

# Influence of Winemaking Practices on the Characteristics of Winery Wastewater and Water Usage of Wineries

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**The winemaking industry produces large volumes of wastewater that pose an environmental threat if not treated correctly. The increasing numbers of wineries and the demand for wine around the world are adding to the growing problem. The vinification process includes all steps of the winemaking process, from the receipt of grapes to the final packaged product in the bottle. To fully understand all the aspects of winery wastewater it is important to know the winemaking processes before considering possible treatments. Winemaking is seen as an art and all wineries are individual, hence treatment solutions should be different. Furthermore, wastewater also differs from one winery to another regarding its volume and composition and therefore it is vital for a detailed characterisation of the wastewater to fully understand the problem before managing it. However, prevention is better than cure. There are a number of winemaking practices that can help lower the volume of the wastewater produced to decrease the work load of the treatment system and increase the efficiency of treatment.**

## INTRODUCTION

### Statistics of the wine industry

Wine production plays a big role in the agricultural industry around the world. In 2012, a volume of 252.9 x 10<sup>6</sup> hL of wine was produced worldwide (OIV, 2013). The top-producing wine countries are Australia, Chile and the United States, followed by Argentina, France, Germany, Italy, Spain and South Africa (SA) (Devesa-Rey *et al.*, 2011), with SA producing 10 x 10<sup>6</sup> hL of wine (OIV, 2013).

Table 1 shows the number of wineries in SA per production category based on the volume of grapes crushed, which ranges from five tons to 75 000 tons of grapes per

harvest. The average winery crushes between one and 100 tons of grapes. White wine production makes up more than 70% of South African wine production (SAWIS, 2013).

### Composition of grape juice and wine

The composition of grape juice and wine is compared in Table 2. There is almost no difference in the compounds found, other than their concentration, although additional compounds are formed during the winemaking process. Some of these compounds have to be removed before bottling. Fermentable sugars are transformed to alcohol according to the variety and the ripeness of the grapes; this is the most important difference between grape juice and wine (Stevenson, 2007).

### Winemaking process

The fundamentals of winemaking have stayed the same since biblical times (Hands & Hughes, 2001). What has changed is our ability to maintain the sterile environment required to produce top-quality wine (Halliday & Johnson, 1994). It is important to understand the winemaking process when looking into the quantities of wastewater produced at wineries. Figure 1 presents a schematic diagram of the major steps in winemaking and where waste is produced. The

TABLE 1

Number of wineries in South Africa per production category in 2012 (SAWIS, 2013).

Category (tons of grapes crushed)	Number of wineries
1 – 100	259
100 – 500	159
500 – 1 000	52
1 000 – 5 000	59
5 000 – 10 000	16
> 10 000	39

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TABLE 2

Composition of fresh grape juice and wine (Adapted from Stevenson, 2007).

Component	Grape juice (percentage by volume)	Wine (percentage by volume)
Water	73.5	86
Carbohydrates	25	0.2
<i>Cellulose</i>	5	-
<i>Sugar</i>	20	-
Alcohol (ethyl alcohol)	-	12
Glycerol	-	1
Organic acids	93	35
<i>Tartaric acid</i>	0.54	0.20
<i>Malic acid</i>	0.25	-
<i>Lactic acid</i>	-	0.15
<i>Citric acid (plus traces of succinic and lactic acid)</i>	0.01	-
<i>Succinic acid (plus traces of citric and malic acid)</i>	-	0.05
Minerals	0.5	0.2
<i>Calcium</i>	0.025	0.02
<i>Chloride</i>	0.01	0.01
<i>Magnesium</i>	0.025	0.02
<i>Potassium</i>	0.25	0.075
<i>Phosphate</i>	0.05	0.05
<i>Silicic acid</i>	0.005	0.005
<i>Sulphate</i>	0.035	0.02
<i>Others</i>	0.1	Traces
Tannin and colour pigments	0.13	0.1
Nitrogenous matter	0.07	0.025
<i>Amino acids</i>	0.05	0.01
<i>Protein and other nitrogenous matter</i>	0.02	0.015
Volatile acids (mostly acetic acid)	-	0.045
Esters	-	0.025
Aldehydes	-	0.004
Higher alcohols	-	0.001
Vitamins	Traces	Traces

waste that is produced during the first step (destemming) is easily separated from the water, thus this is the only step that does not contribute directly to the chemical oxygen demand (COD) in the raw wastewater (Woodard & Curran, 2006).

