

## CHAPTER 2

### LITERATURE REVIEW ON THE COMPOSITION, DISPOSAL AND ENVIRONMENTAL IMPACT OF WINERY WASTEWATER

#### 2.1. PRODUCTION AND COMPOSITION OF WINERY WASTES

Wine is produced through the crushing and fermentation of grapes, followed by the straining of skins and seeds, storage, clarification and maturation of the young wine (NWQMS, 1995). The organic pollution generated by enological industries, especially during vintage and racking periods, is very high. In many Italian regions this load may be three or more times higher during the vintage campaign than the load generated by domestic sewage (Razzi, Malpei & Padoani, 1998). Winery wastes are composed of two components, i.e. liquid waste (effluent) and solid wastes (NWQMS, 1995).

Winery effluent is mostly cleaning waste, as wineries must be kept meticulously clean to avoid contamination and spoilage (Levay, 1995). Effluent originates from rinse water, which is used to wash equipment and floors. Some water containing alkali salts is used to remove tartrates and other organic acids from insides of equipment, and to promote earth filtering and ion exchange processes (NWQMS, 1995). The composition of fresh winery effluent can vary rapidly depending on how various effluent streams are mixed (Levay, 1995). According to Levay (1995), winery effluents contain:

- Simple organic acids, sugars and alcohols from grapes and wine. As a result, the effluents have a high requirement for oxygen for biological decay.
- Moderate salinity, high concentrations of sodium relative to calcium plus magnesium (i.e. high sodicity) and low amounts of nitrogen and phosphorus relative to carbon.
- Inorganic components from the water supply, alkali wash waters and processing operations. Chemical fertilizers, pesticides and herbicides used in producing grapes are insignificant components of the effluent.
- Appreciable amounts of sulphur.

According to Levay (1995), winery solid wastes consist of:

- Stalks, seeds and skins (marc) produced during the crushing, draining and pressing stages.
- Sediments (lees) containing pulp, tartrates and yeasts from the fermentation stage.
- Bentonite clay and diatomaceous earth from the clarification processes. Due to their fine particulate nature, bentonite clay and diatomaceous earth have poor physical properties including tendency to set hard and inability to transmit water.

The organic solid wastes are dominated by complex materials, including polysaccharides that are readily degradable by soil microorganisms and lignins and tannins, which are less degradable (Levay, 1995). Microbes can convert the organic wastes to humus in the soil (Levay, 1995).

The amount of effluent produced depends on the extent of juice extraction, the number of fermentation and clarification stages used in the manufacturing of each wine type and type of equipment used (NWQMS, 1995).

## 2.2. CHARACTERISTICS OF WINERY EFFLUENT

According to Van Schoor (2001a) if on any given day a person wants to irrigate more than 10 m<sup>3</sup> water originating from the production of wine cellars, he/she must register as a water user and up to 500 m<sup>3</sup> per day of this wastewater may be irrigated provided that the conditions in Table 2.1 are met.

Table 2.1: Conditions to which wastewater must comply for irrigation (Water Act, 1998)

- ❖ Electrical conductivity does not exceed 200 milliSiemens per metre (mS/m).
- ❖ The pH is not lower than 6 or higher than 9.
- ❖ Chemical Oxygen Demand (COD) does not exceed 400 mg/l after removal of algae.
- ❖ Sodium Adsorption Ratio (SAR) does not exceed 5.

If the COD value is higher than 400 mg/l, however, but less than 5 000 mg/l, irrigation after registration but without a licence may be up to only 50 m<sup>3</sup> on any given day. The registered water user may only irrigate above the 100 year floodline, or further than 100 metres from the edge of a water resource (Van Schoor, 2001a), while no ground water or surface water may be contaminated. Water with a COD higher than 5 000 mg/l is unacceptable for any kind of disposal.

