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Managing Your Wastewater Treatment Pond

As in making fine wine, pond treatment of winery wastewater requires appropriate evaluation and control.

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WINEMAKING INVOLVES THE application of a living organism (yeast) to organic material (grape juice). A process of fermentation occurs, ultimately leading to the formation of wine. An inevitable side effect of the winemaking process is the generation of process wastewater. While this much is elementary, what may be surprising is that the processes involved in making wine and in conventional winery wastewater treatment share important similarities.

Though the substrates, microbial agents and end products differ widely between the two practices, both processes rely on the metabolic activity of microorganisms to achieve a desired effect. In this regard, efficient winery operation can be seen to depend on management of multiple biological systems. It follows that the same degree of evaluation and control employed in winemaking can and should be applied to treatment of winery process wastewaters.

While small wineries are often able to use underground soil absorption systems, aerated ponds are by far the most prevalent treatment method among medium to large facilities. Aerated ponds are numerous as a result of their operability, reliability and storage function.

A discussion of the mechanisms involved in proper aerated pond functioning is offered here. This information will enable readers to identify best-practice management techniques that can enhance the treatment, performance and reliability of their pond systems. The material should also provide a good background for wineries considering alternative treatment systems.

WINERY TREATMENT PONDS

The objectives of wastewater management are to be protective of the receiving environment and enhance water reuse opportunities. Reduction of organic strength, measured as biochemical oxygen demand (BOD), is the single most important process wastewater treatment objective necessary to support vineyard and landscape irrigation. The organic content of winery wastewater consists of highly soluble sugars, alcohols, acids and recalcitrant high-molecular-weight compounds (e.g., polyphenols, tannins and lignens) not easily removable by physical or chemical means alone. Effective pond treatment supports the uniform dispersal of treated effluent over as large a land area as available.

Biological remediation has been the preferred method of handling organic-strength wastes for several decades. Ponds are among the simplest of biological treatment systems in that they rely on low, native concentrations of bacteria to accomplish treatment. The pond is simply a reactor in which the organic fraction of the wastewater is converted through bacterial oxidation and synthesis into bacterial solids, and benign end products of carbon dioxide and water.

Effective treatment is achieved by controlling the conditions in which the microorganisms grow. The most basic controls inherent to pond design, selection of the hydraulic detention time and sizing of supplemental aeration, mirror the two key elements of aerobic metabolism: substrate and oxygen availability. Deficiencies in either of these criteria will limit the bacterial mass and related treatment performance. As the microorganism's substrate and oxygen needs are satisfied, subsequent factors, such as pH and nutrient availability, may become limiting and affect treatment performance.

Typical winery wastewater characteristics and corresponding regulatory treatment objectives have been comprehensively addressed in prior articles (see, "California's Tightening Winery Wastewater Requirements," *WBM*, September 2002). In addition to organic strength discharge requirements, some regions also consider loading or concentration limits for nutrients and/or salinity. As discussed herein, these constituents should be of equal concern to all wineries from either an algae control or a vineyard irrigation perspective. In some instances, a pond's suitability may be a function of the liner material and characteristics.

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Ponds are among the simplest of biological treatment systems in that they rely on low, native concentrations of bacteria to accomplish treatment.
Above: Facultative winery pond system designed by Summit Engineering.

Pond Microbiology

A wide variety of microscopic organisms may be found in process wastewaters, though the bacteria are the primary mechanism of biological treatment. The pond microbiology is the nexus of physical and chemical treatment interactions. Individual bacteria are on the order of 0.5 to 15 micron in size. As they multiply, the individual cells form porous, fractal structures called "floc." A firm, dense floc enhances gravity settling to produce clear effluent. Thus bacterial growth and floc structure control effluent quality.

There are thousands of different species of bacteria, but the aim of biological treatment is to favor the growth of those species that will enhance treatment. Bacteria are classified by their carbon and energy source requirements. Thus, the bacteria of primary use in conventional wastewater treatment utilize the organic carbon present in the wastewater to synthesize biomass (heterotrophs) and can exist in either the presence or absence of molecular oxygen (facultative). Other microorganisms have their role in treatment, but are not as readily applied because of low growth rates and/or greater requirements of operational control.

