A REVIEW:

Wastewater treatment at winery industry

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Wastewater generated by processing and cleaning operations is the most significant environmental management issue at wineries. An understanding of sources and fate of winery wastewater and the impacts of variations in quality and quantity is an important step towards environmentally sustainable management of winery wastewater. Winery wastewater comprises a rich cocktail of tannins, complex carbohydrates and proteins in an aqueous mixture. Winery wastewater varies significantly over the growing and processing seasons in terms of volume and concentrations of contaminants. Chemical oxygen demand (COD) and biological oxygen demand (BOD) also vary over the growing and processing cycle with the highest concentrations found in the vinification season. Total dissolved solids (TDS), Total suspended solids (TSS) and total solids (TS) are also the other major pollutants in winery wastewater. Ponding and lagooning are low cost treatment methods for winery wastewater. Another option of treatment is use of returned activated sludge system which is more efficient than a pond ecosystem. The BOD reduction in pond or activated sludge process both, require an irrigation pond for final disposal of treated wastewater. Due to fastest growing winery industry, it is essential to treat the winery wastewater by adopting some possible treatment which is cost effective.

Wine is the product obtained from the total or partial alcoholic fermentation of fresh grapes whether, or not crushed, or of a grape must. Producing wine requires implementation of biotechnological sequence involving several unit operations. Although some few products are added to the must and wine, several residues are rejected, either as liquid or solid wastes. White wine is produced by the fermentation of clarified must, which is obtained after grape stem removal, pressing of the resultant grape berries and subsequent clarification. The production of red wine is conducted in non clarified musts, prepared after grape stem removal and crushing of grape cluster. Musts can also be fermented in the presence of grape stems. After fermentation, wine must be clarified and stabilized chemically and microbiologically, before bottling to produce wine (Latin: *vino verde*). This wine follows the ordinary wine making process, but ageing is avoided, in order to preserve the original freshness and fruity characteristics. Worldwide wine production is 261 x 10^5 m^3 of which 69% from Europe, 18% from America, 5% from Asia, 4% from Africa and 4% from Oceania. The worldwide wine consumption is 228 x 10^5 m^3, distributed by Europe 68%, America 20%, Asia 7%, Africa 3% and Oceania 2%. Today water pollution is the largest environmental problem in the country like China and India, where the scarcity of water occurs throughout the year because of continuously increasing population. Today winery industry is the fastest growing industry in Maharashtra state of India because of grape farming activities in Maharashtra. Due to which much more wine is produced in vintage and non-vintage seasons depending on the quantity of production in litres. For that purpose large quantity of water is required for the winery process. The winery wastewater is generated through various operations such as water generated during tank cleaning, barrel washing, equipment washing, bottle washing, floor and crush pad washing, cooling water and water softener waste brine. Wineries and other grape processing industries annually generate large volume of wastewater. This mainly originates from various washing operations during crushing and pressing of the grapes, as well as rinsing of the fermentation tank, barrels and other equipments or surfaces over the year volume and pollution load greatly vary in relation to the working period (vintage, racking, bottling) and to the wine making technology used, e.g., in the production of red, white and special wines. Yeast is used in the fermentation of grape juice and they have high content of polyphenol, so yeast cannot be used in animal dietary and may contain some residues coming from treatment, they must only be composted with pomace. However, pomace, seed, lees effluents resulting from tartar removal and wine rest can be valorized to produce compound with adding value like alimentary colorant E163, alimentary oil, tartaric acid, 1, 3-propanediol and dihydroxy acetone. On the other hand, the grape stem can be composted, the final compost being used for organic soil amendment and the grape pomace can be sold to distilleries. A mass balance of wine production represents water and energy inputs and also outputs respecting residues and sub products, as well as liquid effluents. Simple residues like yeasts, grape stems, pomace and lees should be recycled whenever possible.

Wine processing and wastewater generation:

Winemaking is seasonal with high activity in autumn, which corresponds to vintage and fermentations, notoriously a less important activity in spring on the occasion of transfers (racking period) and filtration and a weak activity during winter and summer. Winery effluents contain four types of principal pollutants.

– Sub-product residues: stems, seeds, skins, sludge, lees, tartar etc,

– Loss of brut products: musts and wine occurred by accidental losses and during washings,

– Products used to wine treatments: fining agents and filtration earths,

Cleaning and disinfection products used, to wash materials and soils.