#### WATER USE IN A WINERY

Winemaking is seasonal and most of the activities related to it occur during the harvest period (Guglielmi *et al.*, 2009). In the Southern Hemisphere, harvest is from the end of January to the beginning of April (Hands & Hughes, 2001). Throughout the year, the water volume and pollution load vary in relation to the different processes taking place (Arienzo *et al.*, 2009a). Large volumes of polluted water are produced by winemaking and may vary from one winery to another, depending on the production period and the unique style of winemaking of the different wineries (Agustina *et al.*, 2007). A big difference can be found when comparing

the water use of different wineries due to parameters such as the type of tanks, processing equipment and various winemaking techniques (Walsdorff *et al.*, 2004).

Table 3 describes the different periods and winemaking practices during the year that contribute to the volume and quality of winery wastewater. Generally, the pre-vintage period (beginning to middle of January) is used to clean the cellar and equipment in preparation for the harvest. This is essential to prevent the growth of micro-organisms on the equipment, which can lead to contamination of the juice (Mercado *et al.*, 2006). Due to the regular/daily cleaning of equipment during the harvesting period (end of January to beginning of April), there is a bigger demand for clean water (Rodriguez *et al.*, 2007). After harvesting, hygiene is still an immense priority, despite the decrease in the volume of clean water used (due to activities in the cellar.) During the post-harvest period, it is possible that there may be days without

water usage in the wine cellar (P. Ngamane, Assistant winemaker, Hartenberg Wine Estate, Stellenbosch, personal communication, 2012).

In the winter months (rainy season) it is important that the storm water and winery wastewater are separated to prevent an increase in the amount of water that needs

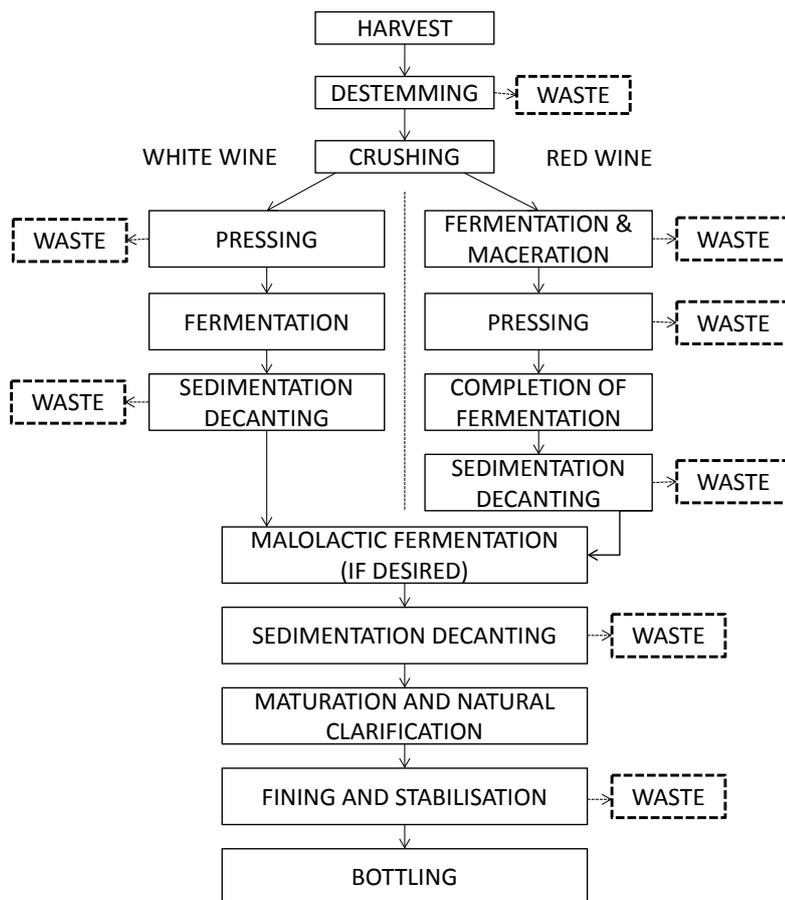


FIGURE 1

Diagram of organic waste generated in the process of making red and white wine (adapted from Arvanitoyannis *et al.*, 2006; Devesa-Rey *et al.*, 2011).

