# NEW INSIGHTS ON WATER MIXING AND AERATION IN WASTE LAGOONS

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## ABSTRACT

Man-made lagoons have been used worldwide for the treatment of domestic and industrial wastewater, it seems,forever. And, at the same time, many humans attempt to satisfy their need for leisure time activities on natural,and manmade, inland bodies of water located within, or close to, their place of habitation. All waste lagoons were first designed and thoughtfully planned considering their locations, soil makeup, and waste reduction processes prior to being implemented. And, either natural or designed recreational ponds went through the same process of engineering critique prior to releasing the public to their leisurely pleasures. In the case of waste lagoons, the biological process of organic waste reduction is always a consideration of the designs. For recreational ponds waste reduction is not considered a problem, so it is not usually addressed in the design phase. In all such designs a number of natural, "known" natural phenomena are discussed and accepted as fact. Natural and man-made mixing of water is one of the assumptions that is, not only taken for granted, but addressed far too often as "acceptable knowledge" without new thought or insight. In fact, water movement and mixing within any body of water is the key to its success as either a waste elimination process container, or a viable, long-lived healthy recreational pond. In a closed, or contained body of water, it is the ability of the water to mix properly that will determine its biological efficiency in organic waste reduction.

This paper will address the following topics;

• The key biological elements to organic degradation in contained water bodies.
• The natural mixing characteristics of water.
• The effect of common man-made mixing devices used in lagoons and ponds.
• A new technology that incorporates new insights into successfully, and economically, mixing water in lagoons and ponds.

**KEYWORDS**
Waste lagoons; sludge; mixing; aeration.

## 1 INTRODUCTION

Man-made lagoons have been used worldwide for the treatment of domestic and industrial wastewater, it seems, forever. All waste lagoons were first designed and thoughtfully planned considering their locations, soil makeup, and waste reduction processes prior to being implemented. The biological process of organic waste reduction is always a consideration of waste lagoon designs. There are three biological concepts considered for waste lagoons –

• Anaerobic lagoons, commonly at least 10 feet deep, have no dissolved oxygen in the lagoon water. Acid and methane bacteria work together to convert complex organics eventually to gases. There is very little, if any, mixing in these lagoons, and they are often used as an initial digestion process with aerobic lagoons downstream.
• Facultative lagoons are more shallow and were conceived to allow for anaerobic digestion in the bottom sediments and to allow for aerobic bacteria to consume the liquid and gaseous intermediate organic products in the water column. Surface water movement supplies the only water movement and daytime algae are the oxygen source for the aerobic bacteria.
• Aerated lagoons are deeper, often up to 20 feet in depth, but mechanical and diffused air systems continuously provide dissolved oxygen to aerobic bacteria in the sediments and water column. The aerators are also the source of mixing in the lagoon.

Sludge Buildup in Lagoons

This discussion will concentrate on facultative and aerobic waste lagoons. Once these types of lagoons reach 5 to 20 years of age, depending on their surface area, owners begin to recognize problems, especially with odors and effluent water quality. In facultative lagoons, Operators will begin to notice that sludge is building up around the edges of the lagoon, especially near the influent, and often the effluent. Algae blooms become prevalent with noxious filamentous and blue-green clusters in the summer. Even in mechanically aerated lagoons sludge buildups will appear. In all cases, odors become apparent, at times, and effluent water quality is negatively affected.

Because we can't actually see inside these lagoons, what we don't realize is that sludge is not only piling up around the influents, effluents and sides of the lagoons, but long "ripple" type mounds of sludge are building up all over these aged lagoons. The sludge mounds also occur in mechanically aerated lagoons but for a different reason than the rippled non-aerated lagoons. The cause of these mounds of sludge is poor mixing. In the case of the facultative lagoons there is never enough flow generated from surface wind action to cause the sludge to level off on the bottom. In fact, the ripples are an expansion of the types of ripples one sees in the surf zone near the shore on a beach. But the mounds of sludge in a lagoon are much larger in size, and made up of very fine silt. See Figure 1.