Musts and wine constituents are present in wastewaters, in variable proportions: sugars, esters, ethanol, glycerols, and organic acid (e.g. citric, tartaric, lactic, malic and acetic etc.), phenol compounds, colouring matters and tannins and a numerous populations of bacteria and yeasts. They are easily biodegradable elements, except polyphenols (60 mg/l to 225 mg/l) which make this biodegradation more difficult requiring an adapted flora. Effluents have a pronounced demand in nitrogen and phosphorus, with a BOD/N/P relation often near 100/1/0.3. Additionally effluent has both variability in quality and quantity, making evaluation of daily pollution complex. Generally the production of 1 m^3 wine generates a pollution load equivalent to 100 person's daily sewage. The pH is usually acidic but punctually it may display some basic values, on the occasion of cleaning operations (with alkaline products and organochlorides) and on the occasion of chemical detartaration.

Rejected volume per volume produced wine varies from one wine cellar tank to another, with extremes values comprise between 0.1 m^3/m^3 and 2.4 m^3/m^3. For the ratio of water consumption to produce wines, 1.0 m^3/m^3 water consumption ratio is the rule of thumb while refers to values between 0.3 m^3/m^3 and 2.5 m^3/m^3. Water is also required for the following operations in winery process.

– During vintage preparation: washing and disinfection of materials;

– During grape reception: washing of reception materials: (hoppers, destemmers, crushers, presses, dejuicers, conveyors and transport pumps) cleaning the floors with or without addition of cleaning products,

– During vintification: rinsing of fermentation and clarification vats; cleaning the floors with or without addition of cleaning products,

– During transfers: rinsing vats after transfers; cleaning the floors with or without addition of cleaning products,

– During filtrations: rinsing kieselguhr and earth

Table 1 : Description of winery wastewater production periods at wineries

Period	Typical months of year	Description
Pre-vintage	January, February	Bottling, caustic washing of tanks, non-caustic washing of equipments in readiness for vintage
Early vintage	February, March	Wastewater production is rapidly rising to peak vintage flows and has reached 40% of the maximum weekly flow, vintage operations dominated by white wine production.
Peak vintage	March, May	Wastewater generation is at its peak; vintage-only operations are at a maximum.
Late vintage	April, June	Wastewater production has decreased to 40% of the maximum weekly flow; vintage operations dominated by production of red wines, distillation of ethanol spirit may coincide with this period.
Post-vintage	May, September	Pre-fermentation operations have ceased; effect of caustic cleaning, ion exchange etc. is at its greatest, and wastewater quality may be poor.
Non-vintage	June, December	Wastewater generation is at its lowest generally less than 30% of maximum weekly flows during vintage; wastewater quality is highly dependent on day-by-day activities.

Resource Management, Council of Australia and New Zealand, 1998)

Table 2 : Pollution load of parameters analyzed in winery wastewater (Groves *et al*., 1985)

Parameters	Value
pH	7.9
EC	6.35 mmho
TSS	190 mg/L
COD	2070 mg/L
BOD	700 mg/L
Calcium	22.2 mg/L
Magnesium	2.3 mg/L
Total Nitrogen (TN)	10.6 mg/L
Total Phosphorus (TP)	12.7 mg/L

filters.

Some of the potential effects on the environment of the various constituents of liquid and solid waste byproducts of winemaking process are summarized in Table 3.

Current wastewater treatments :

A high capacity degrade high concentrated wastewaters with a low sludge production, low energy demand and also for energy recovery (Rajeshwari *et al*., 2000). These features make anaerobic digestion especially attractive for winery industries wastewater treatment (beer, wine etc.). Winery effluents are highly polluted and can produce important negative effects on the environment if they are discharged without treatment. Anaerobic digestion is a well established technology for the treatment of highly concentrated wastewaters like winery effluents. Furthermore, anaerobic digestion has the main advantage when the effluents are seasonal, like in winery processes, where wastewater production occurs mainly during harvesting and wine making. In this situation, the anaerobic digester can start up rapidly after a shut down. 15 days in general are required for restarting period (Moletta, 2005).