Heterotrophic bacteria obtain their energy for growth from the oxidation of soluble organic wastes to simple end products. Oxygen is needed to facilitate this respiration by serving as the terminal acceptor for the electron released from the severing of chemical bonds. Thus the provision of oxygen controls the rate at which aerobic respiration proceeds. A portion of the organic matter remaining after oxidation is incorporated into new cell mass. Cell maintenance, death and predation all contribute to a reduction in bacterial mass. Thus, the conversion of organic wastes is actually the combination of three distinct microbiological activities: oxidation, synthesis and decay.

Periodic microscopic evaluation of unperturbed pond water can provide an indication of the overall health and stability of the system from which appropriate operational changes can be identified. The primary consideration is the character of floc structure as it is indicative of the settling characteristics of the wastewater. A diversity of beneficial, higher level microorganisms, such as protozoa or rotifers, is desirable as it promotes a stable biomass, though their absence is not unexpected in winery ponds subject to intermittent variations in BOD, pH and dissolved oxygen. The presence of certain species can be indicative of low pH (yeasts, filamentous bacteria) or nutrient deficient (*Zoogloea*) conditions. The pathogenic organisms of concern with sanitary wastewaters and high concentrations of filamentous bacteria that cause operational problems in high-rate biological systems are typically not present in ponds treating process wastewaters.

POND TREATMENT OVERVIEW

1. Winery process wastewaters are among the most challenging to degrade biologically due to their extreme variability in duration, quantity and composition.
2. Aerated ponds currently provide the most prevalent and effective means for biological oxidation of large volume winery wastewaters.
3. Wineries employing ponds need to apply best management evaluation and control measures to ensure reliable consistent performance.
   a. Removal of particulate matter entering the pond can effectively increase the capability of the biological treatment system to handle additional load.
   b. Water efficiency practices effectively increase the detention time in existing ponds, resulting in improved treatment performance and increased capacity.
   c. A platform to control aerators based on dissolved oxygen levels is useful for both biological reliability and energy efficiency.
   d. A balanced carbon:nitrogen:phosphorous ratio and pH level is needed to promote aerobic biological activity.
   e. Regular microscopic evaluation of pond water samples provides an indication of the effectiveness of the biological culture.
   f. The water levels in the pond need to be managed to maximize detention time while ensuring that there is adequate freeboard available for wet weather events.

Algae: It is not uncommon for winery ponds to generate dense populations of algae that contribute suspended particles in the pond effluent and cause problems associated with the clogging or fouling of downstream irrigation devices. Elevated, suspended solids can also cause discharge permit violations.

Algae are autotrophic microorganisms, meaning that they utilize inorganic carbon in the form of carbon dioxide to synthesize biomass. The production of oxygen as a byproduct of algal respiration is diurnal (occurring each day) due to the use of light as an energy source to drive photosynthesis. Therefore, a symbiotic relationship is developed within the pond between algae and bacteria wherein the end products of respiration of one organism serve the respiration needs of the other.

Excessive algal growth must be checked as it places additional substrate loading on the pond bacteria that can result in overconsumption of available oxygen and an associated crash in pond microbiology. Algae, as well as some bacteria, may also produce odor-causing organic substances, either directly as toxins or attractants, or indirectly through algal decomposition. Most green algae (*Chlorophyta*) do not cause severe odor problems; however blue-green algae (*Cyanobacteria*), abundant at high nutrient levels, produce the earthy, muddy smelling compounds geosmin and MIB (2-methyl-isoborneol).

Identification of algae species is an important first step in algae control. Algae control can often be achieved with adjustments to aeration and/or nutrient loading. Aeration provides mixing that can inhibit algae growth. Like bacteria, algae require nutrients for growth, and their presence is often an indication of excessive nutrient loading and/or incomplete nutrient removal within the pond. Algae are often limited by available phosphorous, an inert chemical that tends to accumulate in the pond system where it can be re-released and contribute to algae proliferation in the pond. In many instances algae control can be achieved through elimination of phosphate-based cleansers. Chemical management methods are also available, but care must be taken to ensure that their application is effective and does not inhibit the beneficial microbiology within the pond.

