1. INTRODUCTION

Aeration and mixing must be supplied to achieve aerobic conditions required to maintain many biological systems. Aeration in ponds and lagoons, and in aquaculture applications, has been predominately achieved by the use of mechanical surface aerators. Both low speed (i.e. 25-75 RPM) and high speed (i.e. 900-1800 RPM) units have been used for the purpose of aerating and mixing the basin contents. A typical mechanical aerator used in aquaculture is shown below:

A new technology has been developed to achieve more effective oxygen transfer and mixing of these systems. This new technology consists of a porous rubber tube diffuser aeration system. That is, the use of blowers, piping, and diffuser tubing to distribute air throughout the basin contents. The tubing can either be mounted on the floor of the basin (Figure 2) or suspended from a floating carriage (Figure 3).

Figure 1 - Mechanical Aeration Used For Aquaculture

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Figure 2 - Floor Mounted AeroTube™
Figure 3 - Floating AeroTube™
The porous rubber aeration tubing (AeroTube™) has been developed by Colorite Plastics Company, a division of Tekni-Plex, Inc. Colorite Plastics Company is the world’s number one manufacturer of garden hose and aeration tubing. With five manufacturing facilities in the United States, one in Mississauga, Canada and one in Suzhou, China, Colorite produces and ships more garden hose and aeration tubing than any other company in the world.

A section of AeroTube™ aeration tubing is shown below:

![AeroTube™ Aeration Tubing](image)

2. EVALUATION OF AERATION EQUIPMENT

Aeration equipment has historically been evaluated based on how well it transfers oxygen in clean, potable, water. The consensus procedures used in the U.S. and Europe are the American Society of Civil Engineers “Standard – Measurement of Oxygen Transfer in Clean Water” (ASCE 2006). The Standard was first published in 1985 and adopted in principle in Europe as a European Standard in 2000 (CEN/TC 2000). It is now used by a large number of engineering firms and manufacturers.

The ASCE standard involves using Sodium Sulfite to remove dissolved oxygen (D.O.) from the water then reaerating it to near saturation. A regression analysis of the time versus D.O. data is used to determine the mass transfer coefficient $K_{La}$. The test results are reported at standard conditions of 20°C liquid temperature, one (1) atmosphere barometric pressure, zero (0) dissolved oxygen, and alpha ($\alpha$) and beta ($\beta$) equal to 1.0 (clean tap water).

Since many aquaculture applications use high salinity water, testing must be performed not only in clean water but also in high salinity water. For this reason Colorite retained GSEE, Inc. to perform a series of tests to determine the oxygen transfer capabilities of both the AeroTube™ and mechanical aeration in clean water and water with varying salinity concentrations.

The following terms are important when discussing oxygen transfer:

- $K_{La}T$ = Apparent volumetric mass transfer coefficient at test liquid temperature T, hr$^{-1}$
- $C_\infty$ = The observed saturation concentration of oxygen in the test basin at test temperature and barometric pressure at equilibrium, mg/L after an aeration period equal to $6/K_{La}T$
- SOTR = Standard Oxygen Transfer Rate, pounds of oxygen transferred to the liquid, lb O$_2$/hr
- SOTE = Standard Oxygen Transfer Efficiency, %. The fraction of oxygen in an injected gas stream that is dissolved into the receiving liquid. Note that SOTE is only applicable to aeration systems that inject an air/oxygen stream into the water.
SAE = Standard Aeration Efficiency, Lb O₂/Hr/HP. The SOTR per unit total power input. Note that the HP value used to determine SAE must be carefully define. HP is typically presented in one of the following forms:

- **HP\text{wire}** = HP based on the amount of electricity used, i.e. – the actual cost to operate the equipment.
- **HP\text{motor}** = HP based on the Motor nameplate data, i.e. – HP\text{wire} x Motor Efficiency
- **HP\text{brake}** = HP developed or required on the shaft of a piece of rotating equipment, i.e. – HP\text{wire} x Motor Efficiency x Any reducer or belt efficiency.