Table 3: Potential environmental impacts of winery waste water (EPA, 2003)

Winery waste water constituent	Indicators	Effects
Organic matter	BOD, TOC, COD	Depletes oxygen leading to the death of fishes and other aquatic organisms. Odors generated by anaerobic decomposition cause nuisance
Alkalinity /acidity	pH	Death of aquatic organisms at extreme pH. Affects the solubility of heavy metals in the soil and availability and/or toxicity in waters affects crop growth.
Nutrients	N, P, K	Eutrophication or algal bloom. N as nitrate and nitrite in drinking water supply can be toxic to infants.
Salinity	EC, TDS	Imparts undesirable taste to water, toxic to aquatic organisms, affects water uptake by crops.
Sodicity	SAR, ESP	Affects soil structure resulting in surface crusting. Low infiltration and hydraulic conductivity.
Heavy metals	Cu, Ni, Pb, Zn, Hg etc.	Toxic to plants and animals
Solids	TSS	Can reduce light transmission in water, thus, compromising ecosystem health, smothers habitats, odor generated from anaerobic decomposition.

Types of wastewater treatment tacilities:

Oxidation ponds:

Oxidation ponds are effective, low-cost and simple technology for reducing the BOD of a wastewater before it is discharged to an aquatic ecosystem. It consists of ring or oval shaped channel equipped with mechanical aeration devices. Screened wastewater entering the pond, is aerated by mechanical devices which circulates at about 0.25 to 0.35 m/s. Oxidation ponds typically operate in an extended aeration mode with long detention and solids retention times (von Sperling and de Lemos, 2005).

Anaerobic ponds:

Anaerobic pond as a wastewater treatment facility is a biological process ideally suited for the pre-treatment of high-strength winery and brewery wastewaters. The anaerobic process utilizes naturally-occurring bacteria to break down biodegradable material in winery wastewater. Because the bacteria are anaerobic they do not require oxygen like the organisms in an aerobic process. When used prior to aerobic treatment, an anaerobic system can be very effective and economical for removing high concentrations of BOD and COD (Dewil *et al*., 2006) if the pond is relatively deep, 3 to 4 m, as this concentrates the biological action and reduces heat loss. Anaerobic ponds contain an organic loading that is very high relative to the amount of oxygen entering the pond. This maintains anaerobic conditions to the pond surface. Anaerobic bacteria cause breakdown of the organic matter in the wastewater, releasing methane and carbon dioxide. Sludge is deposited at the bottom and a crust may form on the surface (Doorn *et al*., 2006). They work extremely well in warm climates, a properly designed and not significantly under loaded anaerobic pond will achieve around 60% BOD removal at 20°C and as much as 75% at 25 °C.

Aerobic ponds:

This is another wastewater treatment facility which contains bacteria and algae in suspension and maintains aerobic conditions throughout its depth. There are two types of aerobic ponds: shallow ponds and aerated ponds (Vijayaraghavan *et al*., 2007).

Shallow pond:

Shallow aerobic ponds obtain their dissolved oxygen via two processes: oxygen transfer between air and water and oxygen produced by photosynthetic algae. Although the efficiency of soluble biochemical oxygen demand removal can be as high as 95%, the pond effluent will contain a large amount of algae which will contribute to the measured total biochemical oxygen demand of the effluent. To achieve removal of both soluble and insoluble biochemical oxygen demand, the suspended algae and microorganisms have to be separated from the pond effluent (George and Andrew, 2003).

Aerated ponds:

An aerated pond is similar to an oxidation pond except that it is deeper and mechanical aeration devices are used to transfer oxygen into the deep part of the pond. The aeration device also facilitates a proper mixing of the wastewater and bacteria. The main advantage of the aerated pond is that they require less area than oxidation ponds. The disadvantage is that the mechanical aeration devices require maintenance and use energy (Craggs *et al.*, 2003)

Facultative ponds:

