 100,000 had no treatment systems at all (Linsley 1972). The basic aerobic treatment process involves providing a suitable oxygen rich environment for organisms that can reduce the organic portion of the waste into carbon dioxide and water in the presence of oxygen. With the ever increasing development of land, both suburban and rural, large central sewerage systems have not always been cost-effective or available. Many homeowners still rely on individual septic tank or other systems to treat and dispose of household wastewater onsite.

Historically, aerobic treatment was not feasible on a small scale, and septic tanks were the primary treatment device, but recent technology advances make individual aerobic treatment systems efficient and affordable. Aerobic systems are similar to septic systems in that they both use natural processes to treat wastewater. But unlike septic (anaerobic) treatment, the aerobic treatment process requires oxygen. Aerobic treatment units, therefore, use a mechanism to inject and circulate air inside the treatment tank. Because aerobic systems use a higher rate process, they are able to achieve superior effluent quality. The effluent can be discharged to the subsurface as in a septic tank leach field or, in some cases, discharged directly to the surface.

Current Technologies

Individual aerobic systems have been in place since the 1950's, however, these early systems consisted of little more than an aerator placed in a traditional septic tank. They were prone to noise, odor and maintenance complaints, and were used only where standard septic tanks were not feasible. The newer aerobic treatment units are pre-engineered and operate at a high level of efficiency. The demand for these units and the desire for direct surface discharge of the treated waste stream has led to a certification process by the National Sanitation Foundation (NSF). This certification (NSF Standard 40 for Individual Wastewater Treatment Plants) applies to plants with capacities of up to 1,500 gallons per day, and leads to approval as a Class I or Class II plant. A Class I certification indicates performance to EPA Secondary Treatment Guidelines for three parameters: BOD, suspended solids and pH. Noise levels, odors, oily films and foaming are also measured.. The Class II criteria require that not more than 10% of the effluent $CBOD_5$ values exceed 60 mg/L and that TSS not exceed 100 mg/L.

As of June 2000, 15 manufacturers carry NSF 40 Class I Certification with available capacities ranging from 1514.2 Liters/day to 5,678.1 Liters/day (400 to 1,500 gallons per day). Table 1 provides a list of the certified manufacturers, the number of models available, and the range of flows treated. It is important to note that the NSF certified Product Listing is continually changing. The NSF should be contacted directly to confirm the status of the listing provided in Table 1. Table 2 shows the NSF Class I effluent performance limits.

TABLE 1 MANUFACTURERS CARRYING NSF CLASS I CERTIFICATION*

Company	Location	Number of Certified Models	Flow Range (gpd)
Alternative Wastewater Systems, Inc.	Batavia, IL	5	500-1500
American Wastewater Systems, Inc.	Duson, LA	1	500
Aquarobic International	Front Royal, VA	24	500-1500
Bio-Microbics	Shawnee, KS	4	500-1500
Clearstream Wastewater Systems, Inc.	Beumont, TX	10	500-1500
Consolidated Treatment Systems, Inc.	Franklin, OH	10	500-1500
Delta Environmental Productss	Denham Springs, LA	9	400-1500
H.E. McGrew, Inc.	Bossier City, LA	4	500-750
Hydro-Action, Inc.	Beaumont, TX	7	500-1500
Jet, Inc.	Cleveland, OH	6	500-1500
Microseptec, Inc.	Laguna Hills, CA	2	600-1500
National Wastewater Systems, Inc.	Lake Charles, LA	1	500
Nordbeton North America, Inc.	Lake Monroe, FL	1	600
Norweco, Inc.	Norwalk, OH	10	500-1500
Thomas, Inc.	Sedro Woolley, WA	6	500-1000

* As of June 19, 2000. This list is continually changing. Please contact NSF to confirm the status of any listing.
Source: National Sanitation Foundation, 2000

TABLE 2 NSF CLASS I EFFLUENT PERFORMANCE LIMITS

BOD & SS	pH	Color	Odor	Foam	Noise
• 30mg/L (2.504 x 10^{-7} lb/gal) (Monthly Average)	6.0-9.0 Units	15 Units	Non-Offensive	None	<60dbA @20 feet

Source: NSF Evaluation of JET Model J-500 (1998).

APPLICABILITY

Although there have been small scale "home aerobic systems" in the United States for more than 50 years, their use has been fairly limited, in part, because of the widespread use of septic systems, which are relatively inexpensive and easy to maintain. They are the most common onsite wastewater treatment systems in rural areas. However, many households may not be well suited for septic systems.

