VaraCorp White Paper

Lagoon Aeration Technology Is Advancing: What You Need to Know

Wastewater managers have the daily task of overseeing the treatment of contaminated water. Much of their challenge centers on the proper injection of dissolved oxygen into the waste stream. The issues of aeration are complex and involve more than just aerator performance. The manager must also juggle issues of equipment costs, operational costs, maintenance, repairs, and downtime.

While there is no shortage of aerator companies in the market, the task is to look beyond the hype and find the right aerator for the needs of the plant. If you are involved in water remediation, this paper will guide you in selecting the right aerator.

Identifying Problems

To limit the scope of this paper, we will focus on smaller treatment plants which use aerators of 20-hp or less. Smaller treatment plants share a common challenge in their operation, i.e. LACK OF MONEY. While exotic aeration systems exist, they are out of the financial reach of many treatment plants. The focus of this paper is to introduce an affordable aerator which has been sold for eight years, yet, is still considered to be new. This aerator holds the promise of reducing operating costs while dramatically increasing the level of dissolved oxygen in the waste lagoon.

Research

There is no shortage of academic research on lagoon aeration. However, most of the focus is on oxygen transfer efficiency. While efficiency is important, even critical, it is but a small part of a much bigger problem which plant managers face.

Highly efficient aerators can be costly to purchase and even more costly to operate. Bubble diffuser aerators, for example, are known for their high oxygen transfer efficiencies. They also are known to be prone to the clogging of their emitters requiring high dollar repairs.

The importance of aerator efficiency is made apparent in an abstract by Jiang and Stenstrom in the *Journal of Environmental Engineering* in February, 2012. They state that oxygen transfer in wastewater treatment can account for up to 60% of the energy consumption in the activated sludge process. This is a huge amount of money and points to the need for the most efficient aerators possible. In this highly technical abstract, they address the issue of Gas-Phase Oxygen Depletion. They note that in some cases, as the oxygen bubbles rise, the oxygen is absorbed by the liquid reducing the oxygen mole fraction. In like fashion the nitrogen and carbon dioxide can be stripped, further reducing oxygen partial pressure. The net effect is the loss of oxygen needed to remediate the wastewater.

The oxygen transfer efficiencies of aerators are conducted in *clean water* tests. (Such efficiencies are expressed as *pounds of oxygen per horsepower-hour,* (eg., 3 pounds of oxygen per horsepower-hour.) The argument is that such tests place all aerators on a somewhat equal footing in determining transfer efficiency. Of course, plant operators need to aerate *contaminated* water, not clean water. This raises the issue of aerator performance in dirty water. The best way to determine aerator transfer efficiency in contaminated water is to test the aerator in such water. However, this is largely impractical since each wastewater lagoon has a unique combination of contaminants.

The academic researchers overcome this challenge, sort of, by assigning an alpha factor to the clean water oxygen transfer results. Many laymen would call the alpha factor a fudge factor which is grabbed out of the air. The alpha factor is always less than one (say, 0.8) to reflect that the oxygen transfer into dirty water is always going to be less than that in clean water. The researchers can be defended in their use of alpha factors. There is really no other way to bridge the gap between clean water test results and the results to be expected in contaminated water. Still, even these researchers acknowledge that alpha factors can be dependent not only on the contaminants in different lagoons, but also on the type of aerator used.

Clean water tests and alpha factors have been embraced by regulatory authorities and wastewater engineers alike. However, such tests are not without their critics outside the world of academia and government. VaraCorp has received a memo from a leading wastewater scientist in Canada (who chooses to remain unnamed) who unapologetically labels clean water tests as useless. Following is an excerpt from his memo:

> *The principal driving force for oxygen transfer is based on oxygen concentration gradients within the bulk liquid and near the gas bubble membrane as well as the degree of dissolved solids within the water (there are a number of additional factors that affect the transfer efficiency). Since the driving forces change, the oxygen transfer efficiency and the aeration efficiency are also constantly varying. For that reason, the clean water test is useless. Only field test results under different conditions and applications*

can provide what is required to develop effective treatment results especially those that are of an aerobic biological nature.