Facultative ponds are generally aerobic, however, these ponds do operate in a facultative manner and have an anaerobic zone. The depth of natural-aeration facultative ponds (usually 1.0 to 1.5 m) is too deep for oxygen to penetrate to the bottom of the pond and an anaerobic zone develops there. Solids from the incoming waste settle into the anaerobic sludge near the bottom of the pond and degrade anaerobically releasing soluble degradable organic materials and nutrients which diffuse upwards in the pond. Near the top of the pond oxygen is supplied by algal photosynthesis and to a limited extent by diffusion from the air. Dissolved oxygen is present to only a few centimeters depth at night, but diffuses deeper during daylight (Tchobanoglous and Angelaki, 1996; Al-Sa’ed, 2001). Thus, there exists a fully aerobic zone at the top of the pond, and between this and the anaerobic zone at the bottom there is a middle zone where oxygen is cyclically present and bacterial respiration is “facultative” aerobic-anaerobic. A facultative oxidation pond receiving sewage typically achieves between 70 to 95% removal of BOD (non-filtered) at a loading rate to the pond of 2.2 to 3.5 g BOD m^2/d depending on temperature. An effluent quality standard of 30 g BOD m^2/d is typically set. Facultative oxidation ponds are directed at reduction of BOD and to a lesser extent suspended solids in winery wastewater (Al-Sa’ed, 2001).

Trickling filter:

A trickling filter (TF) is a wastewater treatment system that is used to reduce BOD, pathogens, and nitrogen levels. It is composed of a bed of porous material (rocks, slag, plastic media, or any other medium with a high surface area and permeability). The microorganisms in the wastewater attach themselves to the bed (also known as the filter media), which is covered with bacteria. Wastewater is first distributed over the surface of the media where it flows downward as a thin film over the media surface for aerobic treatment and is then collected at the bottom through an under drain system. The effluent is then settled by gravity to remove biological solids prior to being discharged. Like the activated sludge, trickling filter is used in both large and small communities (Kornaros and Lyberatosa, 2006).

Rotating biological contractors:

In rotating biological contractors (RBCs), a number of circular plastic discs are mounted on a central shaft. These discs are submerged and rotated in a tank containing the wastewater to be treated. The microorganisms responsible for treatment become attached to the disc and rotate into and out of the wastewater. The oxygen necessary for the conversion of organic matter adsorbed from the liquid is obtained from the air as a certain area of the disc is rotated out of the liquid. In some designs, air is added to the bottom of the tank to provide oxygen and to rotate the disc when they are provided with air capture cups. It is a very useful system in small communities instead of the conventional secondary treatment, obtaining similar quality in the effluent. RBCs have also been developed for the biological treatment of odors. It is flexible enough to undergo fluctuating organic loads, requires little personal attention, cheap to run and does not require too much land. The RBCs have been used in treating winery wastewater and have also been used in the treatment of effluents produced by various industries such as gold mining and domestic sewage treatment (Smeets *et al*., 2006).

Activated sludge process:

The activated sludge process is a biological method of wastewater treatment that is performed by a variable and mixed community of microorganisms in an aerobic aquatic environment. These microorganisms derive energy from carbonaceous organic matter in aerated wastewater for the production of new cells in a process known as synthesis, while simultaneously releasing energy through the conversion of this organic matter into compounds that contain lower energy, such as carbon dioxide and water, in a process called respiration. A variable number of microorganisms in the system also obtain energy by converting ammonia nitrogen to nitrate nitrogen in a process termed nitrification. This consortium of microorganisms, the biological component of the process, is known collectively as activated sludge (Norström, 2005). Bacteria, fungi, protozoa, and rotifers constitute the biological mass of activated sludge. In addition, some metazoa, such as nematode worms, may be present. Cell makeup depends on both the chemical composition of the wastewater and the specific characteristics of the organisms in the biological community. However, the constant agitation in the aeration tanks and sludge recirculation are deterrents to the growth of higher organisms. The activated sludge process is the most widely applied biological wastewater treatment process in the world. The primary objective of the activated sludge system is the removal of soluble biodegradable compounds. It also removes pathogenic microorganisms from wastewaters. It is capable of achieving equal reductions in soluble substrate in reactors of much smaller volume while producing an effluent relatively free of suspended solids (Mara, 2004; Dewil *et al*., 2006). The removal efficiency of pathogenic and indicator microorganisms in these wastewater treatment plants varies according to the treatment process type, retention time, other biological flora present in activated sludge, oxygen concentration, pH, temperature and the efficiency in removing suspended solids (Doorn *et al*., 2006).