Of these, HP\text{wire} is the value of importance to the end user. This is the value relating to the actual cost to operate a piece of machinery. The end user should always demand that SAE values be given in terms of SAE – Lb O₂/Hr/HP\text{wire}. The following sketch illustrates the various definitions of HP:

![Diagram of HP definitions](image)

**Figure 5 - HP Defined**

GSEE, Inc. performed a series of tests on the AeroTube™ aeration tubing in both clean water and in water with TDS (salt) concentrations of 5,000, 10,000, 15,000, 20,000, 25,000, 30,000 and 35,000 mg/L. Tests were conducted on the mechanical aerator shown in Figure 1 in clean water and at TDS concentrations of 20,000 and 35,000 mg/L.

The result of the testing is shown in Figure 6:
Figure 6 - SAE change with TDS Concentration

Note that in clean water the mechanical aerator produces about 2 lb O₂/Hr/HPwire while the AeroTube™ produces about 5 lb O₂/Hr/HPwire. As the TDS (salt) concentration increases, the observed oxygen transfer also increases. The rate of increase is much higher for the Aerotube™.

Figure 7 shows the comparative increase in oxygen transfer of the Aerotube™ over the mechanical aerator:

Figure 7 - AeroTube™ O₂ Advantage Compared to Mechanical Aeration

Since the AeroTube™ is a fine bubble diffuser using a blower to supply air for release beneath the water surface, the rate at which air is supplied to the tubing influences the oxygen transfer. Figure 8 shows the effect of air flow rate (SCFM/Linear ft. of Tubing) on the Standard Oxygen Transfer Efficiency (SAE):
Figure 8 - Air Flow Rate v SAE

3. APPLICATIONS

The AeroTube™ can be used in many aeration applications. Traditional applications are Wastewater Treatment and Post Aeration with floor cover diffuser systems.

Figure 9 - Typical Wastewater Application

Other Wastewater applications such as Lagoon aeration can be installed with AeroTube™ using either floating lateral systems or Pontoon systems:
Figure 10 - Lagoon Aeration Options
The AeroTube™ is also a good alternative for reaeration of freshwater lakes and reservoirs:

Figure 11 - Lake Reaeration
The newest and possibly most promising use of the AeroTube™ is in Aquaculture applications:

Figure 12 - Aquaculture Applications
In all of these applications, the AeroTube™ provides the maximum amount of oxygen and mixing at a substantial power savings when compared to typical mechanical aerators.

4. DIFFUSER DEGRADATION WITH USE

An important aspect of using fine bubble diffusers such as the AeroTube™ in aeration applications, is the degradation that occurs with diffuser material over time. In 2001 and 2002 GSEE, Inc. evaluated AeroTube™ diffusers after several months of service in a municipal wastewater activated sludge system. The results are presented in the following graph:

![AeroTube™ - Used Diffuser Comparison](image)

**Figure 13 - New and Used AeroTube™ Comparison**

The used diffusers showed about 15% reduction in Oxygen transfer. a reduction of 15-20% is typical for Fine Bubble Diffusers in municipal wastewater activated sludge systems. In waters with low waste concentrations such as Lakes, Lagoons and Aquaculture, the amount of degradation is expected to be less.

5. CONCLUSIONS

The results of testing completed by GSEE, Inc. on the AeroTube™ porous rubber tube diffusers indicate the following:

1. The observed clean water Standard Aeration Efficiency (SAE – Lb O₂/Hr/HP_wire) ranges from 4.0 to 8.0 Lb O₂/Hr/HP_wire, decreasing with increasing air flow rate. **In all cases, the AeroTube™ diffusers provided more than two times the oxygen produced by the Paddle Wheel mechanical aerator.**
2. Increasing TDS (Salt) concentrations result in increased oxygen transfer.
3. The AeroTube™ SAE increased from 5.0 in fresh water (0 mg/L TDS) to 13 Lb O₂/Hr/HP_wire in water with a TDS of 35,000 mg/L (~ sea water)
4. The Paddle Wheel mechanical aerator SAE increased from 2.0 in fresh water (0 mg/L TDS) to 3.4 Lb O₂/Hr/HP_wire in water with a TDS of 35,000 mg/L (~ sea water)
5. The AeroTube™ had a much greater increase in oxygen transfer with increasing TDS (Salt) concentration than that observed for the Paddle Wheel mechanical aerator.
6. The AeroTube™ shows only a moderate decline (~15%) in oxygen transfer after operating in activated sludge treating municipal wastewater.

The AeroTube™ should be considered for any application involving the aeration of water or wastewater. The high SAEs observed make the AeroTube™ an excellent alternative to the high power requirements of mechanical aeration systems.