### **2.2.1. COD (Chemical oxygen demand)**

Winery effluent is characterized by very high chemical oxygen demand (COD). This is the main problem from the perspective of discharging the wastewater. According to Shepherd & Grisner (1997), the oxygen in the wastewaters is rapidly consumed and where it is discharged this will also be done to the receiving waters. This will result in other constituents of the wastewater, most notably (because of the odour) the sulphur, becoming chemically reduced as the oxygen is consumed. While this is good news for pH neutralization (most reduction reactions consume hydrogen ions), it produces hydrogen sulphide and other reduced organo-sulphides, which cause odour problems and can become toxic to plants (Chang & Lin, 1997).

The problem from the treatment perspective is not only high COD, but also the particular chemical species that create COD. COD is a bulk measure for all the chemicals that consume oxygen as they are degraded (Duncan, Brady & Stoll, 1994). In winery wastewater, these are primarily organic compounds, which include organic acids, alcohols (ethanol) and phenolic compounds.

The phenolic compounds polymerize into longer chained compounds (eventually tannins), thus becoming a problem. Because of their ring structure, and later polymerized structures, they take longer to degrade, or treat, and consume considerable oxygen or other electron acceptors in the process (Shepherd & Grisner, 1997).

### **2.2.2. BOD (Bio-chemical oxygen demand)**

A waste is normally characterized according to the effect its various contaminants have on the sewer or receiving waters (Gajdos, 1998). The main properties are described as BOD (bio-chemical oxygen demand) and suspended solids. The BOD is a measure of the organic loading of a waste that can be consumed by bacteria. In doing so the bacteria use oxygen and so de-oxygenate the wastes, creating anaerobic conditions that cause bad odours (Parkes, 1974).

Application of untreated winery effluent can deplete the oxygen content of the soil and lead to anaerobic conditions, as the BOD is moderately high (Levay, 1995). Prolonged oxygen depletion reduces the capability of the soil microorganisms to decompose the organic matter in the effluent and may lead to bad odours and surface or groundwater pollution (NMWQS, 1995). It is therefore essential to allow sufficient time between irrigations for the soil to become aerobic (Chapman, 1983). The quantity of oxygen that can be held in different types of soil varies according to soil texture and structure (NMWQS, 1995).

### **2.2.3 pH**

The pH of fresh winery effluents varies with the relative concentrations of organic acids and caustic cleaning wastes (which can change very quickly). It ranges between 4 and 8, but is normally below 5.5 (Levay, 1995). Hence their application to land will usually tend to increase acidity depending on the buffering capacity of the soil (Bruvol & Ibenhalt, 1997). Many wineries choose to adjust the pH of the effluent at the point at which the effluent leaves the storage dam for irrigation (Hazell, 1997). The use of calcium hydroxide slurry to adjust the pH, in preference to other hydroxides, will at the same time help to correct the imbalance of sodium to calcium (Hazell, 1997). The collection ponds used to store effluent also influence the pH either to be high or low due to a number of processes that happen in the pond (Van Schoor, LH, Personal communication, 2001).

Thus both sodicity and pH can be effectively managed via the same system that would consist of an extra ‘monitoring’ step between effluent storage and land application (Chapman, 1995b). An acid condition favours the production of hydrogen sulphide, which is the dominant malodorous gas. Raising the pH of stored water can greatly reduce the production of hydrogen sulphide and hence lessen the impact of malodours on neighbouring properties (Chapman, 1994). The source of low pH is the citric acid used to dissolve tartaric crystals (Van Schoor, 2000).

Most soils have buffering capacity, i.e. they resist pH change. Nutrient deficiencies, toxicity or soil structural problems may result from strongly acidic or alkaline irrigation waters (Chapman, 1995b). The optimum pH of effluent should be in the range 6.5-8.4, but seasonal fluctuations can be expected, particularly if the wastewater is stored prior to irrigation (Chapman, 1995b). A soil pH of 5.5 to 8.0 is favourable for plant growth. pH strongly influences many soil characteristics, including the plant-availability of nutrients, the solubility of potentially toxic elements and microbial activity (Chapman, 1983). The South African legislation requires effluent pH to be in the range between 6 and 9 when irrigating (Table 2.1).