Anaerobic zone:

The anaerobic zone is considered to be one in which both dissolved oxygen and oxidized nitrogen are absent. In this zone, sludge from the clarifier flows in jointly with the influent wastewater. It has been reported that for this zone to operate efficiently, oxygen and nitrates must be absent. This is responsible for the release of phosphate.

Primary anoxic zone:

The primary anoxic zone is the main dentrification reactor in the process, it is fed by the effluent from the anaerobic zone and mixed liquor recycled from the aerobic zone. The presence of nitrate or nitrite and absence of oxygen leads to the enrichment of denitrifying bacteria, which reduces nitrate or nitrite to molecular nitrogen. Thus, soluble and colloidal biodegradable matters are readily removed in this zone (Metcalf and Eddy, 2003).

Primary aerobic zone:

The primary aerobic zone functions mainly to oxidize organic material in wastewater, ammonia into nitrate and also provides an environment to take up all the phosphate released in the anaerobic zone. For the removal of ammonia, it must first be oxidized to nitrites by nitrifying bacteria such as Nitrosomonas, Nitrosospria and Nitrosolobus spp. Nitrites are then oxidized to nitrates by *Nitrobacter, Nirtosospira* and *Nitrococcus* spp. These nitrates are then removed by denitrifying bacteria. Phosphates uptake is based on the enrichment of the activated sludge with bacteria capable of taking orthophosphate and *E. coli* have been associated with the phosphate removal in activated sludge (Sci-Tech. Encyclopedia, 2007).

Secondary anoxic zone:

This zone further converts an excess nitrate which was not removed in the zone preceding it into nitrogen. Because of the very slow dentrification rate in this zone, the quantity of nitrate removed is very small. The retention time in the anoxic zone is relatively long because of the lower chemical oxygen demand.

Secondary aerobic zone and clarifier:

This zone removes additional phosphate, which were not removed in the primary aerobic zone. Residual ammonia is also oxidized in this zone. The secondary aerobic zone increases the level of the dissolved oxygen between 2 and 4 mg/l in the mixed liquor before it enters the clarifier. Aeration should be more to promote phosphate uptake and maintain good aerobic conditions. Phosphorus is retained in the biomass as long as aerobic condition prevails (von Sperling and de Lemos Chernicharo, 2005). This zone prevents the development of anaerobic condition in the clarifier and phosphate release before clarification. In the clarifier, treated wastewater, free of organic matter and dissolved solid, is released (Zhou and Smith, 2002; Smeets *et al*., 2006).

Stages of treatment of wastewater:

Preliminary treatment:

As wastewater enters a treatment facility, it usually undergoes preliminary treatment. This treatment typically involves screening to remove large floating objects, such as rags, cans, bottles and sticks that may clog pumps, small pipes, and downstream processes. Screens are generally placed in a chamber or channel and inclined towards the flow of the wastewater. The inclined screen allows debris to be caught on the upstream surface of the screen, and allows access for manual or mechanical cleaning. Some plants use devices known as comminutors or barminutors which combine the functions of a screen and a grinder. These devices catch and cut the heavy solid and floating materials. In the process, the pulverized matter remaining in the wastewater flow in smaller pieces to be removed later in a primary settling tank (Mara, 2004).

Primary treatment:

Primary treatment is the second step in wastewater treatment and this step helps to separate suspended solids and grease from wastewater. In some treatment plants, primary and secondary stages may be combined into one basic operation. At many wastewater treatment facilities, influent passes through preliminary treatment units before primary and secondary treatments begin. With the screening completed and the grit removed, wastewater still contains dissolved organic and inorganic constituents along with suspended solids. The suspended solids consist of minute particles of matter that can be removed from the wastewater with further treatment such as sedimentation or gravity settling, chemical coagulation, or filtration. Pollutants that are dissolved or are very fine and remain suspended in the wastewater are not removed effectively by gravity settling. When the wastewater enters a sedimentation tank, it slows down and the suspended solids gradually sink to the bottom, as primary sludge which can then be removed from the tank by various methods (Sci. Tech. Encyclopedia, 2003).

