United States Environmental Protection Agency | Office of Water Washington, D.C. | EPA 832-F-99-065 September 1999

Wastewater Technology Fact Sheet
Fine Bubble Aeration

DESCRIPTION

In wastewater treatment processes, aeration introduces air into a liquid, providing an aerobic environment for microbial degradation of organic matter. The purpose of aeration is two-fold: 1) to supply the required oxygen to the metabolizing microorganisms and 2) to provide mixing so that the microorganisms come into intimate contact with the dissolved and suspended organic matter.

The two most common aeration systems are subsurface and mechanical. In a subsurface system, air is introduced by diffusers or other devices submerged in the wastewater. A mechanical system agitates the wastewater by various means (e.g., propellers, blades, or brushes) to introduce air from the atmosphere.

Fine pore diffusion is a subsurface form of aeration in which air is introduced in the form of very small bubbles. Since the energy crisis in the early 1970s, there has been increased interest in fine pore diffusion of air as a competitive system due to its high oxygen transfer efficiency (OTE). Smaller bubbles result in more bubble surface area per unit volume and greater OTE.

APPLICABILITY

Saukville Wastewater Treatment Plant, Saukville, Wisconsin

The Saukville Wastewater Treatment Plant (SWTP) uses fine bubble aeration to increase treatment efficiency and oxygen transfer, as well as reduce power costs. Initially, the plant used stainless-steel coarse bubble diffusers requiring two centrifugal blowers. Although these diffusers required little maintenance, oxygen transfer was inadequate to meet process needs, and power requirements were excessive.

In an attempt to reduce power costs and increase treatment plant efficiency, the plant was retrofitted with a combination of coarse bubble and fine bubble ceramic diffusers in 1985. One of the two treatment cells was retrofitted with fine bubble ceramic diffusion, and the second retained its coarse bubble diffusion system. This reduced power requirements by eliminating the need for one blower.

After start-up, it was noticed that the mixed liquor dissolved oxygen (DO) levels were not as high in the fine bubble cell as in the coarse bubble cell, due to uneven air distribution between cells. To correct this, a positive displacement blower was added to the fine bubble cell. To reduce fouling of the ceramic diffusers, an in-place gas-cleaning system was installed to inject anhydrous hydrochloric acid into the air stream while the system was in operation.

In 1990, the plant switched to fine bubble membrane diffusers, which were interchangeable with the ceramic diffusers. The ceramic and membrane efficiencies were comparable, so few adjustments in air rate were needed. The SWTP was awarded the U.S. Environmental Protection Agency Award of Excellence in 1991 based on overall energy savings and optimized operations and maintenance practices.

Renton Wastewater Treatment Plant, Renton, Washington

The Renton Wastewater Treatment Plant serves the urban and suburban areas east, south, and north of Lake Washington, just east of Seattle. Rising power costs created a need for modification of its coarse bubble aeration system.

Perforated membrane fine bubble diffusers were selected for an in-plant study in 1982. These diffusers were placed in the first two passes of one aeration tank, while the other tanks retained their coarse bubble units. DO was compared in the two systems, and it was determined that the perforated membrane diffusers required 30 to 40% less air than coarse bubble diffusers to maintain a comparable mixed liquor DO. Total energy consumption decreased from 390 to 355 kW/1,000 m^3 after installation of the fine bubble diffusers.

Ridgewood Wastewater Treatment Plant, Ridgewood, New Jersey

The Ridgewood Wastewater Treatment Plant (RWTP) was retrofitted from coarse bubble diffusion to a fine pore diffusion aeration system in 1983. Fine pore aeration would allow the use of one blower and maintain the same oxygen utilization rate as provided by the coarse bubble system. Oxygen transfer studies were performed on the fine pore ceramic dome diffusers in order to compare results with the coarse bubble diffusers.

The results showed that the coarse bubble diffuser had an average standard oxygen transfer efficiency (SOTE) under field conditions of 4.8% with an average alpha (α) of 0.55. In contrast, with two tanks in operation, the fine pore system had an average SOTE under field conditions of about 9.5% and an average α of 0.4 during normal daytime high-load operation. Alpha is defined as the ratio of KLa (volumetric mass transfer coefficient) of a clean diffuser in process water to the KLa of the same diffuser in clean water.

Two methods of cleaning were used at the RWTP: anhydrous hydrochloric acid brushing and water hosing. Installation of the fine pore aeration system achieved the oxygen utilization desired, reduced power consumption by approximately 28%, and resulted in a significant improvement in effluent quality with respect to nitrification.