#### **2.2.4. SAR (Sodium adsorption ratio)**

SAR provides a measure of the relative concentrations of sodium to magnesium and calcium and the potential for soil structure to be adversely affected by sodium (Levay, 1995). For effluent applied to the land, SAR of less than 6 is desirable and short periods up to 9 is tolerable (Ryder, 1995). The South African legislation requires SAR not to exceed 5 when irrigating (Table 2.1). Excessive sodium in winery effluent relative to calcium and magnesium can adversely affect soil structure and reduce the rate at which water moves into and through the soil as well as soil aeration. Most researchers agree that the problems of low permeability increase when SAR approached 10 (Levay, 1995). Where effluent with a high SAR poses a problem, it could be blended with better quality water. Using water-soluble gypsum or applying gypsum to the soil surface should be considered (NMWQS, 1995).

If calcium is the dominant adsorbed cation in a soil, the soil tends to have a granular structure that is permeable and easy to cultivate. It is generally accepted that when adsorbed sodium exceeds 10-15% of total exchange capacity of the soil (i.e. when the ESP exceeds 10-15%) the clay becomes dispersed and puddles when wet, lowering infiltration, permeability and aeration and forming a hard impermeable crust when dry. Strongly crusting soils occur widespread throughout South Africa, including the Western Cape. A characteristic of many South African soils is their strong crusting tendencies at ESP values as low as just above 2 (Bloem, 1992).

### 2.2.5. General

Chapman (1996) highlighted the potential environmental and social impacts of different wastewater characteristics (Table 2.2).

Table 2.2: Environmental and social impacts of different wastewater characteristics  
(From Chapman, 1996)

Parameter	Potential environmental or social impact
Volume	Waterlogging, poor aeration of soil and malodours
Solids	Pore clogging, reduced soil aeration and permeability to water
Organic carbon	Removal of oxygen during degradation
Nitrogen, Phosphorus	Eutrophication of water
pH	Acidification of soil (if not adjusted with lime)
Salinity (NaCl, KCl etc)	Salinisation of soil and water
Sulphur	Bad odours in storage dams
Sodicity	Decline of soil structural stability leading to poor infiltration and drainage, waterlogging, poor aeration, hardness, compaction, breakdown of clay, pore clogging and erosion
COD	Reduction in oxygen content of water.

### 2.3. DISPOSAL OF WINERY EFFLUENT

The disposal of liquid wastes is a major problem of ever increasing proportion. With increasing of waste generation rates, the greater quantities of waste produced for a given area are placing increasingly heavy demand on existing disposal systems, particularly in today's environmental climate (Conolly, 1975). Disordered waste disposal has caused problems which can only be solved through the knowledge and management of the disposal system (Mahler & Oliveira 1998).

The treatment and disposal of wastes is one of the most important problems and greatest challenges facing mankind (Gajdos, 1998). The disposal of winery wastes has been a problem of concern for many years in nearly all winemaking areas (Bond, 1998). Traditionally wastewaters or effluents from wineries have been disposed of in evaporation ponds and in some cases in natural watercourses. The wastes should be disposed in a manner that is not a threat to health because general liability would arise if the place and manner of its disposal were not subject to controls (Leeson, 1995). Since the disposal to rivers in most countries has been restricted by timely legislation, the industry now generally utilizes lagoons to evaporate the wastes (Jolly, 1974). Waste management is a versatile part of environmental hygiene, which if mishandled can lead to an array of environmental problems (Steyl, 1996).

### **2.3.1. Land Application**

Land application of untreated effluent is considered to be one of the most effective and practicable methods of using the water, nutrient and organic matter values of winery effluent (Ryder, 1995). Liquid effluent from winery operations should be used for its water, nutrient and organic matter values in an environmentally safe manner. There should be no discharge of effluent to surface or ground waters (Shepherd & Grisner, 1997).