Secondary treatment:

This is a biological treatment process that removes dissolved organic matter from wastewater. Ninety per cent of the organic matter in wastewater could be removed by this treatment processes. Sewage microorganisms are cultivated and added to the wastewater. The microorganisms absorb organic matter from sewage as their food supply in the process removing such organic matters from circulation. The three most common conventional methods used to achieve secondary treatment are attached growth processes, suspended growth processes and lagoon systems. Attached growth processes involve microbial growth on surfaces such as stone or plastic media. Wastewater passes over the media along with air to provide oxygen. Attached growth process units include trickling filter, biotowers and rotating biological contactors. The growth processes are effective at removing biodegradable organic material from the wastewater (Sci. Tech. Encyclopedia, 2003). Suspended growth processes are designed to remove biodegradable organic material and organic nitrogen-containing material by converting ammonia nitrogen to nitrate. In this growth process, the microbial growth is suspended in an aerated water mixture where the air is pumped in, or the water is agitated sufficiently to allow oxygen transfer. Suspended growth process unit include variations of activated sludge, oxidation ditches and sequencing batch reactor. A wastewater lagoon or treatment pond is a scientifically constructed pond, three to five feet deep, that allows sunlight, algae, bacteria and oxygen to interact. Biological and physical treatment processes occur in the lagoon to improve water quality. The quality of water leaving the lagoon, when constructed and operated properly, is considered equivalent to the effluent from a conventional secondary treatment system. Lagoons remove biodegradable organic material from wastewater (Larsdotter *et al*., 2003).

Advanced or tertiary treatment:

Tertiary treatment is the term applied to additional treatment that is needed to remove suspended and dissolved substances remaining after conventional secondary treatment. This may be accomplished using a variety of physical, chemical or biological treatment processes to remove the target pollutants. Tertiary treatment may include: filtration, chemical precipitation, ion exchange, electro dialysis, reverse osmosis, removal of Ammonia and other specific contaminants etc. (Hijnen *et al.*, 2006).

Disinfection:

Untreated or inadequately treated effluents may contain pathogens. Processes used to kill or deactivate these harmful organisms are called disinfection. Chlorine is the most widely used disinfectant but ozone and ultraviolet radiation are also used for wastewater effluent disinfection. Chlorine kills microorganisms by destroying cellular materials and can be applied to effluents as gas, liquid or in a solid form. However, any free (uncombined) chlorine remaining in the water, even at a low concentration, is highly toxic to beneficial aquatic life. Therefore, even removal of trace amount of free chlorine by dechlorination is often needed to protect fish and aquatic life. Ozone is also used for disinfection, and it is produced from oxygen exposed to high voltage current. Ozone is very effective at destroying viruses and bacteria and decomposes back to oxygen rapidly without leaving harmful by-products. The set back in the use of ozone however, is its high cost (Hinjen *et al.,* 2006). Ultraviolet radiation is a physical treatment process that leaves no chemical traces. Organisms sometimes repair and reverse the destructive effects of UV when applied at low doses Furthermore, UV can only be applied on small scale basis (Hoyer, 2006).

Disposal of winter wastewater:

The main disposal alternatives for the treated effluent include:

- Reuse in the winery
- Agricultural crop irrigation or
- Discharge to a water resource.

Wastewater must be treated and discharged into a water resource to sustain the environment or to be available for a potential downstream user. It is important for winery management to take into account that the treatment systems do not always guarantee a proper quality of the effluent that could allow its discharge to a natural water resource. Therefore, the most common method proposed and practiced in large scale by the wineries is irrigation.

Irrigation use:

The treated winery wastewater is used for irrigation. The discharge level of BOD as well as the restriction of standing water in an irrigation field is regional dependent and is regulated by National Legislation. Where wastewater irrigation of crops is not feasible, constructed wetlands offer an alternative for wineries that have sufficient land area available for wetland creation. A wetland ecosystem acts as a water 'filter'. Water quality improves as surface water moves through soils, plant stems and plant roots, and is acted on by microorganisms living in the system. The required land area is deduced from the volume and characteristics of the winery effluent, climatic data and evaporation rates at different times of the year as well as characteristics of the soil and the corps.

Conclusion:

Though the advancement of wastewater treatment technology is not withstanding, treated effluent may still contain some harmful substances (including microbial pathogens) irrespective of thoroughness and sophistication of the treatment process. In order to propose an efficient way of treating wastewater, there is need to understand the negative environmental impacts posed by the untreated or inadequately treated wastewater entering the nearby ecosystems, especially on the lives that depend on the ecosystem for sustenance.

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