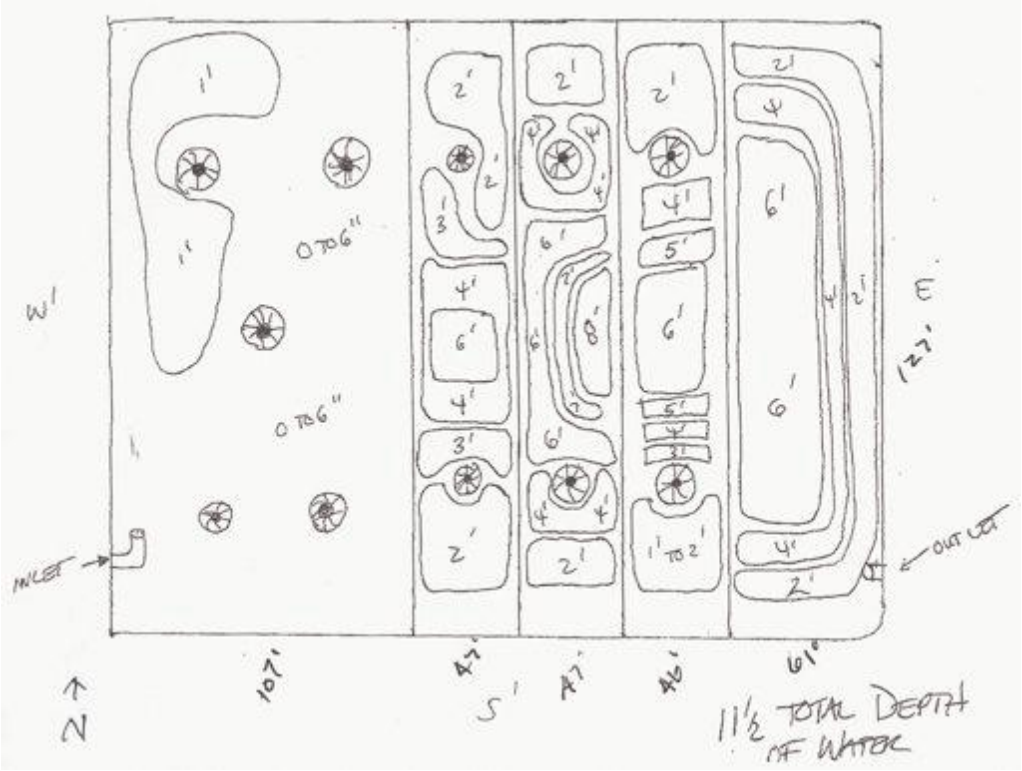


**Figure 1 –** A plant superintendent's profile drawing of the sludge "mounds" in his lagoon system. Notice the elongated mounds where there is no mechanical aeration, and the circular mounds of sludge that is dropped around the vertical splash aerators in the lagoon.

## Aerators as Mixers

In the case of aerated lagoons, depending upon the type of aeration, the sludge mounds form around vortex and vertical splash aerators (See Figure 1), in front of aspirating and paddlewheel aerators, and along the sides of the hoses in diffused air aeration systems (See figures 2 through 4). While all of these aerators provide dissolved oxygen to the water, their water mixing capabilities are stunted or defeated by the mounds of sludge their high horsepower invokes on the fine silt that lies underwater. There is no question that some of the high horsepower aerator designs move water, thereby somewhat mixing the water; but, when water flow is deflected by mounds of sludge on the bottom, or the bottom itself, the forward momentum of the water flow has a tendency to deflect backwards, thus stunting forward flow and reducing efficient mixing. For diffused air hose and uplift or vertical splash aerators, they merely lift water, thereby dropping the solids particles directly beside the rising bubbles, and these particles become the basis for sludge mounds between the hoses or below the vertical lift aerator. In these cases water mixing is minimal at best.

**Figure 2 –** Vortex or vertical splash aerators.

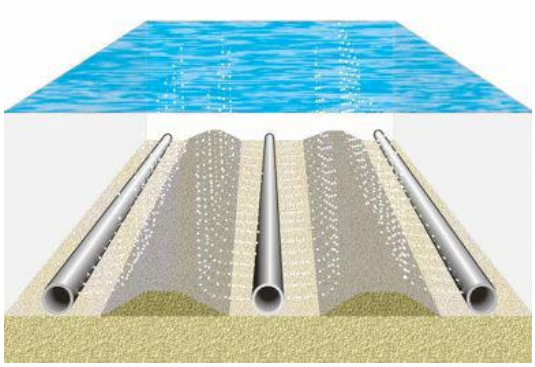

**Figure 3 -** Diffused air tubes with a vertical bubble rise, causing sludge to pile up between the tubes due to lack of mixing.