Physical removal devices to upgrade pond effluents vary in effectiveness with the type of algae present. **Bill Phillips**, CEO of **Summit Engineering, Inc.** in Santa Rosa, CA indicates that they have tested a variety of chemical and physical filtration systems, including mesh filters and sand filters, on recalcitrant algae blooms without achieving the desired results. **Kendall-Jackson** has had some success using a suspended air flotation (SAF) device for removal of algae and reduction of suspended solids concentrations.

Hydraulic Detention Time

Ponds are once-through systems, so they must be sized sufficiently to allow the microorganisms to remain in the system long enough to reproduce and metabolize the maximum organic waste load entering the pond. In pond systems, this control is effectively limited to the detention time of the pond, which is inversely related to the concentration of microorganisms. Consequently, the low concentrations of bacteria achievable in a pond (measured as volatile suspended solids) require large detention times for complete processing of the waste. Large detention times equate to a large footprint.

Reductions in process wastewater volumes achieved through water efficiency methods effectively increase the detention time in existing ponds, resulting in improved treatment performance and increased capacity. The conventional use of sodium-based caustics and tri-sodiumphosphate cleaners can result in the tank cleaning fraction constituting up to 85 percent of the overall process wastewater salinity load. In this case, the use of non-filming, potassium-based caustics can eliminate the need for citric rinses ,and the use of peracetic acid can provide more effective microbial control and eliminate a final rinse. In addition to saving water, these changes reduce salinity by up to 60 percent, reduce algae occurrence and vineyard irrigation impacts, and save labor and time. Peracetic acid and ozone chemistries also provide a reliable means to shift away from the formation of chlorinated disinfection byproducts in the winery.

In practice, microorganism growth and decay rates are developed based on empirical observations. Winery wastewater ponds typically require 60 to 90 days of detention time for the peak flow from a facility. The water levels in the pond need to be managed to maximize detention time while ensuring that there is adequate freeboard available for potential wet weather events. Although a spreadsheet balance is a useful design tool to size for storage and transfers, there is always an operational requirement to ensure that adequate freeboard is maintained. Related design considerations include the number of ponds, their geometry, water control structures and flow paths between ponds. Hydraulic bottlenecks may often be found on the disposal/reuse side of the pond.

Since ponds are once-through systems, the pond microbiology is not retained in the system much longer than the hydraulic detention time. High-rate biological systems incorporate solids separation and recycle components to increase the concentration of microorganisms and consequently are able to achieve treatment in a shorter period of time, greater energy efficiency and smaller footprint, albeit with a greater level of operational oversight (see, "Wineries Turn to Advanced Technology to Meet Wastewater Requirements," *WBM*, March 2003). The level of simplicity associated with ponds, while often a good fit for winemaking facilities, is effectively a tradeoff for long hydraulic detention times, which equate to the large footprint of a pond system.

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Selection of an aeration device represents the largest single equipment and operating expense associated with pond treatment. Above: Floating brush aerators in use at The Hess Collection Winery.

Aeration

Selection of an aeration device represents the largest single equipment and operating expense associated with pond treatment. The chemical reactions of bacterial metabolism establish the basis for sizing the appropriate quantity of oxygen necessary to fully convert the waste entering the system. The mass of oxygen provided must be proportional to the mass of organic waste (and possibly nitrogen) anticipated during the peak loading period.

The single most important consideration is the efficiency of the aeration mechanism at diffusing oxygen into the water column. At the same time, it is necessary to consider the manner in which the aeration provides effective circulation to distribute the oxygen, organic waste and bacterial solids. The preferred pattern is a partially mixed pond divided into zones with an aerated upper layer and an anaerobic bottom layer. For this reason, aerator type, intake and outlet position, and periods of operation must be considered such that it is appropriate to the volume of waste being treated.

Dissolved oxygen concentrations of at least 1.0 mg/L typically ensure a favorable environment; however, this condition must be maintained continuously. Failure to provide sufficient oxygen under peak loading conditions can lead to a crash in the populations of aerobic bacteria and a loss of treatment performance. A dissolved oxygen concentration greater than 2.0 mg/L is a likely indication that the bacteria are not limited by oxygen and that aeration can be reduced. In this regard, a platform to control aerator operation based on dissolved oxygen levels, like the Pond Sentry offered by **Heritage Systems, Inc.**, is useful for both biological reliability and energy efficiency.