Certain land application systems are ideally suited for the treatment of organic carbon contained in winery effluents (Chapman, 1994). Treatment of organic contaminants added in wastewaters by soil is almost analogous to batched-flow fixed-film secondary treatment systems (Chapman, 1994). The movement of water within the soil system transports the organic contaminants to the microbial populations that are supported on a stationary medium. Sufficient contact time is allowed for microbial treatment and removal of the organic contaminants from the soil solution before it is displaced by the next application of wastewater (Chapman, 1994).

To minimize pollution of water bodies through surface run-off and soil erosion, effluent should not be applied on land which is adjacent to streams and watercourses, subject to flooding or steeply sloping or on rocky areas (Levay, 1995).

Two main types of land application of winery effluent are used, viz. (a) irrigating with effluent or (b) discharging the effluent into evaporation ponds.

### ***2.3.1.1. Amount of land required***

The amount of land required depends on a number of factors, including climatic conditions, nature of the soils, topography and the type of land disposal (irrigation or ponding) used (Levay, 1995). It also depends on the amount and composition of the effluent. According to Australian legislation, 1 hectare must be available for every 5 megalitre wastewater generated per year at a winery depending on the soil type (EPA, 1997)

#### *2.3.1.1.1 Climatic conditions*

Climatic factors, which affect the amount of land required for land disposal of winery effluent, are rainfall, temperature and humidity. Both the seasonal distribution and amount of rain are important factors (Levay, 1995). Heavy rain during the vintage season, when most effluent is discharged, creates a problem situation. It increases the hazard of flooding, which leads to transport of pollutants in surface runoff, and/or waterlogging, which causes unfavourable anaerobic decomposition of organic constituents.

Temperature and humidity affect evaporation and evapotranspiration rates (NMWQS, 1995). High temperatures and low humidities are favourable because they enhance high evaporation and evapotranspiration rates, thus minimizing the potential for waterlogging (Levay, 1995). Wastewater should as far as possible be applied during conditions which minimize polluted run-off and/or waterlogging.

#### *2.3.1.1.2. Nature of the soils*

The infiltration rate and drainage rate of the soil should not be exceeded during land application of effluent (Levay, 1995). Major factors, which influence the infiltration and drainage rates, are texture, structure, porosity, condition of soil surface and presence of impermeable layers. Soils can be degraded physically, chemically or



biologically by extremes in salinity, acids, alkalis and prolonged anaerobic conditions (NMWQS, 1995).

Highly permeable soils are often unsuitable, except at very low application rates, because contaminants may be leached rapidly into groundwater before uptake or breakdown has occurred (Levay, 1995).

#### *2.3.1.1.3. Topography*

In order to minimize surface run-off and soil erosion, effluent should not be used on land, which is immediately adjacent to streams and watercourses, subject to flooding, steeply sloping and rocky areas (Table 2.1).

## **2.4. IRRIGATION WITH WINERY EFFLUENT**

**Note: This section is based mainly on Chapman (1983). In cases where no specific reference is given, reference to this paper is implied.**

According to Chapman (1983) the current trend in discharge of winery wastewater by irrigation is a direct response to social pressure for minimizing malodours and avoidance of costly pretreatment systems. Numerous beneficial uses of treated wastewater are possible, including irrigation of pastures, trees, cereals, forage and horticultural crops. Irrigated pastures and woodlots currently form the basis of most public schemes. One of the difficulties with irrigation of horticultural crops using wastewater is that the nutrient content may be insufficient for early vegetative growth but excessive at the seed or fruit bearing stage.

Chapman (1983) further indicated that improved pasture for wastewater irrigation sites is commonly based on perennial rye grass because it is moderately salt-tolerant and highly productive. The ideal pasture composition would be a balanced mix of perennial, deep-rooted species to maximize water and nutrient uptake while providing the nutrient requirements of livestock.