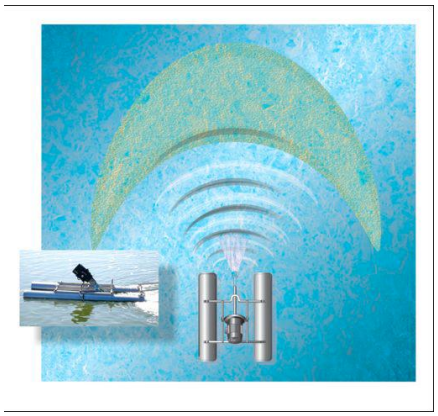

**Figure 4 –** Various pontoon mounted aeration devices showing the sludge mounds generated by the high horsepower water thrust. These sludge mounds deflect water mixing movement across the rest of the lagoon bottom.

These mounds, or rows, of sludge in waste lagoons shorten the life of the lagoon and provide major problems for the owner. The first problems that appear are odors, extremely high algal blooms, and the inability of the water in the lagoon to hold dissolved oxygen through the night. Eventually, the degradation of effluent water quality becomes the end result that leads the lagoon owner into problems with their state and local environmental quality authorities.

When the content of sludge mounds is analyzed in the laboratory, it is common for the mound to include from 30% to 60% undigested organic solids. These are solids that could not be digested by the natural bacteria in the lagoons, primarily, because of the excess of noxic gases from biological waste that is trapped in the sludge mounds. Visual proof that this trapped gas exists, is the large methane - smelling bubbles that break the surface of a waste lagoon throughout the year.

Solar Powered Mixing

A recent technology introduced to the lagoon industry for the purpose of aiding water mixing, is the solar powered surface skimmer. While these products have the advantage of not requiring electricity, their effectiveness as true lagoon mixers is quite limited. In fact, they do cause a small amount of surface mixing; but, the mixing influence is not much greater than a constant fair wind over the surface of the lagoon. There is never enough movement to affect the sludge mounds that have naturally built up on the lagoon bottom; so, eventually, the

effluent water quality of lagoons using this technology will exhibit the same negative results as if they were never used. This minimal mixing influence does help in keeping algae mixed – to a point - as long as there are large numbers of the mixers in a relatively small area. But initial cost and maintenance upkeep have often been recognized as a poor cost to advantage ratio.

The Water Moving Aerator

A few years ago, a new technology was introduced to the waste lagoon industry that is making major headway in the rehabilitation of old waste lagoons; some of which were not able to meet effluent permit requirements due to the amount of sludge in the lagoon. This technology is unique because it was developed recognizing that sludge mounds do exist and because of an understanding of how those mounds negatively affect water quality.

This water moving aerator performs two key requirements that are necessary for the complete success of any waste lagoon –

• The continuous pressure of moving water that slowly falls to the lagoon bottom to quietly move sludge for full biological digestion of organic wastes, and

• Adding dissolved oxygen that is required to keep the lagoon's natural biology capable of digesting the organic sludge.

This unique aerator design uses only 2 horsepower of energy to move from 2 to 5 acres of water continuously – not on the surface - but on the bottom, where the weight of the water is used to shear the mounds of sludge and break them up. Within several days the sludge becomes a low level, fluid mass of moving sludge. This movement allows for natural bacteria in the lagoon sediments to digest the organic sludge. The continuous, very slow, movement of the sludge also frees trapped ammonia and nitrogen gases to oxidize in the water column. Also, due to the downward movement of the water within the water column, a slight vacuum pulls algae cells down below the photozone, reducing or eliminating summer blooms.

Another 2 horsepower blower feeds air to eight fine-bubble diffusers that are located below and forward of the coarse bubble water moving diffuser bars. Because the fine bubbles are too small to rise through the coarse bubbles and turbulence on the surface, they are carried horizontally forward for 25 to 35 feet, diffusing dissolved oxygen into the water. Due to the water column becoming free of polluting ammonia, nitrogen and hydrogen sulfide gases, the water can hold more oxygen, thus improving water quality overall. See figure 5.