TABLE 3

General winemaking practices during the different wine-production periods in wineries for South Africa (adapted from South Australian EPA, 2004).

Period	Months	Action in cellar
Pre-harvest	Beginning to middle of January	Caustic washing of tanks and equipment, non-caustic washing of equipment in preparation for vintage
Early harvest	Middle to end of January	Wastewater production is rapidly increasing and has reached 40% of the maximum weekly flow. Vintage operations dominated by white wine production
Peak harvest	February and March	Wastewater generation is at its peak, vintage operations are at a maximum
Late harvest	Beginning of April	Wastewater production has decreased; vintage operations are dominated by red wine production
Post-harvest	End of April and May	Vintage operations have ceased. Caustic washing of the tanks and equipment used during the harvest
Non-harvest	June	Filtering of white wines in preparation for bottling. Filtering earth residues in waste water
Non-harvest	July	Cleaning bottling equipment with caustic. Bottling white wines
Non-harvest	August, September and October	Put red wine to barrel and filtering of previous year's reds. Water use is low
Non-harvest	November, December and beginning of January	Cleaning bottling equipment with caustic. Bottling wines

TABLE 4  
Estimates of volumes of virtual water used to produce wine.

Volume of water per litre of wine produced	Estimated volume of total water used for the wine industry worldwide	Reference
5 – 8	1.3 – 2.1 x 10 <sup>9</sup> hL	Mosse <i>et al.</i> (2011)
1 – 4	2.6 – 10.5 x 10 <sup>7</sup> hL	Bolzonella <i>et al.</i> (2010)
0.97 – 1.25	2.5 – 3.3 x 10 <sup>7</sup> hL	Lucas <i>et al.</i> (2010)

to be treated. It is also vital that the storm water remains unpolluted (Walsdorff *et al.*, 2004).

The term ‘virtual water’ was first used by Allan in 1997 to describe water embedded in water-intense commodities (Allen, 1997; Wichelns, 2001). Since then the term has been widely used to describe the volume of fresh water used to produce a product, in this case wine, from the beginning of the process, through harvest, right to the end where it is in the bottle and ready for trade and consumption. Virtual water is being used to calculate the impact of the water footprint of specific production systems (Herath *et al.*, 2012).

The virtual water used to produce one litre of wine varies according to different literature sources from around the world. Table 4 provides a summary of estimates of global winery water-use volumes according to the Organisation Internationale de la Vigne et du Vin (OIV, 2011) of wine produced in 2010. It is clear that there is a significant difference between the respective estimates.

Furthermore, the wine industry in South Africa has grown by 58% since 1997, from 5.5 x 10<sup>6</sup> hL in 1997 to 8.7 x 10<sup>6</sup> hL in 2012 (Fig. 2). This is a significant increase in wine, and goes hand in hand with the volume of water used and consequently the wastewater generated for every litre of wine produced (SAWIS, 2013).

#### COMPOSITION OF WINERY WASTEWATER

One of the biggest issues for the wine industry is the management of large volumes of wastewater (Bustamante *et al.*, 2005). While wine production does not have a reputation as a polluting industry, the wastewater volumes worldwide are increasing and the wastewater has a high organic load, low pH, variable salinity and nutrient levels, all of which indicate that the wastewater has the potential to pose an environmental threat (Mosse *et al.*, 2011).