A plant manager does not have the luxury of testing a new aerator in the plant lagoon prior to purchase. Even if such tests were possible, the manager still would not know if the aerator performance was the BEST for a particular lagoon.

Background

In 2009 the *Society of Petroleum Engineers* published a paper which touched on the benefits of dissolved oxygen in a lagoon. While the focus was on frac flowback water, the article provided a great summary of the benefits of aeration.

One of the points addressed in the above article was the threshold level of dissolved oxygen (DO) needed to keep the water from going septic (i.e. toxic). This level is considered to be 2 parts per million (ppm) of dissolved oxygen. Below this level anaerobic (high odor) bacteria take over the lagoon.

What exactly is dissolved oxygen? First, dissolved oxygen is NOT the oxygen atoms attached to the hydrogen atoms creating what is called "water." Second, dissolved oxygen is NOT some oxygen atom floating freely in the water. Instead, dissolved oxygen refers to the small clusters of oxygen molecules that position themselves in between the water (H2O) molecules. Think of water as being a lattice network of loosely connected H2O molecules. Spaces actually exist in between these water molecules. These gaps are sometimes referred to as an interstice (in-TER-stes – singular) or in plural, interstices (in-TER-ste-sez).

As water gets warmer, the lattice network spreads apart making it possible for dissolved oxygen to work its way through the lattice and escape into the atmosphere. The opposite is true for cold water. That is why cold water can hold more DO than warm water.

You can see that an aerator, such as a paddlewheel which injects large macro-sized oxygen clusters, might not be particularly effective at ramping up DO levels. True, such aerators might force a lot of air into the water. Sadly, much of this air, being too buoyant and too large too fit into the water interstices, tends to escape into the atmosphere immediately. This would represent a waste of horsepower.

Going back to the SPE article above, if a lagoon needs at least 2 ppm of DO to keep it from going septic, is it possible to put too much DO into a lagoon? Authors W. Higgins and J. Kern say yes. In an article in the March, 2016 issue of *Treatment Plant Operator* magazine they note that over-aeration can break apart floc and keep it from settling properly. They also say that too much DO can inhibit the denitrification process. While their article is very informative, most operators of small treatment plants are faced with too little DO, not too much.

Aeration is noted for its ability to remove organics (**Organics**: *of or relating to carbon compounds in living things*) in wastewater. If organics are not removed, they will decompose using up more DO. Byproducts like ammonia, nitrogen, and soluble phosphates are likely to form. These byproducts become food sources for high-odor anaerobic bacteria. Aeration takes away these food sources preventing anaerobic bacteria from growing and reproducing. Aeration also removes hydrogen sulfide (think rotten egg odor) and other reduced sulfur compounds.

Aerator Market

Aerators can be loosely grouped into the following categories:

> **Paddlewheels** – Paddlewheels and brush aerators consist of large rotating paddles or brushes mounted between two pontoons. Such aerators can be large enough to move the surface water around a raceway in a treatment plant. Underwater videos of paddlewheels often show a lot of water agitation down to about 24 inches below the surface. Yet, below 24 inches, there appears to be very little activity.
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> Paddlewheels are particularly popular in aquaculture settings. In fish ponds the fish are mobile and can swim to the vicinity of the aerator where the DO levels are higher. However, contaminants in a wastewater lagoon are not self-mobile. Thus, paddlewheel aerators can sometimes create dead zones where very little DO is present.
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> **Bubble Diffusers** – Bubble diffusers are classified as being either macro- or micro-sized. The classification is based upon the size of the holes in the emitters. Fine bore (micro) diffusers are said to have some of the highest DO transfer efficiencies of all aerators. However, it is difficult to keep the emitters from clogging. Since the emitters are mounted on an underwater pipe manifold, the whole manifold usually must be pulled out of the lagoon so the emitters can be repaired or replaced. This operation can be very costly and time consuming.
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> **Splash Aerators** – Splash aerators represent a large class of aerators, each of which throws water up into the air. Examples are fountain sprayers and large aerators which throw water upward around a volute. The goal is to

imitate rain which picks up dissolved oxygen as it falls to the earth. These aerators present several challenges. First, the contact time between the water and the air is only a few seconds. This short time does not allow the water to pick up much DO. Second, the water droplets are usually quite large making it difficult for the whole droplet to pick up DO. Finally, it takes a massive amount of energy to throw water into the air compared to other aerators.

