ALGAE CONTROL PRR

ALGAE CONTROL IN WASTEWATER AND FRESH WATER PONDS

Whether wastewater or fresh water, algae are important sources of dissolved oxygen. Without absorption of pure oxygen from the atmosphere (atmospheric reaeration), which is the subject of another white paper ("Oxygen Supply Via Enhanced Reareation and Recirculation), the only other major source of free oxygen in quiescent ponds is from algal

photosynthesis. When there is no ice and temperatures increase to 20°C and above, the supply of O2 via photosynthesis is significant. Oswald(1) suggests that under satisfactory conditions of illumination, temperature, and nutrition, photosynthesis may give rise to 200 lbs. of oxygen per acre per day.

Excessive growth of algae, however, may cause problems such as bad taste (in fresh water) and odor, increased color and turbidity, decreased filter run at a water treatment plant, unsightly surface scum and aesthetic problems, and oxygen depletion after die-off. Blue- green algae tend to cause the most severe problems, as it tends to resist precipitation. To prevent such proliferation (upset the ecological balance), wastewater treatment operators often resort to chemicals or circulation/aeration devices. Lake and watershed managers try to reduce the amounts of nutrients entering downstream waters, which act as fertilizers in promoting algal growth.

Although there are negative aspects of algal growth, in quiescent ponds, this oxygen source, along with atmospheric reaeration, are essential for waste degradation and the support of other life forms. It therefore is a control issue, and eradication is not a desirable objective even if all the oxygen required is provided by mechanical aeration equipment.

Algal growth control is an important aspect of the Progressive Reaeration and Recirculation Process (PRR™ Process) technology employed by an engineered device called the "LiquidTEK LLC®." This paper discusses the growth and control of algae and the influence that the LiquidTEK LLC technology has on this natural phenomenon in wastewater and freshwater ponds.

In wastewater treatment ponds, the ability of algae to produce oxygen by photosynthesis is vital to the ecology of the water environment. The classic reaction, $CO_2 + 2H_2O \rightarrow CH_2O$

$+ O_2 + H_2O$, when modified to account for the usual composition of algae, as determined by Oswald, Hee and Gotaas[2], may be written as:

$$NH_4^+ + 7.6CO_2 + 17.7H_2O + 886\text{ Kcal.} \rightarrow C_{7}H_{8.1}O_{2.5}N_{1.0} + 7.6\,CO_2 + 15.2H_2O + H^+ \quad (1)$$

This formula illustrates the synthesis of algae from an ammonium ion, carbon dioxide, water, and energy. This balanced equation shows that about 3.68 calories are fixed for each mg of oxygen liberated, and about 1.67 mg of oxygen are liberated for each mg of algae synthesized.

Algae acquire carbon from carbon dioxide, energy from light, and nitrogen, phosphorus, and other nutrients from the wastewater. All of these necessary ingredients are readily available in wastewater stabilization ponds as well as aerated ponds.

Since oxygen production by photosynthesis occurs during daylight hours, total reliance on this source of oxygen results in diurnal fluctuations in aerobic biological activity. They depend on carbon dioxide from bicarbonate sources, converting it to organic matter and oxygen. The removal of carbon dioxide from the water results in an increase in pH and a decrease in alkalinity.

Green water is caused by an excessively large number of tiny organisms in the water called phytoplankton. These minute plants are part of the algae family that has thousands of distinct species found in water (and ice) throughout the world. All pond water contains large numbers of different kinds of these plants and other microorganisms. Water that appears to be crystal clear just doesn't have as many.

Each of the many types of algae has different characteristics. Some die and decay readily while others are hardier. Some are viable even after long periods of anaerobiosis, drying, or freezing. Some species may cover the pond surface and interfere with light penetration.

Occasionally, duck weed or blue-green algae and diatoms of various types grow profusely on stabilization ponds. This may indicate some special water quality that inhibits green algal growth.