The four biggest components contributing to wastewater pollution in a winery are:

1. Sub-product residues: stems, skins, sludge, lees, tartar (Musee *et al.*, 2005).
2. Lost brut production: must and wine occurred by spillage during winemaking activities (Mosse *et al.*, 2011).
3. Products used for wine treatment: fining agents and filtration earths (Pérez-Serradilla & Luque de Castro, 2008).
4. Cleaning and disinfection products (e.g. sodium hydroxide (NaOH) and potassium hydroxide (KOH) used to wash materials and equipment (Mahajan *et al.*, 2010).

Table 5 shows the influence on wastewater of the different steps in the winemaking process.

An analysis of the average characteristics of wastewater showed that winery wastewater around the world and in different wineries in the same country has significant differences (Mosse *et al.*, 2011). A summary of data for a few wineries is given in Table 6 to illustrate the differences in wastewater characteristics in different studies. The variance in wastewater composition complicates the issue of finding a general solution for wastewater treatment at different wineries (Andreottola *et al.*, 2009). To find the correct treatment and reuse efficiencies for wastewater it is important to understand the detailed composition of the wastewater (Bustamante *et al.*, 2005).

#### Organic compounds in winery wastewater

Most of the wastes generated in a cellar (80 to 85%) are organic wastes (Ruggieri *et al.*, 2009). The organic material in winery wastewater is generated from the grapes and wine (Valderrama *et al.*, 2012). Figure 1 illustrates the points in the winemaking process where organic material contributes to the composition of winery wastewater. After destemming and pressing the grapes, (white and red) grape marc is produced that consists of grape skins and pips (Devesa-Rey *et al.*, 2011). Despite the fact that the skins are kept separate from the wastewater system, the residue on the floors of the cellar and in the press will contribute to the high levels of COD (chemical oxygen demand) and variation in pH (Van Schoor, 2005). Apart from this, lees will form on the bottom of the wine tank or barrels after fermentation of the grape juice. This sediment will also have an effect on the organic compounds and COD of the wastewater (Mosse *et al.*, 2011). COD is used to measure the oxygen demand of the organic load present in the wastewater (Andreottola *et al.*, 2009). COD levels for grape marc can range from 15 000 to 44 900 mg/L, for lees from 27 200 to 36 100 mg/L and for wine from 26 200 mg/L (Fillaudeau *et al.*, 2008).

Bories *et al.* (1998, cited in Fillaudeau *et al.*, 2008) studied the composition and components portions of winery wastewater. Their study showed that 90% of the organic component is ethanol, except during harvest, when it is mainly sugars (Fillaudeau *et al.*, 2008). Ethanol concentrations of 4 900 mg/L and sugar (glucose and fructose) of 870 mg/L were detected in winery wastewater with a dissolved COD of 12 700 mg/L (Table 7). In addition to this, a study by Colin *et al.* (2005) showed that there is a linear correlation between COD and the ethanol concentration, and therefore the organic load of winery wastewater can be estimated when the ethanol concentration is known.

Contributing to the difference in the composition of the organic material in wastewater are the uncontrolled chemical reactions that take place in the wastewater (Mosse *et al.*, 2011). Organic acids (acetic, tartaric, malic, lactic

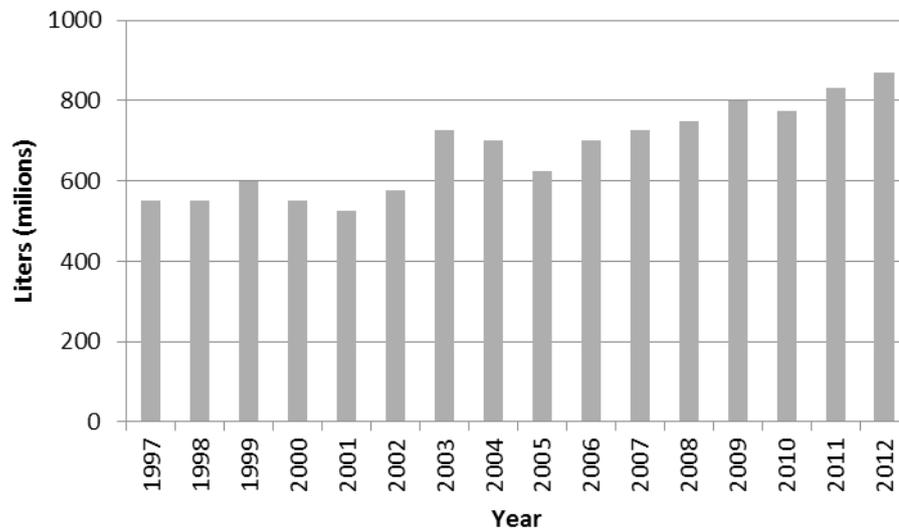


FIGURE 2  
Wine production volumes in South Africa from 1997 to 2012 (SAWIS, 2013).