Prop Aerators – Prop aerators typically have a subsurface propeller attached to a rotating shaft. The shaft and the motor are mounted at an angle to the pontoons. As the propeller turns, it creates a semi-horizontal underwater current which mixes the water. These aerators have an air pump which sits on the pontoons. When turned on, the air pump pushes air down the jacket which surrounds the rotating shaft. In this manner the aerator injects DO into the water.

There are several drawbacks to prop aerators. First, in shallow lagoons the force of water created by the propeller can scour the bottom. If the lagoon has a pit liner, the constant force of the water and any debris in the water can rip the liner. This is one reason you rarely see prop aerators in a frac pit where liners can cost over $400,000. If no liner exists, the force of the water can create what is called a donut hole as the water scours the dirt bottom.

Another drawback is the tendency in some prop aerators for the motor bearings to wear out due to the strain on the bearings caused by the angled air shaft. Other maintenance issues can arise due to the failure of the sub-surface, water lubricated bearing near the end of the air shaft.

Next Generation Turbine Technology – Keep reading to learn about an aerator which overcomes virtually all of the drawbacks of the above aerators.

Oxygen dispersion is one of the keys to a good aerator. More to the point, ideally the aerator should disperse DO in a uniform pattern respective to the shape of the lagoon. Further, the aerator should be able to inject enough micro bubbles to handle the throughput of contaminated water in the lagoon. The aerator should be able to push DO deep into the depth of the lagoon, but not so deep as to stir up bottom sediment. If the bottom sediment is unduly stirred, the result can be the re-introduction of organic material, thus, ramping up anaerobic bacteria.

Of critical importance the DO clusters should be small enough that they remain in the subsurface areas of the lagoon. The issue is contact time, sometimes called residency time, between the DO and the contaminants. With enough contact time the DO will be able to ramp up the populations of aerobic bacteria to process the wastes.

How Much Dissolved Oxygen Is Needed?

Aeration equipment suppliers are often asked this question. The treatment plant operator provides the parameters of the plant operation and expects the aerator supplier to calculate the amount of DO needed. Technically, aeration companies supply equipment only. They are NOT qualified to calculate the amount of DO needed in a particular plant. It is up to the plant operator and his staff or outside consultants to determine the amount of DO needed.

Once the plant operator determines the amount of DO needed, then the aeration supplier will determine how many of the supplier's aerators are needed. To be sure, most aeration companies will try to help the plant manager determine the amount of DO required. Yet, in the final analysis, the DO levels are to be determined by the plant operator.

Over the years the relationship between the contaminant load and the amount of DO needed has been determined both by scientific study and by empirical data. Not surprisingly, the results are all over the map. Differences seem to vary due to the assumptions made, the type of aeration system being used, and the actual empirical results versus scientific calculations.

Contaminant levels are often expressed as Biological Oxygen Demand (BOD). According to Wikipedia BOD is *the amount of dissolved* oxygen *needed or demanded by aerobic biological organisms to break down organic material present in a given water sample at a certain temperature over a specific time period.*

Various entities and organizations have published their methods for determining how many pounds of DO are needed to process one pound of BOD. The number ranges from 0.8 pounds of DO to 1.5 pounds or more. You can read about the topic by doing an Internet search. For example, the Ten States Standard suggests that 1.1 to 1.5 pounds of DO are needed to process one pound of BOD.

Suppose the plant manager provides the pounds of BOD entering into the treatment lagoon daily. Knowing the efficiency of its aerator, the aeration company can then calculate how many of its aerators would be needed.

Summary of Problems

To summarize, the plant manager needs an aerator that is affordable, efficient, low in maintenance and repair costs, low in electrical power consumption, easy to assemble and install, and long lived. The aerator should not scour the bottom of the lagoon or create dead zones. The aerator should produce oxygen clusters which have a long retention time in the water where they can help the populations of aerobic bacteria grow and multiply. Finally, the aerator should drive out odors. Such an aerator exists and has been sold by VaraCorp LLC for over eight years. In fact, some of the largest corporations, government entities, and wastewater treatment plants in the U.S.A. have purchased this aerator. Many of these entities such as the Army Corps of Engineers (Jordan and Kuwait) and the U.S. Department of Energy are repeat buyers.