Facultative wastewater treatment ponds generate large concentrations of algae. The dynamics of growth and decay, and the dominance of four classes of freshwater algal types, affect the levels of suspended solids in most lagoon effluents. The four classes of algae are:

1)Green. Common green algae are those of the *Chlorella* group found in lagoons.

2)Motile-green. Euglena is a member of this particular group of algae. The presence of motile green usually means the lagoon is overloaded organically.

3)Yellow-green or golden-brown. Of this group, the most important are the diatoms.

4)Blue-green. These unicellular algae have the ability, when dying or dead, to form dense mats on the water surface that do not settle readily. They can also fix nitrogen from the atmosphere. Blue-green algae include *Anabaena*, *Anacystis*, and *Oscillatoria*.

The dominant form of algae in a lagoon changes with the seasons. When blue-green algae predominate, problems with settle-ability of the algal solids often occur, resulting in higher suspended solids in the effluent.

Algal growth control in wastewater stabilization ponds has been a challenge since this method of treatment gained acceptance. Primarily the problems are unveiled in the effluents of these ponds. The use of polishing ponds following a variety of treatment processes has focused attention on the control of algae in the effluent. Design standards contribute to the problem by requiring long detention times in the final pond.

Algae in the effluent is often blamed only for its contribution to total suspended solids (TSS). The measure of BOD5 or CBOD5 in the effluent is incorrectly assumed to be the residual of the BOD5 in the influent. Rich(3) suggests, however, that most of the effluent CBOD5 is the result of algae that has grown in the lagoon, thereby skewing the perception of the performance of the treatment process. Rich points out that engineers often mistakenly assume that because the effluent TSS and CBOD5 are approaching, or exceeding permit limits, additional treatment capacity is required. However, in reality the current capacity may actually be excessive.

Municipal wastewaters have an abundance of nitrogen and phosphorus, and, thus, when treated in lagoons with excessive hydraulic detention times, provide an optimal environment for the growth of algae. The concentration of algae in the effluent is reflected in the magnitude of the TSS. In the absence of algae, the TSS of the effluent of a lagoon system with a terminal settling pond will normally be less than 10 mg/L. Not only will algae increase the TSS, they will also increase the CBOD5 as pointed out above. Such increase is the result of the respiration of algae during the 5-day test. Toms, et al.[4] found, that on average, the ratio of CBOD5 to TSS is 1:0.5.

In summary, most of the TSS and CBOD5 in the effluents of ponds is caused by algae growing in the lagoons. Very little, if any, TSS and CBOD5 in the effluents are residuals of the TSS and CBOD5 that enter the lagoon.

Besides the likelihood of introducing suspended solids to the receiving stream, as algae die, settle out and decay, they induce an oxygen demand on the receiving stream. The concern about permit violations and oxygen consumption resulted in investigations as to the most effective methods to remove algae and system designs that minimize growth in settling basins.

Control of growth generally focuses on limiting those elements which contribute to that growth. For example, light seldom limits algae growth, except when the surface becomes thick enough to limit the light for algae produced in lower strata. Even without surface matting, light penetration is reduced as the depth of a pond is increased; however, because of the trapazoidal shape of most ponds, little advantage is achieved by increasing the depth beyond 10-14 ft.

Oswald(5) found that in continuously mixed ponds, the optimal depth should be up to three times the depth of the algal culture. Increasing depth also has the added beneficial effect of discouraging emergent vegetation. The depth must be such that it is possible to maintain the algal concentration at a level sufficient to meet the desired BOD reduction, yet not allow it to choke itself out.

Oswald's work on continuously mixed ponds revealed that light penetration would be limited to about 16 inches with an algae concentration of 50 mg/L. At 400 mg/L, light will penetrate less than 8 inches. If all the desired BOD reduction is dependent upon oxygen supplied exclusively through photosynthesis, this self-limiting depth of algal concentration becomes the principle limit for loading in such ponds.