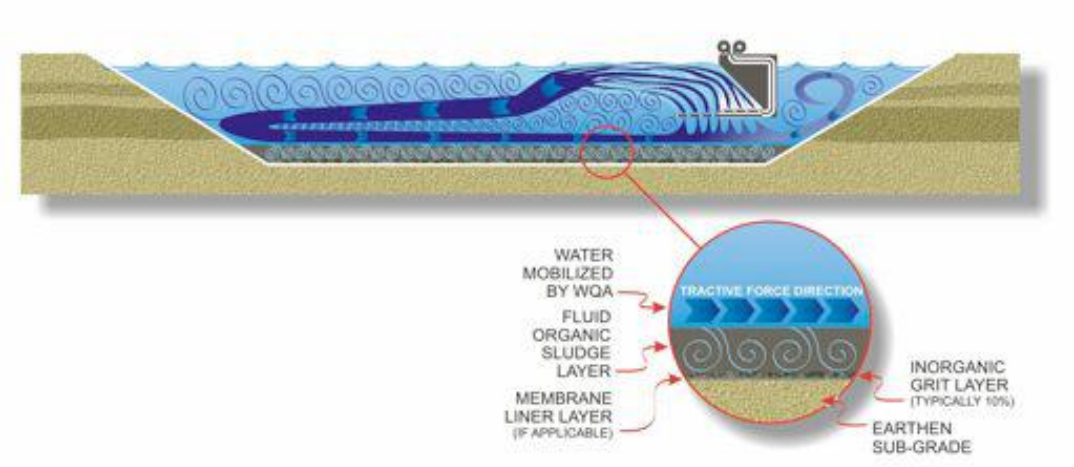


**Figure 5 -** Reliant Water Technologies Model WQA Water Moving Aerator – uses 2 HP to move over 9 million gallons of water per day. The weight of the water makes the sludge a constantly moving fluid mass along the lagoon bottom – this releases all gases and allows natural bacteria to break down organic solids. Another 2 HP blower provides DO through fine bubble diffusers that are placed forward and below the water moving diffusers.

Installations of this unique "water moving aerator" have shown the following results –

• Twenty eight acre segmented municipal lagoon system in the Midwest – **Problem**: Could not meet effluent permit requirements.
o ***Resolution*** **-** Four Model WQA units reduced effluent ammonia, BOD and TSS to the point that the lagoons were in compliance within 8 months.

• Two acre chicken rendering lagoon in the SE US – **Problem**: Extremely high ammonia and an inability to hold DO with 4-20HP aerators.
o ***Resolution*** **-** Turned 2 large aerators off, and single Model WQA cut ammonia in half and brought DO to over 3 PPM.

• Three acre racetrack infield lagoon in NE US – **Problem**: Extremely high fecal coliform and E. coli counts leaving the lagoon during the racing season
o ***Resolution*** **-** One Model WQA reduced both fecal coliform and E. coli counts over 99% during the racing season.

• One quarter acre hog waste lagoon in eastern US – **Problem**: Wanted to use lagoon water for pen wash-down, but sludge was breaking the surface of the lagoon - and ammonia, nitrogen, phosphates and BOD were extremely high
o ***Resolution*** **-** In 60 days one Model WQA aerator leveled the sludge in the lagoon to 3 feet under the surface, while at the same time reducing all the residual components in surface water from 50% to 70%.

## 2 CONCLUSIONS

Conclusion

Wastewater lagoons, both municipal and industrial, have been proven to be an effective waste treatment technology for many years, if the land is available. But, because of their low level of technology they have a tendency to be neglected and burdened with minimal attention. After a number of years, if effective attention is not provided to the lagoon, problems become apparent and effluent quality falls out of compliance or becomes an ongoing problem.

One of the major problems facing lagoon owners, has been the inability to effectively mix the lagoon in such a way as to allow for the sludge to become evenly distributed around the lagoon. This lack of total mixing causes the sludge to form into mounds that hold undigested organic solids. The mounds also hold large amounts of waste gases that have a tendency to degrade the lagoon's water quality, and feed intense algae blooms that only add to the problems.

Standard aeration technologies have not focused on mixing, so they do little, if anything, to address the sludge buildup problem. But, a new patented design of a low powered air-lift based aerator has proven to use the weight of slow moving water to break up sludge mounds located on the lagoon bottom. Eventually, tons of slow moving water turns the sludge in the lagoon into a fluid bottom layer that is readily accessible to natural bacteria. While the bacteria digests the organic solids in the sludge, the waste gases are oxidized in the water column. This unique aerator, which uses a total of only 4 HP of energy, also adds oxygen to the water at a rate of over 1.5 lbs of DO per HP/hr.

At a time when the economies of small communities and rural industries does not allow for lagoon upgrades and overhauls, this new low-powered, low-priced water moving aeration technology is –

- Providing lagoon owners a low cost way to get back into compliance
- Rehabilitating old lagoons that have been considered out of date
- Providing lagoon owners with another, lower priced, answer to lagoon overhauls other than vacuuming or dredging.