ADVANTAGES AND DISADVANTAGES

Some advantages and disadvantages of various fine pore diffusers are listed below:

Advantages

- Exhibit high OTEs.
- Exhibit high aeration efficiencies (mass oxygen transferred per unit power per unit time).
- Can satisfy high oxygen demands.
- Are easily adaptable to existing basins for plant upgrades.
- Result in lower volatile organic compound emissions than nonporous diffusers or mechanical aeration devices.

Disadvantages

- Fine pore diffusers are susceptible to chemical or biological fouling, which may impair transfer efficiency and generate high head loss. As a result, they require routine cleaning. (Although not totally without cost, cleaning does not need to be expensive or troublesome.)
- Fine pore diffusers may be susceptible to chemical attack (especially perforated membranes). Therefore, care must be exercised in the proper selection of materials for a given wastewater.
- Because of the high efficiencies of fine pore diffusers at low airflow rates, airflow distribution is critical to their performance and selection of proper airflow control orifices is important.
- Because of the high efficiencies of fine pore diffusers, required airflow in an aeration

basin (normally at the effluent end) may be dictated by mixing - not oxygen transfer.

- Aeration basin design must incorporate a means to easily dewater the tank for cleaning. In small systems where no redundancy of aeration tanks exists, an in-situ, nonprocess-interruptive method of cleaning must be considered.

DESIGN CRITERIA

Diffusers

In the past, various diffusion devices have been classified based on their OTE as either fine bubble or coarse bubble. Since it is difficult to clearly demarcate or define between fine and coarse bubbles, diffused aeration systems have been classified based on the physical characteristics of the equipment. Diffused aeration systems can be classified into three categories:

- Porous (fine bubble) diffusers: Fine pore diffusers are mounted or screwed into the diffuser header pipe (air manifold) that may run along the length or width of the tank or on a short manifold mounted on a movable pipe (lift pipe). These diffusers come in various shapes and sizes, such as discs, tubes, domes, and plates.

- Nonporous (coarse bubble) diffusers: The common types of nonporous diffusers are fixed orifices (perforated piping, spargers, and slotted tubes); valved orifices; and static tubes. The bubble size of these diffusers is larger than the porous diffusers, thus lowering the OTE.

- Other diffusion devices: These include jet aerators (which discharge a mixture of air and liquid through a nozzle near the tank bottom); aspirators (mounted at the basin surface to supply a mixture of air and water); and U tubes (where compressed air is discharged into the down leg of a deep vertical shaft).

Types of fine pore diffusers

Fine pore diffusers (discs, tubes, domes, and plates) are usually made from either ceramics, plastics, or flexible perforated membranes. Although many materials can be used to make fine pore diffusers, only these few are being used due to cost considerations, specific characteristics, market size, and other factors.

Ceramic media diffusers have been in use for many years and have essentially become the standard for comparison since, in the past, they were the primary media in the fine pore aeration market. Ceramic, plastic, and flexible materials are resistant to the chemicals used in wastewater treatment. Discussed below are common types of fine bubble diffusers. However, recent advances in technology have resulted in modifications to these types, which are shown in Figure 1.

3Disc diffusers

Disc diffusers are relatively flat and range from approximately 18 to 24 cm in diameter with thicknesses of 13 to 19 mm. Materials for discs include ceramics, porous plastics, and perforated membranes. Therefore, thicknesses vary, as do construction features. Currently, manufacturers provide plenums or base plates that will accept all materials.

The disc is mounted on a plastic saddle-type base plate, and either a center bolt or a peripheral clamping ring is used to secure the media and the holder together. More commonly, the disc is attached to the holder via a screw-on retainer ring. Disc diffusers are designed to have an airflow range of 0.25 to 1.5 L/s per diffuser.

Tube/flexible sheath diffusers

A typical tube diffuser is either a rigid ceramic or plastic hollow cylinder (tube) or a flexible membrane secured by end plates in the shape of a tube. A tube diffuser has a media portion up to 200 cm long. The thickness of the diffuser varies, but the outside diameter is approximately 6.4 to 7.6 cm. The various components of a tube diffuser are made of stainless steel or durable plastic. Threaded rods are used with ceramic or porous plastic. The rod is threaded into the feed end of the holder with a hexagonal nut secured on the rod to hold the assembly in place. Air flows through tube diffusers in the range of 1 to 5 L/s.