Recirculation, or the lack thereof, is also a limiting factor. Without recirculation, the supply of oxygen from algae is confined to the depths to which light may penetrate. An anaerobic zone exists in ponds which are not mixed and which are deeper than the depth of light penetration. If the oxygen produced through photosynthesis is to be brought into contact with microbial cells in the organic matter at the bottom of the pond, recirculation is required. In an unassisted facultative pond, recirculation action is dependent upon wind, convection currents, and to a small extent, on microorganism motion. If no recirculation is available, or is insufficient, aerobic oxidation is limited or precluded by lack of oxygen, and therefore un- oxidized organic matter must either undergo storage, or be decomposed anaerobically.

In his technical notes published on the internet, Rich(6) suggests that all lagoon basins, including those that are used for sedimentation (polishing), should be mixed. Such recirculation is beneficial from several points of view. Without recirculation, thermal stratification will occur, thereby permitting the retention of undisturbed surface layers for relatively long periods of time, a condition that provides an excellent environment for algae to grow.

Recirculation will also exhaust the carbon dioxide from the system. For wastewaters, such as those from domestic origin, in which there is an excess of nitrogen and phosphorus, carbon dioxide can be growth limiting during a portion of the diurnal cycle. During the night hours when light is not available, carbon dioxide accumulates as the result of respiration of the microorganisms in the pond. At dawn, with available light, the rate of consumption of carbon dioxide through photosynthesis exceeds that of respiration and, as a result, the store of carbon dioxide is depleted and algal growth becomes limited. In short, the carbon dioxide accumulated at night is stored for use in daylight. Carbon dioxide concentrations as high as 25 mg/L have been observed at night in lagoons.

Since at sea level the saturation concentration of carbon dioxide is only about 0.42 mg/L at

20°C, recirculation by aeration will remove significant quantities of carbon dioxide from the system during the night hours. This ensures that carbon dioxide becomes growth limiting earlier in the day. When carbon dioxide is growth limiting, aeration does not significantly replace carbon dioxide in the system because the concentration gradient is too low.

The availability of nutrients, particularly nitrogen, can be a limiting factor in the production of algal growth. If there are other more aggressive demands on essential nutrients, algal growth will be curtailed. For example, assimilation of nitrogen compounds by bacteria or loss of ammonia gas to the atmosphere will rob algae of this vital nutrient. For more information on this subject, see the white paper in this series entitled "Nitrogen Removal In Wastewater Stabilization Ponds".

Thermal stratification occurs in ponds without mechanical recirculation and provides an excellent environment for algae growth. Disturbing stratification will reduce algae. Rich(6) recommends some degree of aeration in ponds to control algae. The intensity of aeration also has an influence or algal growth by suspending more and more solids as the intensity increases. This results in a reduction in light transmission and ultimately, fewer algae.

Of the several chemicals that are available, copper sulfate is frequently used for algal growth control, and sometimes is applied on a routine basis during summer months, whether or not it is actually needed. One should try to identify the causes of the particular problems, then take corrective measures selectively, rather than on a shot-in-the-dark basis. The literature suggests that a concentration of 0.05 – 0.10 mg/L as Cu^{2+} is effective in controlling blue-green algae in pure cultures under laboratory conditions.

It has been shown that photosynthetic oxygen supply or light conversion efficiency in ponds, is dependent upon time, light penetration, pond depths, availability of nutrients (nitrogen and phosphorus), temperature, as well as, the type of plants involved. These relationships have been studied and can be reasonably predicted(5). For example, using the fact that the ratio of oxygen to organic matter in photosynthesis from equation (1) is about 1.67, one can calculate the permissible BOD loading of a pond which obtains all of its oxygen from photosynthesis by applying the following equation:

$$L_o = 0.25\,FS, \tag{2}$$

in which,

L_o = the areal loading (lbs. BOD/ac/day),

F = the photosynthetic efficiency (fraction of available light energy converted to fixed energy in algae cells), and

S = the sunlight energy (cal/cm^2/day).