Many species of trees, particularly eucalypts, have grown well under irrigation with wastewater. Selection depends on wastewater quality, soils, climate and the proposed method of irrigation. Irrigation of vineyards may be the only option available in many areas due to the lack of available land for other forms of effluent disposal on land, such as irrigation of cultivated pastures or ponding (Chapman, 1994). In order to ensure sufficient leaching, the soil must be sufficiently permeable and this is an essential selection criterion for a suitable irrigation site for most effluents (Bond, 1998). The problem is that leaching of large quantities of salts will lead to salinisation and/or sodification of streams or other water bodies.

Where irrigation with winery wastewater is considered as an option, the following criteria need to be met (EPA, 1998):

- The infiltration rate of each soil type should not be exceeded.
- The capacity of the soils and associated vegetation to store and use the water, organic matter and nutrients in the wastewater should not be exceeded.
- There should be no structure loss, salinisation, waterlogging, chemical contamination or erosion of the soil in the area irrigated with wastewater.
- Wastewater should not be irrigated onto waterlogged areas, land within 50 meters of a stream or wetland, onto land subject to flooding, steep sloping or rocky or highly permeable soil. (In South Africa the requirement is 100 metres.)
- There should be no increase in the salinity, total organic carbon or other effects on surface or underground water sources, which would make it incapable of supporting all existing uses in the future.
- Irrigation of wastewater should not be done using equipment which sprays the wastewater more than 1.5 metres into the air and creates significant quantities of fine droplets, and should not be undertaken within 50 meters of any residence on neighbouring land or 25 meters of any type of publicly owned land.
- Increases in the median total organic carbon or total nitrogen concentrations in a water course downstream of the winery waste water irrigation area should not exceed more than 50% of the concentrations at a site upstream from the irrigated area .

## 2.4.1. Suitabilities of different types of irrigation systems

### 2.4.1.1 Flood irrigation

The advent of land forming and laser grading combined with high flow rates, has improved the efficiency of flood irrigation. Excessively steep or uneven land is expensive to prepare, irrigation is more difficult to control and there is a greater risk of soil erosion and polluted runoff. Deep, sandy soils or other highly permeable soils are not suitable for flood irrigation because the water rapidly percolates below the root zone and may raise the water table or affect groundwater quality.

The slope and dimensions of the bays and the rate of water supply need to be matched to the rate of infiltration so that the water will be evenly spread over the surface and will penetrate uniformly to the required depth within 5-8 hours.

### 2.4.1.2 Drip irrigation

Drip irrigation systems can be highly automated and are adaptable to many different combinations of slope, soil and crops but it is not always the case in all areas. The physical properties of the soil determine the distribution of water below the surface and not all soils are suitable for drip irrigation. In coarse sandy soils lateral distribution of water below drippers is, for example, inadequate. Drippers can also not be used on soils with strong crusting tendencies due to being chemically dispersive (Laker, 2001). Poor infiltration under such circumstances leads to ponding and runoff. Such soils occur widespread in South Africa (Laker, 2001). For the same reason applying sodic effluent by means of drip irrigation may not be feasible.

Frequent short irrigations may be preferred to minimize the risk of concentrating salts and decreasing permeability through the destruction of soil structure. The soil must be allowed to dry out between irrigations so that it can become aerobic again (Chapman, 1983).

Wastewater often contains dissolved substances and suspended organic matter that can block the emitters directly, or as a result of corrosion. Filtration of the wastewater

immediately before irrigation is necessary to minimize blockages. Efficient drip irrigation depends on regular checking of operating pressures and maintenance of emitters and control equipment.