Dome diffusers

Made from ceramics or porous plastics, dome diffusers are typically circular, 18 cm in diameter, and 3.8 cm high. The media is about 15 mm thick on the edges and 19 mm on the horizontal or flat surface. The dome diffuser is mounted on either a polyvinyl chloride or a steel saddle-type base plate. The airflow rate for dome diffusers is usually 0.5 L/s with a range of 0.25 to 1 L/s.

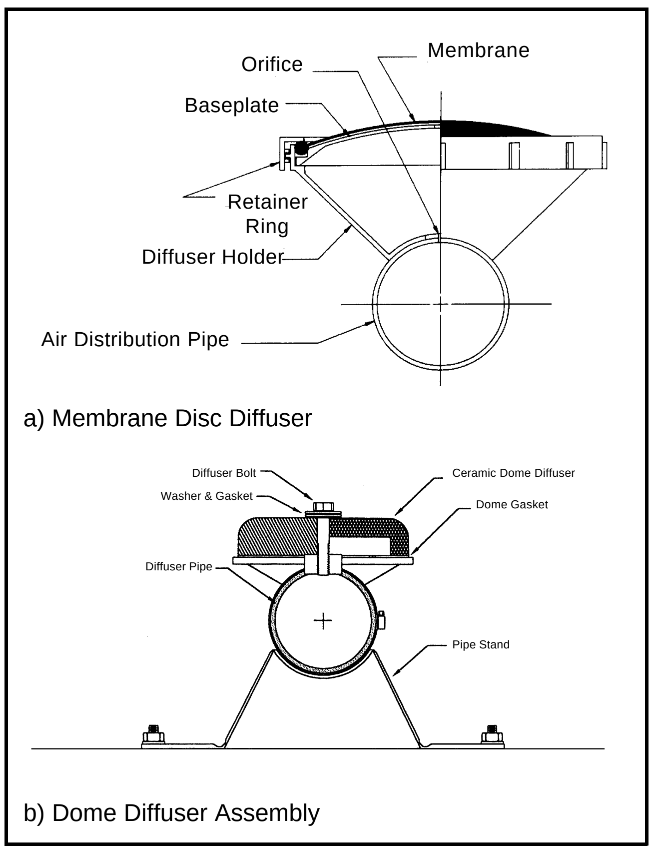
Plate diffusers

Plate diffusers are flat and rectangular, approximately 30 cm^2 in area, and 2.5 to 3.8 cm thick. They are normally made from ceramic or membrane materials. Installation involves either grouting the plates into recesses in the floor, cementing them into prefabricated holders, or clamping them into metal holders. Air plenums run under the plates and supply air from headers. Plate diffusers have largely been replaced by porous discs, domes, and tubes in new installations.

PERFORMANCE

The performance of diffused aeration systems under normal operating conditions is directly related to the following parameters:

- Fouling.
- Wastewater characteristics.
- Process type and flow regime.



Source: SANITAIRE brand products, reprinted with permission by the Water Pollution Control Corporation, Brown Deer, Wisconsin, 1999.

FIGURE 1 SCHEMATIC OF VARIOUS FINE BUBBLE DIFFUSERS

- Loading conditions.
- Basin geometry.
- Diffuser type, size, shape, density, and airflow rate.
- Mixed liquor dissolved oxygen (DO) control and air supply flexibility.
- Mechanical integrity of the system.
- Operator expertise.
- The quality of the preventive operation and maintenance (O&M) program.

The wastewater characteristics that establish the oxygen demand placed on a fine pore aeration system are the influent flow rate, biochemical oxygen demand load, and ammonia-nitrogen (NH_3-N) load.

Fouling is generally classified as one of two types: Type I and Type II. Characteristics of Type I fouling are clogging of the diffuser pores, either by airborne particulates clogging the air side, or metal hydroxides and carbonates clogging the liquid side. Type II is characterized by a biofilm layer forming and growing on the surface of the diffuser. In practice, it can be difficult to distinguish between the two types because they occur together, with one or the other dominating.

Historically, the rate of fouling was measured by monitoring the rise in backpressure. However, this proved to be a crude and qualitative method because significant fouling can occur without much increase in backpressure, but with great reductions in OTE.

The presence of constituents such as surfactants, dissolved solids, and suspended solids can affect bubble shape and size and result in diminished oxygen transfer capability. In general, ceramic domes and discs yield slightly higher clean water transfer efficiencies than typical porous plastic tubes or flexible sheath tubes in a grid placement. Other key parameters that have an effect on the performance characteristics of a fine pore media diffuser are permeability, uniformity, dynamic wet pressure, and strength.