The detention period required in a pond for complete photosynthetic oxygenation of sewage can be calculated as follows:

$$D = \frac{hC_cd'}{1000\,FS}, \tag{3}$$

in which,

h = the specific heat of combustion of algae (cal/mg),

Cc = the algal concentration (mg/L),

d' = the pond depth (cm),

F = the conversion efficiency (discussed above), and

S = the sunlight energy (discussed above).

The reader will note that the above calculations do not incorporate the effect of recirculation. Yet recirculation the pond content has an effect on several important influences on algal production and removal including: temperature, oxygen and pH, destratification, nutrient distribution, surface renewal, and bioflocculation. It is expected that wind, waves, and/or any other methods of recirculation should be factored into those calculations. Otherwise, when recirculation is occurring regularly (by any mechanical means), these calculations are conservative in estimating the areal loading potential of a wastewater stabilization pond.

Without recirculation, algal growth on the surface becomes a "treatment liability." As an example, a quiescent pond surface may become "super saturated" with oxygen, yet the strata below may be oxygen deprived and septic. Photosynthetic plants produce pure oxygen. The oxygen content of any liquid is defined by Henry's Law as being proportional to the partial pressure (or percent) of oxygen in the gas above it. In stagnant ponds, the equalization of the oxygen content of water with the air above it is seldom rapid. This fact allows temperature changes to produce water conditions that lead to dissolved oxygen readings over 100% saturation.

A relatively stagnant pond may have a dissolved oxygen reading at night of 9.65 mg/L when the temperature is 17oC. This corresponds to 100% saturation. During the next day, the sun warms the water to 22oC where 8.22 mg/L represents the 100% saturation value. However, the temperature change has occurred rapidly enough to prevent the oxygen from "escaping" (deaeration) to the air because of non-ideal equalization conditions (quiescence). The pond still contains 9.65 mg/L of dissolved oxygen, but now the temperature is 22oC where 9.65 mg/L corresponds to 117% saturation. Super-saturation occurs in ponds during the time that photosynthesis takes place in the surface layers. In warm periods, due to a decrease in water density, these oxygen-bearing layers tend to remain at the surface of a quiescent pond.

Under such conditions, the dissolved oxygen concentration may increase to three times the saturation point. Doubtless, there are considerable losses of valuable oxygen resources through deaeration during these conditions. Moreover, if this layer of complete saturation remains on the surface, it will effectively insolate the pond from receiving oxygen through atmospheric reaeration.

The LiquidTEK LLC technology, through its controlled recirculation action and reaeration, affect algal production through the following functions:

1. Algal mats (particularly Blue-Green Algae) on the surface are stripped and folded back into the pond at the depth of intake dish setting, resulting in:

   a. improvement of light penetration and algal growth beneath the surface
   b. removal of the supersaturated surface film, redistributing dissolved oxygen into the depths
   c. of the pond
   d. opening the surface to the effects of atmospheric reaeration

2. Pond contents are mixed to the depths at which the intake dish is set, resulting in:

   a. destratification of temperature, pH, and O2
   b. leveling effect in diurnal fluctuations in pH and DO
   c. broad distribution of nutrients and access to other users of nutrients
   d. gassing off of ammonia (reduction of nutrient source)

3. Bioflocculation stimulation resulting in:

   a. aggregation and settling of dying and decaying suspended solids, including algae
   b. algae removal from aerobic zone with decomposition taking place in sludge layer, reducing demands on dissolved oxygen source
   c. clarification of water pond improvement in odor, taste, and aesthetic qualities
   d. stabilized algae – carbonate interactions contributing to pH stability and enhanced conditions for methane fermentation

Observations of, and data collected at, dozens of wastewater treatment ponds confirm the rationalized affects that the LiquidTEK LLC technology has on algal growth and control.

However, LiquidTEK LLC, engineers carefully analyze each application before prescribing the number and location of units on a pond, whether wastewater or freshwater. Expected treatment objectives are stated in the treatment plan, together with a recommended monitoring protocol.

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