TABLE 5

Winery actions related to winery wastewater quantity and quality and the impact on the quality parameters (adapted from Van Schoor, 2005).

Winery action	Impact on wastewater quantity	Impact on wastewater quality	Impact on legal wastewater quality parameters
<b>Cleaning water</b>			
Alkali washing and neutralisation	Up to 33%	Increase in NA, K, COD and pH	Increase in EC, SAR, COD, variation in pH
Rinse water (tanks, floors, transfer lines, bottles, barrels, etc.)	Up to 43%	Increase in NA, P, Cl, COD	Increase in EC, SAR, COD, variation in pH
<b>Process water</b>			
Filtration with filter aid	Up to 15%	Various contaminants	Increase in COD and EC
Acidification and stabilisation of wine	Up to 3%	H <sub>2</sub> SO <sub>4</sub> or NaCl	Increase in COD and EC, decrease in pH
Cooling tower waste	Up to 6%	Various salts	Increase COD and EC
<b>Other sources</b>			
Laboratory practices	Up to 5–10%	Various salts, variation in pH, etc.	Increase COD and EC

EC – electrical conductivity; SAR – sodium absorption rate; COD – chemical oxygen demand

TABLE 6

Summary of reported winery wastewater characteristics.

Parameters	Unit	Min	Max	Mean	References
COD	mg/L	340	49105	14426	1–10
BOD	mg/L	181	22418	9574	4, 6, 7, 10
pH	-	3.5	7.9	4.9	2, 4, 6, 8, 9, 10
Total solids	mg/L	190	18000	4151	2, 4, 5, 8
EC	S/m	1.2	7.2	4.16	2, 4, 6, 8
Suspended solids	mg/L	1000	5137	2845	4, 9, 10

The reference numbers in the last column refer to the following: 1. Agustina *et al.* (2007); 2. Arienzo *et al.* (2009b); 3. Bolzonella *et al.* (2010); 4. Bustamante *et al.* (2005); 5. Eusebi *et al.* (2009); 6. Mahajan *et al.* (2010); 7. Rodriguez *et al.* (2007); 8. Rytwo *et al.* (2011); 9. Yang *et al.* (2011); 10. Zhang *et al.* (2006)

TABLE 7  
Composition and breakdown of the COD of winery wastewater (Adapted from Fillaudeau *et al.*, 2008)

	Concentration (mg/L)	COD (%)
COD raw	14 600	
COD dissolved	12 700	100
Ethanol	4 900	80.3
Glucose and fructose	870	7.3
Glycerol	320	3.1
Tartaric acid	1 260	5.3
Malic acid	70	0.4
Lactic acid	160	1.2
Acetic acid	300	2.6

and propionic), alcohols, esters and polyphenols play an important role in the composition of winery wastewater (Zhang *et al.*, 2006; Mosse *et al.*, 2012).

There is not a lot of research available on the organic components of winery wastewater, but it is essential to characterise the organic composition of winery wastewater to establish the impacts the wastewater will have on the environment (Bustamante *et al.*, 2005; Mosse *et al.*, 2011).

#### Inorganic compounds in winery wastewater

The composition of the inorganic compounds in winery wastewaters is dependent mainly (up to 76%) on the components of the cleaning agents used in wineries (Table 5), except for potassium, which is present in high concentrations in grape juice (Mosse *et al.*, 2011). Strong alkaline-based cleaning agents that are good for tartrate removal include caustic soda (NaOH) and caustic potash (KOH) (Sipowicz, 2007). Wineries that uses sodium-based cleaning agents have problems with the salinity of the wastewater if it is used for irrigation. The inorganic ions present are predominantly potassium and sodium, with low levels of calcium and magnesium, although the concentrations of both organic and inorganic constituents vary with differences in winemaking operations over time, as well as between individual wineries (Mosse *et al.*, 2012).