#### ***2.4.1.3. Micro-sprinkler irrigation***

Micro-sprinklers are used for irrigating vineyards, orchards, vegetables and landscaped areas. They are likely to produce aerosols and are therefore not suitable for irrigation with low quality water at windy locations, particularly where dwellings and public places may be affected. Serious problems with the use of micro-sprinkler irrigation have been found on strongly crusting soils in South Africa (Laker, 2001; Vanassche, 2001). On strongly crusting soils furrow irrigation is a better option than either drip or micro-sprinkler irrigation (Laker, 2001).

#### ***2.4.1.4. Overhead sprinkler irrigation***

Sprinkler irrigation is preferred on undulating or steep land and for soils with rapid infiltration rates, which are unsuitable for surface flood or drip irrigation systems. According to Chapman (1983) it can be used on easily eroded soils and also on shallow soil profiles. The first case is true **only** if the application rate does not exceed the infiltration rate of an erodible soil, otherwise severe erosion will occur due to the irrigation – as has happened in the White Kei scheme in the former Transkei (Laker, Personal communication).

When water is applied by spray irrigation at a rate equal to, or less than the infiltration capacity of the soil, the risk of erosion and off-site pollution by polluted sediment or runoff is minimal. Bloem (1992) developed criteria for the adaptation of the design and management of overhead irrigation systems to the infiltrability of soils for South African soils, with special attention to crusting soils.

The success achieved in the case of shallow soils will depend on the type of system and the accuracy of irrigation scheduling to ensure that the amount of water applied never exceeds the low water storage capacity of the soil (Laker, Personal communication). Good irrigation scheduling, i.e. the timing of irrigations and

applying the correct quantity of water per irrigation is essential to the success of sprinkler irrigation, just as for all other types of irrigation (Chapman, 1983).

Overhead sprinklers cannot be used in areas where strong winds prevail. Sprinkler efficiency is reduced by distortion of the wetting pattern by wind. Wind drift of sprays increases the potential for public exposure to wastewater. In this regard not only the velocity of the wind, but also its prevailing direction (to or away from nearby residential areas, for example) is important. Evaporation during hot, windy weather also reduces sprinkler efficiency. Environmental concerns about spray irrigation are usually associated with bad odours and transport of aerosols from the site.

#### **2.4.2 Benefits of irrigating with winery effluent**

Continued irrigation of a red brown earth with wastewater from a winery led to an increase in the organic carbon content and contents of P, N and K within the top 10 cm layer of the soil (Papini, 2000). Repeated application of winery wastewater over 17 years resulted in a 30-75% increase in the total organic carbon content within the 0-15cm layer of a brown earth soil when compared to a non-irrigated soil (Chapman, 1995b).

Organic matter helps to maintain or improve nutrient and moisture retention and also the structure of the soil. Improved nutrient retention is due to increases in cation exchange capacity. Irrigation of soils with organic rich effluents increases the microbial biomass (Papini, 2000). Ion exchange and microbiological activity in soils can improve effluent quality (NMWQS, 1995).

#### **2.4.3. Problems associated with irrigating with winery effluent**

##### ***2.4.3.1. Sodicity***

Sodium is not an essential element for plant growth. Irrigating with sodic winery effluent, i.e. effluent with a relatively high SAR, can lead to the development of sodic conditions in the soil where it is applied. The source of sodium is hot wash water containing caustic soda (sodium hydroxide) which is used to help dissolve potassium

bitartrate from storage vessels (Van Schoor, 2000). It is important to manage sodicity in order to prevent degradation of the irrigation site (Rhoades, 1989). Irrigating with wastewater having high amounts of sodium can also lead to the clogging of irrigation systems as a result of algal growth in these systems (Van Schoor, Personal communication).

Irrigation with wastes low in salinity but high in sodium salts may result in sodium ions occupying such a proportion of the ion exchange sites on soil particles, that the soil tends to lose its capacity to transmit water. Run-off and erosion hazards are increased as a result (Parkes, 1974). The use of sodic groundwater and wastewater to irrigate vineyards may also result in loss of potential exports to European destinations due to unacceptably high sodium levels in wine (Chapman, 1996). There are many factors that influence the magnitude of the effect of sodicity, particularly the type of clay in the soil and electrical conductivity of the soil water (Chapman, 1994).