For example, septic systems are not suitable for all decentralized wastewater treatment applications. In fact, approximately two-thirds of all land area in the United States is estimated to be unsuitable for the installation of septic systems (Linsley 1972). Some homes may not have enough land area or appropriate soil conditions to accommodate the soil absorption drainfield. In some communities, the water table is too high to allow the drainfield to give adequate treatment to the wastewater before it is returned to the groundwater.

Other site-related concerns include homes located on wooded lots or on lots close to a body of water. Homeowners in wooded areas may not want to clear enough land to install a septic tank and drainfield, and wastewater treated by a septic system is often not of high enough quality to be discharged near a body of water.

One of the most common reasons to select aerobic wastewater treatment units is to replace failing septic systems, which are a major source of groundwater pollution in some areas. If a failed septic system needs to be replaced or if a site is inappropriate for a septic system, aerobic wastewater treatment may be a viable option.

ADVANTAGES AND DISADVANTAGES

Advantages:

- Can provide a higher level of treatment than a septic tank
- Helps protect valuable water resources where septic systems are failing
- Provides an alternative for sites not suited for septic systems
- May extend the life of a drainfield
- May allow for a reduction in drainfield size
- Reduces ammonia discharged to receiving waters

Disadvantages:

- More expensive to operate than a septic system
- Requires electricity
- Includes mechanical parts that can break down
- Requires more frequent routine maintenance than a septic tank
- Subject to upsets under sudden heavy loads or when neglected
- May release more nitrates to groundwater than a septic system

DESIGN CRITERIA

On-site aerobic processes typically produce a higher degree of treatment than septic tanks, but periodic carryover of solids due to sludge bulking, chemical disinfection addition, or excessive sludge buildup can result in substantial variability of effluent quality. Regular, semi-skilled operation and maintenance are required to ensure proper functioning of moderately complex equipment. Inspections every two months are recommended. Power is required to operate aeration equipment and pumps. Absorption beds are dependent upon site and soil conditions, and are generally limited to sites with percolation rates less than 2.4 minutes/millimeter (60 minutes/inch), depth to water table or bedrock of 0.61 to 1.2 meters (2 to 4 feet), and level or slightly sloping topography.

Two aerobic primary systems have been adapted for onsite use: suspended growth and fixed film. In suspended growth systems, the microorganisms responsible for the breakdown of wastes are maintained in a suspension with the waste stream. In fixed film systems, the microorganisms attach to an inert medium. Very few commercially produced fixed film systems are available for onsite application, and they include a variety of proprietary devices, making it difficult to prescribe design guidelines. In many cases, however, design guidelines for fixed film systems are similar to those applied to suspended growth systems.

Configuration

Most aerobic treatment units designed for individual home application range in capacity from 1514 to 5678 Liters (400 to 1,500 gallons), which includes the aeration compartment, settling chamber, and in some units, a pretreatment compartment. Based upon average household flows, this volume will provide total hydraulic retention times of several days.

Pretreatment

Some aerobic units provide a pretreatment step to remove grease, trash and garbage grindings. Pretreatment devices include trash traps, septic tanks, comminutors, and aerated surge chambers. The use of a trash trap or septic tank before the extended aeration process reduces problems with floating debris in the final clarifier, clogging of flow lines, and plugging of pumps. Pretreatment is required in fixed film systems to prevent process malfunction.

Flow Mode

Suspended growth aerobic treatment plants may be designed as continuous or batch flow systems. The simplest continuous flow units provide no flow equalization and depend upon aeration tank volume and/or baffles to reduce the impact of hydraulic surges. Some units use more sophisticated flow dampening devices, including air lift or float-controlled mechanical pumps to transfer the wastewater from aeration tank to clarifier. Still other units provide multiple-chambered tanks to attenuate flow. The batch (fill and draw) flow system eliminates the problem of hydraulic variation. This unit collects and treats wastewater over a period of time (usually one day), then discharges the settled effluent through pumping at the end of the cycle. Fixed film treatment plants operate on continuous flow.

Method of Aeration

Oxygen is transferred to the waste stream by diffused air, sparged turbine, or surface entrainment devices. When diffused air systems are used, low pressure blowers or compressors force the air through diffusers on the bottom of the tank. The sparged turbine uses a diffused air source and external mixing, usually from a submerged flat-bladed turbine. The sparged turbine is more complex than the simple diffused air system. A variety of surface entrainment devices are used in package plants to aerate and mix the wastewater. Air is entrained and circulated in the mixed liquor through violent agitation from mixing or pumping. Oxygen transfer efficiencies for these small package plants are normally low (3.4 to 16.9 kg O_2/MJ or 0.2 to 1.0 lb O_2/hp/hr) as compared with large-scale systems which may transfer 50.7 kg O_2/MJ or more (3+ lbs O_2/hp/hr). This difference is primarily due to the high power inputs to the smaller units. Normally, there is sufficient oxygen transferred to produce high oxygen levels. In an attempt to reduce power requirements or enhance nitrogen removal, some units use cycled aeration periods. Care must be taken to avoid developing poor settling biomass when cycled aeration is used.