#### WHY MANAGE WASTE/WASTEWATER?

In the past, the small volumes of winery wastewater that were produced by wineries had little effect on the immediate environment, but with increasing wine production all around the world, winery wastewater is a rising concern for the contamination of subsurface flow, soil and the environment (Grismer *et al.*, 2003).

Research on the composition and volumes of winery wastewater is receiving more attention, and awareness of the effects of winery wastewater is assisting in the establishment and improvement of winery wastewater treatment systems (Devesa-Rey *et al.*, 2011). Moderate quantities of winery waste and wastewater that are exposed to soils can increase the organic material due to the high concentration of soluble organic carbon in winery wastewater, which, in turn, will enhance the fertility of the soils (Bustamante *et al.*, 2011).

Unfortunately, continuous exposure to the organic material can lead to organic overload that blocks the pores and lowers the quality of the soils immensely (Vries, 1972). The continuous addition of winery wastewater to soils can also contribute to high soil salinity, which can lead to dispersion (Halliwell *et al.*, 2001).

The disposal of grape marc, a complex lignocellulose material made up of the skin, stalks and seeds, has also been a problem for wineries. In total, more than 20% of wine production is waste, comprising thousands of tons (Arvanitoyannis *et al.*, 2006). Untreated grape marc can lead to several environmental threats, including foul odours and ground water pollution (Table 8). Decomposing grape marc provides the perfect environment for flies and pest to flourish (Laos *et al.*, 2004). Leachate from the marc contains tannins and other chemical compounds that infiltrate the surface soil and ground water, leading to oxygen depletion (Arvanitoyannis *et al.*, 2006). It is possible to use the marc in other industries (Kammerer *et al.*, 2005); however, this can be expensive and therefore other, alternative solutions must be found (Ruggieri *et al.*, 2009). The impact of winery wastewater on the biological and physiochemical properties of soil has not been researched in depth (Mosse *et al.*, 2012). Table 8 shows the potential impacts of winery wastewater on the environment.

#### MINIMISATION OF WATER USAGE AND POLLUTION LOAD

Before discussing the different treatment options it is important to understand that the minimisation of winery wastewater should be the goal of all wineries (Lee & Okos, 2011). The term 'zero discharge process' is used by Lee and Okos (2011) to refer to the substantial reduction of water and energy usage and ultimately to generate no waste during the production of food and beverages. Furthermore, water saving does not only cut the cost of fresh water used, but also reduces the cost accompanying the treatment of the wastewater (Fillaudeau *et al.*, 2008). Avoiding waste is the most cost-effective and often the easiest principle to implement – better known as 'prevention (waste minimisation/cleaner production) is better than cure' (Chapman *et al.*, 2001).

Not only is water a limited resource, but it can also contribute to the total cost of the final product. When the total cost of production water is calculated for the food and beverage industry it is vital not just to look at the cost of the volume used and the volume disposed, but also to look at the potential loss in income when the product is disposed as effluent (Casani *et al.*, 2005). Fillaudeau formulated it as follows:

Water cost savings =  $W_{\text{Saved}} \times (W_{\text{Rate}} + W_{\text{Treat}})$   
where  $W_{\text{Saved}}$  is the volume of water saved,  $W_{\text{Rate}}$  the incoming water rate (e.g. \$/m<sup>3</sup>), and  $W_{\text{Treat}}$  the treatment cost of the incoming water (Fillaudeau *et al.*, 2008).

Wastewater treatment charge =  $WW_{\text{Saved}} \times WW_{\text{Charge}}$   
where  $WW_{\text{Saved}}$  is the volume of wastewater saved and  $WW_{\text{Charge}}$  is the volumetric wastewater charge, which is generally a function of several parameters such as COD, total solid content as well as other specific components (Fillaudeau *et al.*, 2008).