The main problem associated with sodicity is severe degradation of the physical condition of the soil. This is primarily because  $\text{Na}^+$  is a highly dispersive cation, causing dispersion of the colloidal fraction of the soil, i.e. the clay fraction and the colloidal organic fraction (e.g. humus). Dispersion of the organic fraction sometimes leads to a condition known as “black brack”.

Dispersion of clay colloids leads to loss of soil structure (Chapman, 1995b). This sharply reduces the macro-porosity of the soil, severely lowering its hydraulic conductivity and drainage capacity. Sodic conditions in the surface layer of the soil lead to extreme crusting (surface sealing) of the soil. This reduces infiltration and thus increases the runoff of polluted water and erosion. A seal also inhibits soil aeration.

When a sodic subsoil is exposed it leads to gully erosion (Chapman, 1995b). High sodium levels will imbalance the cations and anions present in the soils leading to a degradation of soil structure and permeability (Glaetzer, 1998). Sodicity induces calcium and magnesium deficiencies because of repressed solubilities of these nutrients due to high pH and bicarbonate conditions (Rhoades, 1989).

#### 2.4.3.2. *Salinity*

If too much water is applied, the groundwater surface, known as the water table, may rise significantly. If the saturated conditions persist within 1-1.5 metres of the surface, salts present in the groundwater tend to accumulate in the topsoil as water evaporates from the surface and are extracted from the soil by plants (Chapman, 1994). Under natural conditions, the water table rises and falls in response to infiltration or rainfall.

### 2.5. DISPOSAL OF WINERY EFFLUENT IN EVAPORATION PONDS

According to Batchelor (1998), stabilization ponds have been employed for the treatment of wastewater for over 3000 years. They can be used alone or in combination with other wastewater treatment processes.

According to Wood *et al.* (1995), in Australia, wastewater treatment ponds remain a popular form of treatment for wastewater from small towns and many industries isolated from sewerage treatment systems. They further said that ponds are commonly used because land is readily available, they are easy to construct and require only minimal maintenance and operational control.

Stabilization ponds are an effective means of treating wastewater, reducing BOD and coliforms, but can have an occasional high concentration of suspended solids in the effluent. The occasional high concentration of suspended solids, which can exceed 100 mg/l in the effluent, is the major disadvantage of pond systems (Middlebrooks, 1995).

The high concentration of total suspended solids is mainly due to large quantities of algal cells. The presence of such algae can impose serious constraints on effluent reuse potential, which is particularly important in water-scarce regions. Agriculture is perhaps the sector where effluent reuse is most likely to be applied. This being the case, the presence of algae in large quantities in the effluent is bound to create undesirable effects in the water receiving bodies and in the irrigation networks (Saidam, Ramadan & Butler, 1995).

According to Shelef & Kanarek (1995), wastewater treatment by stabilization pond is regaining much interest in countries where climatic conditions are suitable and land is readily available.

Advantages of stabilization ponds include:

- Low capital investment, especially with regard to construction cost and where land is available at reasonable cost.
- Simplicity of operation and maintenance, which does not require technical sophistication, or highly trained personnel.
- Smoothing of peak hydraulic loads and relative resistance to shock organic loads and toxicants due to the large pond volumes, long retention period and high buffer capacity.
- Possibility of “ultimate disposal” by evaporation and seepage.
- Impoundment and storage of effluent for reuse by irrigation.

Disadvantages of stabilization ponds include:

- High land area requirements
- Performance is dependent to a large extent on climatic conditions such as temperature, solar irradiance, wind velocity etc.
- Overloading or abrupt change in climatic conditions can cause odour nuisances and deterioration of effluent quality.
- Possibility of groundwater contamination by seepage from the ponds, particularly in sandy and loamy soils.
- Water losses due to evaporation and seepage where effluent reuse is essential.