Environmental Controls

The two key elements of pond design account for (1) appropriate sizing of the pond to provide adequate time for the biological treatment to occur and (2) provision of adequate aeration capacity to satisfy the oxygen requirements of the biological conversion. However, additional criteria are also critical to supporting the pond microbiology, including the following:

- pH and alkalinity
- Nutrients
- Temperature
- Solids separation

Acceptable ranges of key water quality criteria for biological activity include:

Parameter	Acceptable	Optimum
Dissolved oxygen	> 0.5 mg/L	1.0 - 2.0 mg/L
pH	6.0 - 9.0	7.0 - 7.5
Ammonia	1.0 - 3.0 mg/L	2.0 - 3.0 mg/L
Ortho-phosphate	0.5 - 2.0 mg/L	1.0 - 2.0 mg/L
Temperature	50 - 95 °F	77 - 95 °F

Systems operating within these criteria are generally able to function effectively. Systems with one or more criteria outside of these ranges may operate inefficiently or not at all.

pH and alkalinity: Operation of most biological processes is limited to a pH range of 6.5 to 8.5. Outside of this range biological activity declines or ceases. Wine itself is known for its natural disinfection properties, in part because of its low pH and high volatile acidity.

Bacterial oxidation of organic waste produces carbon dioxide, and a bicarbonate buffer system results that can prevent a rapid change in pH. While the buffer system results in the pH in the pond behaving independent of the pH of the incoming wastewater, its effectiveness will depend on a variety of factors, including detention time, mixing, salinity and the presence of algae. Consequently, under certain conditions, large volume acid or alkaline discharges can overwhelm the pond buffer system resulting in impaired treatment. In short detention time biological systems, pH control is a necessity to maintain viable biological treatment. Pond systems can often benefit from pH adjustment.

Michael Long, president of Heritage Systems, Inc. in Napa, indicates that the pond systems they manage that incorporate pH adjustment are consistent in treatment performance with reduced occurrence of nuisance conditions.

Nutrients: In addition to carbon, a number of inorganic and organic nutrients are required for the proper growth of the bacteria and the subsequent degradation of the waste material. An approximate formula for the organic fraction of bacterial cells is $C_5H_7O_2NP_{1/12}$, thus nitrogen and phosphorous are key nutrients for cellular synthesis. Where carbon and oxygen are plentiful, these substances may be the limiting material, and nutrient addition may be necessary.

Other mineral elements needed for proper metabolic activity, such as sodium, potassium, magnesium, manganese, sulfate, zinc, iron and copper, are essential only in trace concentrations and are typically provided in sufficient concentrations in the source waters.

It is not uncommon with winery wastewater for there to be a need for additional nitrogen and/or phosphorous. The formula above suggests a C:N:P ratio of 60:12:1. However additional carbon is needed for cellular oxidation to provide the energy needed for synthesis. Consequently, a C:N:P ratio of 100:5:1 is typically applied to ensure an excess of carbon for oxidation and synthesis while maintaining a slight limitation for phosphorous to prevent associated algae growth. A typical winery wastewater with BOD, nitrogen

Winery Wastewater Chemistry

H^+ Hydrogen

OH^- Hydroxyl

$C_nH_aO_bN_cS$ Wastewater substrate, complex matrix including the following organics:

$C_6H_{12}O_6$	glucose/fructose
$C_3H_8O_3$	glycerol
C_2H_5OH	ethanol
$C_2H_4O_2$	acetic acid
$C_6H_8O_7$	citric acid
$C_4H_6O_5$	malic acid
$C_4H_6O_6$	tartaric acid
$C_{76}H_{52}O_{46}$	tannic acid
$C_9H_{10}O_2(OCH_3)n$	lignens

NH_3, NH_4^+, NO_3^-, NO_2^-, N_2 Ammonia, ammonium, nitrate, nitrite, nitrogen(g)

PO_4^{-3}, P Phosphate, phosphorous

SO_4^{-2}, S^{-2} Sulfate, sulfide

$C_{60}H_{84}N_{12}O_{24}P$ Bacterial cells

$C_nH_aO_bN_cS + O_2 +$ nutrients $\xrightarrow{bacteria}$ $CO_2 + H_20 + NH_3 + C_5H_7NO_2$ Oxidation/synthesis (bacterial growth)

$C_5H_7NO_2 + 5O_2 \xrightarrow{bacteria} 5CO_2 + 2H_20 + NH_3$ + energy Endogenous respiration (bacterial decay) and phosphorous concentrations of 3,000 mg/L, 50 mg/L and 25 mg/L, respectively, will be deficient in one or both of nitrogen and phosphorous, and will likely benefit from nutrient addition. Aqueous ammonia is a useful source of nitrogen to the pond system.