In Figure 3, the principles of cleaner production are

TABLE 8

Potential environmental impacts of winery wastewater (adapted from South Australian EPA, 2004).

Winery wastewater components	Indicators	Effects
Organic matter	BOD, TOC, COD	Reduces oxygen levels – death of fish and other aquatic organisms. Odours generated by anaerobic decomposition
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 water 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	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, odour generated from anaerobic decomposition

BOD – biochemical oxygen demand; TOC – total organic carbon; TDS – total dissolved solids; TSS – total suspended solids

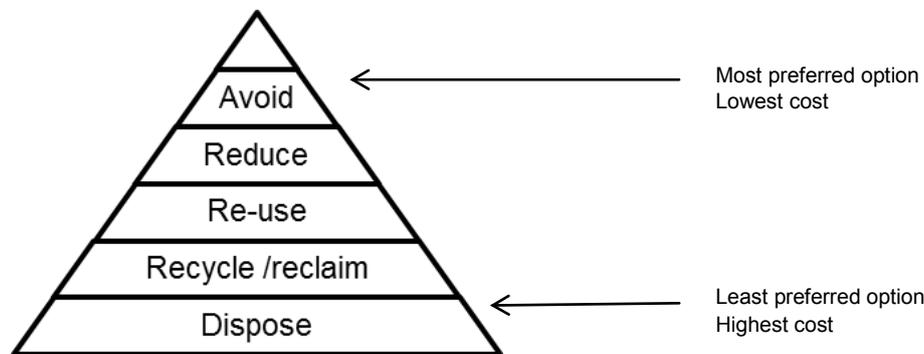


FIGURE 3  
Hierarchy of cleaner production principles (Chapman *et al.*, 2001).

illustrated, with the most preferred option, avoidance, as the most important principle (Chapman *et al.*, 2001).

Water management is a particular concern in the wine industry and there are practices that can be implemented to help reduce the wastewater volumes of wineries by using cleaner production principles (Van Schoor, 2005). In general, a considerable volume of up to 30% can be reduced through simple changes with minimum capital input (Kirby *et al.*, 2003). These changes include the evaluation of water usage in controlled areas; the improvement of planning and the control of water use; the option to reuse water; water recycling after treatment; and, lastly, the improvement of the layout of the processing area (Klemeš *et al.*, 2009). In particular, the evaluation (water auditing) of water usage is important to all industries (Klemeš *et al.*, 2008). Water auditing will not only help the winery to understand where the water is used, but also will indicate the place/process of largest usage. More importantly, it will point out the areas of unnecessary waste (Klemeš *et al.*, 2008).

The first step for all wineries should be to install a

water meter to control their water usage and identify water usage peaks, and to seek possible solutions (water-saving practices) to decrease water usage (Chapman, 1996). These water-saving practices include the use of nozzles on water pipes to avoid wastage. Water can be turned on and off conveniently each time the handle is compressed. The dry sweeping of floors with brushes and squeegees will also ensure the reduction of water usage before the floors are washed (Walsdorff *et al.*, 2004). Furthermore, water-saving practices that could be introduced to winery staff with the appropriate training are listed in Table 9. In addition to these principles, it is vital that the management is 100% committed. Winewatch also recommends that all winery staff should be involved when a cleaner production strategy is developed, as this will heighten their awareness (Klemeš *et al.*, 2008; Anonymous, 2009).

The next step in minimising the pollution load of the winery wastewater is the reduction of organic material in the raw wastewater. A number of practices that wineries can implement to achieve this is listed in Table 10. Firstly,

TABLE 9  
Water-saving practices (Chapman, 1996; Walsdorff *et al.*, 2004).

Water-saving practices	Description
Installation of water meter	Control water usage and identify water usage peaks
Use minimum water	Use no more water than needed for the job
High-pressure water system	Less water required for more efficient cleaning
Nozzle on water pipes	Avoid wastage of water so that a hose will not run when not required
Use of brushes and squeegee	Dry sweeping of floors before washing
Water awareness training	Developing of a cleaner production strategy

TABLE 10  
Pollution load-minimisation practices (Chapman *et al.*, 1996; Woodard & Curran, 2006; Winewatch, 2009).