Solution

VaraCorp's aerator solves virtually all of the challenges created by competing aerators. It is based upon technology that heretofore has not been seen in the aeration industry. Developed over ten years, the aerator consists of a subsurface rotating turbine. The operation of the turbine is not unlike the operation of a turbine on a jet engine. As the turbine spins beneath the water, it creates a low-pressure zone within its internal chamber. This chamber is immediately filled with air driven down the air tube by atmospheric air pressure. This air is then discharged rapidly outward by centrifugal force.

The VaraCorp aerator is the picture of simplicity, yet engineers and scientists claim that multiple physics principles are at play within the turbine chamber. They use terms like hydraulic paradox, shearing action, and expansion of gases to explain the turbine's remarkable performance.

Scientific explanations aside, the turbine creates oxygen clusters which have been measured as small as 0.001 to 0.01 millimeters. These small sizes all but guarantee a long retention time in the lagoon. While small oxygen clusters are critical, the turbine also generates oxygen clusters that are slightly larger. Being buoyant, these larger bubbles slowly rise to the surface and escort volatile, odor-filled gases upward until they quietly escape into the atmosphere.

Weighing less than 350 pounds, the VaraCorp turbine aerator can push dissolved oxygen outward in a 100+ foot diameter and downward for 10 feet or more. Critically, the turbine does not stir up bottom sediment. Instead, in shallower lagoons it gently washes DO over the bottom sediment which slowly dissolves the sediment.

The aeration zone of the turbine, being a circle, provides DO in a vertical and horizontal pattern that cannot be matched by competing aerators. Note that bubble diffusers send DO straight up and out of the lagoon providing very limited horizontal dispersion. Splash aerators claim to disperse DO horizontally by drawing water from the area surrounding the aerator. Yet, most of this is the same volume of water being moved over and over again. Prop aerators can push DO in only one direction. To achieve any sort of significant horizontal dispersion, several aerators must be positioned in a circle. In long, narrow lagoons this is impractical.

In regard to the emphasis on transfer efficiency (as discussed by Jiang and Stenstrom in the *Journal of Environmental Engineering* above), the VaraCorp turbine boasts a very high transfer efficiency. It should be noted that a large portion of VaraCorp's sales are to wastewater entities that want to replace existing aerators, mostly prop aerators. Almost without fail the feedback from these entities is that the 5-hp turbine aerator greatly increases the DO levels compared to the existing prop aerators. This increase comes with a dramatic drop in electrical usage. The motors in the prop aerators being replaced are usually 20-hp. So, the savings in electrical costs by installing the 5-hp turbine can reach 70%. Stated differently, with a reduction in horsepower from 20-hp to 5-hp the power costs can drop to only 30% of prior levels.

Given the client feedback above, VaraCorp had its aerator tested for transfer efficiency by Mike Kettner, PE with Makoshika Enterprises, LLC. The test was NOT conducted in clean water with the use of a questionable alpha factor. Rather, the test was conducted in the field in some of the most contaminated water that could be found, i.e. frac flowback water. The results showed a transfer efficiency of 4.7 pounds of O_2/horsepower-hour.

Conclusion

The technology employed in the VaraCorp turbine aerator represents a paradigm shift in wastewater aeration. In contrast, most competing aerators use technology that is at least four decades old. The turbine can produce bubble sizes as small as those created by fine bore bubble diffusers, but without emitters that clog. The turbine can both mix and disperse DO in a pattern that surpasses prop aerators but without needing constant adjustments or suffering bearing failure. The turbine does not create dead zones like splash aerators. The turbine aerator injects oxygen into water and NOT water into air like paddlewheel aerators or splash aerators. It takes much less energy to move air than to move water. Finally, the turbine boasts a transfer efficiency superior to just about every other aerator in the market.

To learn more about the VaraCorp aerator, visit us at https://varacorp.com/. We are here to answer your questions. Feel free to use the contact page on our website for answers to your questions or call us at the phone number listed.