Effective long-term process control depends on appropriate selection and integration of the solids' retention time, the food-to-microorganisms loading, and the wastewater flow regime. Short-term, day-to-day variables at the disposal of the operator include control of diffuser airflow rate and mixed liquor DO concentration. It is essential to understand how each of these parameters affects aeration efficiency in order to develop optimum short- and long-term operating procedures.

OPERATION AND MAINTENANCE

The main operational objective is to achieve acceptable effluent quality while maximizing the aeration efficiency. It is essential that diffusers be kept clean through cost-effective preventive maintenance procedures. Preventive maintenance can virtually eliminate air-side (blower filtration system) particulate fouling of fixed fine pore diffusers.

Filtration equipment maintenance entails cleaning and changing filter media. Calibration and/or zeroing of meters is necessary as part of preventive maintenance because accurate airflow and DO measurements are a critical part of monitoring aeration systems.

Preventive maintenance is needed to keep an aeration system operating at the required level of performance and to decrease the need for corrective maintenance. In addition, preventive maintenance will reduce the number of interruptions in the air supply, thus preventing solids from entering the air distribution system.

The cleaning methods used to restore diffuser efficiency are either process interruptive (aeration basin out of service) or process noninterruptive (access to basin not needed). Diffusers can be cleaned by removing them from the basin (ex-situ) or onsite inside the basin (in-situ). Some cleaning techniques used are acid washing, alkaline washing, gas injection, high-pressure water jetting, and air bumping.

When placing an empty aeration basin into service, all recommended operational steps for start-up and shutdown should be followed. If a basin is put into service during cold weather, care must be exercised to prevent any damage from buoyant forces exerted by ice trying to float. Aeration basins must not be drained during freezing weather unless absolutely necessary because ice and frost can cause serious damage. In the event that an aeration basin should stand idle for more than 2 weeks, it should be drained and cleaned thoroughly.

COSTS

The aeration system consumes approximately 50 to 65% of the net power demand for a typical activated sludge wastewater treatment plant. Therefore, the designer is responsible for selecting a system that will meet the mixing and oxygen requirements for the process at the lowest cost possible. Once the requirements for aeration are determined, comparative costs for different types of aeration systems can be estimated and the final equipment configuration selected to best match the requirements of the job.

Construction cost items mainly consist of aeration basins, air piping and headers as appropriate, aeration devices and their supports, air cleaning equipment, blowers, and buildings to house these items. O&M costs are primarily for power, cleaning, and replacement.

Operational costs are determined in part by the OTE of the fine bubble aeration system being used, as well as the characteristics of the influent wastewater. Aerator cleaning costs depend on the aerator type; how easily the aerators can be removed, cleaned, or replaced; and the plant's O&M procedures.

REFERENCES

1. Egan-Benck, K.; G. McCarty; and W. Winkler. 1993. "Choosing Diffusers." Water Environment and Technology. vol. 5. no. 2. pp. 54–59.

2. McCarthy, J. 1982. "Technology Assessment of Fine Bubble Aerators." U.S. Environmental Protection Agency (EPA) Wastewater Research Division. Municipal Environmental Research Laboratory. Cincinnati, Ohio.

3. U.S. EPA, 1995. *Technological Assessment of Fine Bubble Aerators*. EPA-600/2-82-003.

4. Metcalf & Eddy, Inc. 1991. Wastewater Engineering: Treatment, Disposal, and Reuse. 3d ed. The McGraw-Hill Companies. New York, New York.

5. U.S. EPA, 1985. *Summary Report: Fine Pore (Fine Bubble) Aeration Systems*. EPA Water Engineering Research Laboratory. Cincinnati, Ohio. EPA/625/8-85/010.

6. U. S. EPA, 1989. *Design Manual: Fine Pore Aeration Systems.* EPA Center for Environmental Research Information. Cincinnati, Ohio. EPA/625/1-89/023.

ADDITIONAL INFORMATION

Mike McGee
President
EP Aeration
2615 Meadow Street
San Luis Obispo, CA 93401

Gordon F. Pearson
Vice President
International Ecological Systems & Services, IESS
P.O. Box 21240
B-1 Oak Park Plaza
Hilton Head Isl, SC 29925

Leroy C. Reid, Jr., Ph.D
1273 Annapolis Drive
Anchorage AK 99508-4307

National Small Flows Clearing House at
West Virginia University
P.O. Box 6064
Morgantown, WV 26506

For more information contact:

Municipal Technology Branch
U.S. EPA
Mail Code 4204
401 M St., S.W.
Washington, D.C., 20460

OWM MTB
Excellence in compliance through optimal technical solutions
MUNICIPAL TECHNOLOGY BRANCH