Pollution load-minimisation practice	Description
Installing mesh sieves	Prevent organic matter in winery wastewater
Pomace animal feed/fertiliser	Mixed with stems and other solids
Transfer lees and first rinse to separate tank	Prevent the lees and diluted lees from draining into the wastewater system
Ensure that conveyers, storage bins and tanks are not overfilled	Reduce spillage
Grape seed oil	Edible oils can be extracted from grape seeds
Use fining agents that produce most compact lees	Reduce volume of lees
Install in-line screening of organic matter	Reduce finer solids in wastewater
Recovery of tartrates	Use in cooking as cream of tartar
Resettle lees	Remove as much organic material as possible
Keep transfers to a minimum	Reduce changes of spillage

the installation of mesh sieves in the floor, especially in the grape-processing section, will prevent organic material (stalks, skins and pips) from entering the wastewater system. Secondly, installing in-line screening in the initial stages of the treated wastewater system will reduce finer solids in the wastewater. To add to this, the accumulated lees after the initial alcoholic fermentation is thick and spillage can easily increase the COD (Fillaudeau *et al.*, 2008) of the generated wastewater. The average COD of wine lees is 76 000 mg/L (Boires *et al.*, 1998, cited in Fillaudeau *et al.*, 2008), therefore a small volume (of spillage when the tank is washed out after use) could have a vast influence on the raw wastewater of the winery. Thus it would be better if the lees and the first rinsing of the lees are transferred to a separate tank to prevent the lees and diluted lees from draining into the wastewater system (Woodard & Curran, 2006). It goes without saying that lees that is more compactly settled will simplify this last-mentioned practice. The use of fining agents that produce more compactly settled lees should be considered by the winemaker to help reduce the volume of the lees (Anonymous, 2009). Chapman (1996) has drawn attention to the fact that avoidance is an important principle to consider when planning to reduce wastewater pollution, therefore, transfers of wine should be kept to a minimum to reduce the chances of spillage.

Primarily, the elimination of salt (K, Ca, Na & Mg) usage in the winery should be promoted to reduce the EC and sodium absorption rate (SAR); consequently no treatment would be necessary before irrigation with the wastewater.

The use of non-sodium-based cleaning chemicals is advised by Chapman (Chapman, 1996). Replacing disinfectants and cleaning agents with ozone will result in lowering the EC and COD (Van Schoor, 2005). The initial cleaning with caustic can also be substituted with a high-pressure rinse or with heat/steam (Anonymous, 2009). When caustic is used for cleaning, the aim should be to re-use it (Chapman, 1996).

## CONCLUSIONS

Wine production is a growing industry all around the world because the demand for wine is increasing and new wineries are being established. Subsequently, this industry produces large volumes of wastewater that potentially pose a risk to the environment and thus require treatment.

It is clear from the literature that the volumes of water used in wineries vary, but also that the wastewater characteristics differ significantly. This is an indication that the winemaking practices (white, red, rosé or blends; type of press; bottling operations; filtering and barrel work; to name a few) influence the wastewater characteristics. Contributing to this problem is that many winemakers see winemaking as an art and thus are not overly concerned with water use and wastewater treatment.

Even though the characteristics of wastewater produced by wineries differ immensely from winery to winery, there are practices that wineries can implement to reduce the volume and the pollution load. The implementation of cleaner production practices offers a partial solution for wineries to minimise wastewater produced and also reduce

their water usage. It goes without saying that this, in return, will potentially reduce cost by avoiding wastages. Apart from these principles it is vital that the management of the winery is absolutely committed to contributing to the awareness and motivation of their employees.

A number of studies have recently shown that there is a correlation between winemaking practices and the characteristics of the wastewater, but further investigation is required to elucidate how specific winery practices influence the characteristics/composition of winery wastewater.

More specific information on these practices and their effects might encourage wineries to implement more efficient practices, thereby reducing water usage and the pollution loads of winery wastewater.

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