Mixing the aeration tank contents is also an important consideration in the design of oxygen transfer devices. Rule of thumb requirements for mixing in aeration tanks range from 0.465 to 0.931 kW/m^3 (0.5 to 1 hp/1,000 ft^3) depending upon reactor geometry and type of aeration or aeration system configuration. Commercially available package units are reported to deliver mixing inputs ranging from 0.005 to 2.8 kW/m^3 (0.2 to 3 hp/1,000 $ft^{3)}$. Solids deposition problems may develop in units with lower mixing intensities.

Biomass Separation

The clarifier is critical to the successful performance of the suspended growth process. A majority of commercially available package plants provide simple gravity separation. Weir and baffle designs have not been given much attention in package units. Weir lengths of at least 12 in. (30 cm) are preferred and sludge deflection baffles (Stamford baffles) should be included as a part of the outlet design. The use of gas deflection barriers is a simple way to keep floating solids away from the weir area.

Upflow clarifier devices have been used to improve separation, but hydraulic surges must be avoided in these systems. Filtration devices have also been employed in some units, but they are very susceptible to clogging.

Controls and Alarms

Most aerobic units are supplied with some type of alarm and control system to detect mechanical breakdown and to control the operation of electrical components. They do not normally include devices to detect effluent quality or biomass deterioration. These control systems are subject to corrosion because they contain electrical components. All electrical components should be waterproofed and regularly serviced to ensure their continued operation.

Additional Construction Features

Typical onsite extended aeration package plants are constructed of noncorrosive materials, including reinforced plastics and fiberglass, coated steel, and reinforced concrete. The unit may be buried as long as there is easy access to all mechanical parts, electrical control systems, and appurtenances requiring maintenance such as weirs, air lift pump lines, etc. Units may also be installed above ground, but should be properly housed to protect against severe climatic conditions. Installation should be in accordance with the manufacturers specifications.

Appurtenances for the plant should be constructed of corrosion-free materials including polyethylene plastics. Air diffuser support legs are normally constructed from galvanized steel or an equivalent. Large-diameter air lift units should be used to avoid clogging problems. Mechanical units should be waterproofed and/or protected from the elements.

For fixed film systems, synthetic packing or attachment media are preferred over naturally occurring materials because they are lighter, more durable, and provide better void volume-surface area characteristics.

Since blowers, pumps, and other prime movers are abused by exposure to severe environments, lack of attention, and continuous operation, they should be designed for heavy duty use. They should be easily accessible for routine maintenance and tied into an effective alarm system.

PERFORMANCE

In extended aeration package plants, long hydraulic and solids retention times (SRT) are maintained to ensure a high degree of treatment at minimum operational control, to hedge against hydraulic or organic overload to the system, and to reduce sludge production. Since waste of accumulated solids is not routinely practiced in many of these units, SRT increases to a point where the clarifier can no longer handle the solids, which will be uncontrollably wasted in the effluent. Treatment performance (including nitrification) normally improves with increasing hydraulic retention time and SRT to a point where excessive solids build-up will result in high suspended solids washout. This is one of the biggest operational problems with these extended aeration units, and is often the reason for poor performance.

Dissolved oxygen concentrations in the aeration tank should exceed 2 mg/L (1.669×10^{-8} pounds/gallon) to insure a high degree of treatment and a good settling sludge. Normally, onsite extended aeration plants supply an excess of dissolved oxygen due to minimum size restrictions on blower motors or mechanical drives. An important element of aeration systems is the mixing provided by the aeration process. Package units should be designed to provide sufficient mixing to ensure good suspension of solids and mass transfer of nutrients and oxygen to the microbes.

Wastewater characteristics may also influence performance of the process. Excess amounts of certain cleaning agents, grease, floating matter, and other detritus can cause process upsets and equipment malfunctions.

Process efficiency may also be affected by temperature, generally improving with increasing temperature.