Nutrient additions must be balanced with the need to control nutrient levels in the discharge. If nutrients are not limiting, adding nutrients will have no beneficial effect. Nitrogen in the form of ammonia can be removed within the pond biologically to nitrogen gas, but places additional demands on the management of the pond system in terms of provision of sufficient quantities of oxygen, alkalinity and anaerobic environments. In the absence of these conditions, nitrogen added in excess of the assimilative demand of the bacteria will exit in the discharge. Phosphorous, on the other hand, is relatively inert; and although it can be removed chemically or biologically, it often stays in the pond system where it can be re-released and contribute to algae proliferation. Excessive concentrations of ammonia nitrogen, chloride and/or heavy metals can inhibit bacterial growth and should be restricted.

Temperature: Temperature affects all microbes greatly. High temperatures destroy microbes, low temperatures suspend them and within acceptable ranges, microbial respiration rates double with every 10-degree Fahrenheit change.

Although the temperature of wastewater entering a pond can on occasion exceed acceptable ranges, the overall pond temperature is regulated by the large volume stored in the pond and environmental conditions, which tend to be favorable in winegrowing regions.

For wineries that use hot water in sanitizing, it is a good reason to keep the water level in the first pond high. Although cooler temperatures can slow down biological activity, these occurrences typically coincide with periods of relatively low loading. Temperature is also a factor in the solubility of oxygen in the water column. For this reason, aeration requirements are greater during periods of high temperatures.

Solids Separation: Particulate matter entering the pond is generally removed by sedimentation. However, organic particulate matter not removed from the influent wastewater will exert additional treatment demand on the pond system. Inorganic matter will remain indefinitely within the pond and reduce the volume available for treatment. Consequently, it is preferable to minimize the quantity of particulate matter entering the pond, and doing so can effectively increase the capability of the biological treatment system to handle additional load.

This is typically done with a fine screen with openings anywhere from 0.01 inch to 0.125 inch in size (250 to 3,000 micron). Opening sizes as small as 0.002 inch (50 micron) are available and may be appropriate depending on the particle size distribution of a particular wastewater. Where winery lees, diatomaceous earth and bentonite are not effectively screened from the wastewater, other measures may be considered, such as lees filtration, smaller opening sizes, gravity settling prior to entering the pond, increased aeration, increased frequency of removal of the accumulated material, and supplemental detention time. Other factors to consider in screen selection are self-cleaning and solids dewatering capabilities, overflow bypass, energy usage and the need for post-screen pumping facilities. Screened material should be incorporated into the winery's composting operation.

SUMMARY

Many types of treatment systems exist for management of winery process wastewaters. Aerated ponds are most common and provide a good basis for describing the fundamentals of biological treatment. Although ponds are inherently robust due to their large buffering volume, they are flow-through systems, and the maintenance of conditions that will consistently sustain the microbiology that provide the mechanism of treatment is of primary importance.

Design of pond systems is based on sizing for the peak organic load entering the pond. Therefore, efforts to reduce flow through water efficiency and organic concentration through screening will minimize pond and aeration size requirements, and enhance performance of existing ponds. Winery process wastewater is variable in many regards and specifically with respect to pH, nitrogen and phosphorous. These and other environmental factors must be considered to ensure consistent and reliable performance.

A final consideration beyond the scope of this article is the use of conjunctive treatment strategies to enhance pond performance and discharge water quality. This may involve the incorporation of pretreatment devices, such as screening or roughing filters to enhance the organic waste removal function of an existing pond and increase capacity without substantial increase in footprint. It may also involve membrane or advanced oxidation treatment of pond effluents to achieve high purity water to enhance reuse opportunities. In any scenario, aerated pond treatment is an effective application of microbiology to the enhancement of water quality and reuse. **wbm**

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