The clarifier is an important part of the treatment process. If the biomass cannot be properly separated from the treated effluent, the process will fail. Clarifier performance depends upon the settleability of the biomass, the hydraulic overflow rate, and the solids loading rate. Hydraulic surges can result in serious clarifier malfunctions. As mentioned previously, high solids loadings caused by accumulation of mixed liquor solids result in eventual solids carryover. Excessively long retention times for settled sludges in the clarifier may result in gasification and flotation of these sludges. Scum and floatable material not properly removed from the clarifier surface will also impair effluent quality.

Generally, extended aeration plants produce a high degree of nitrification since hydraulic and solids retention times are high. Reductions of phosphorus are normally less than 25 percent. The removal of indicator bacteria (fecal coliforms) in onsite extended aeration processes is highly variable and not well documented. Reported values of fecal coliforms appear to be about two orders of magnitude lower in extended aeration effluents than in septic tank effluents.

Aerobic units can achieve higher BOD_5 removals than septic tanks, but suspended solids removals, which are highly dependent on solids separation methods, are similar. Nitrification is normally achieved, but little reduction in phosphorus is accomplished. NSF studies indicate that suspended growth units can provide from 70 to 90 percent BOD_5 and SS reductions for combined household wastewater, yielding effluent BOD_5 and suspended solids concentrations as low as 20 mg/l.

OPERATION AND MAINTENANCE

General Plant Operation

The activated sludge process can be operated by controlling only a few parameters; the aeration tank dissolved oxygen, the return sludge rate, and the sludge wasting rate. For onsite package plants, these control techniques are normally fixed by mechanical limitations so that very little operational control is required. Dissolved oxygen is normally high and cannot be practically controlled except by "on or off" operation. Experimentation with the process may dictate a desirable cycling arrangement using a simple time clock control that results in power savings and may also achieve some nitrogen removal.

The return sludge rate is normally fixed by pumping capacity and pipe arrangements. Return sludge pumping rates often range from 50 to 200 percent of the incoming flow. They should be high enough to reduce sludge retention times in the clarifier to a minimum (less than one hr), yet low enough to discourage pumping of excessive amounts of water with the sludge. Time clock controls may be used to regulate return pumping.

Sludge wasting is manually accomplished in most package plants, usually during routine maintenance. Through experience, the technician knows when mixed liquor solids concentrations become excessive, resulting in excessive clarifier loading. Usually 8 to 12-month intervals between wasting is satisfactory, but this varies with plant design and wastewater characteristics. Wasting is normally accomplished by pumping mixed liquor directly from the aeration tank. Wasting of approximately 75 percent of the aeration tank volume is usually satisfactory. Wasted sludge must be handled properly.

Start-up

Prior to actual start-up, a dry checkout should be performed to insure proper installation. Seeding of the plant with bacterial cultures is not required as they normally develop within a 6 to 12-week period. Initially, large amounts of white foam may develop, but will subside as mixed liquor solids increase. During start-up, it is advisable to return sludge at a high rate. Monitoring by qualified maintenance personnel is desirable during the first month of startup.

Routine Operation and Maintenance

The maintenance process for suspended growth systems is more labor-intensive than for septic systems and requires semi-skilled personnel. Based upon field experience with these units, 12 to 48 man-hours per year plus analytical services are required to ensure reasonable performance. Power requirements are variable, but range between 2.5 to 10 kWh/day (8,530.8 to 34,123.2 Btu/day). Maintenance for fixed film systems is less labor-intensive but still requires semi-skilled personnel. Based upon limited field experience, 8 to 12 man-hours per year plus analytical services are required for adequate performance. Power requirements depend upon the device employed, but range from 1 to 4 kWh/day (3,412.3 to 13,649.3 Btu/day). Maintenance for both types of aerobic treatment units is usually completed through routine contract services. No chemicals are required for either method unless chemical disinfection or additional nutrient removal (N and P) is required for surface discharge.

Operational Problems

Major mechanical maintenance problems for onsite treatment units include blower or mechanical aerator failure, pump and pipe clogging, electrical motor failure, corrosion and/or failure of controls, and electrical malfunctions. Careful attention to a maintenance schedule will reduce these problems and alleviate operational problems due to the biological process upset. Emphasis should be placed on adequate maintenance checks during the first 2 or 3 months of operation.

COSTS

Costs for both suspended growth and fixed film systems of between 1,892 and 5,678 Liters/day (500 to 1,500 gallons per day) are typically in the $2,500 to $9,000 cost range, installed. These costs have been updated using the ENR construction cost index (ENR=6076). These units need more frequent maintenance than a traditional septic tank, and quarterly servicing is recommended. This maintenance cost averages $350 per year. Since many of these systems are being installed to replace failed septic systems, additional costs may be incurred to account for site conditions and additional piping.

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