ENVIRONMENTAL IMPACT OF WINERY EFFLUENT IN THE WESTERN AND NORTHERN CAPE PROVINCES

by

AZWIMBAVHI RECKSON MULIDZI

Mini – dissertation presented in partial fulfilment of the requirements for the degree

of

Magister Institutionis Agriculturae in Land Use Planning

In the Department of Plant Production and Soil Science
Faculty of Natural and Agricultural Sciences
University of Pretoria

Supervisor: Prof M.C. Laker

Co-supervisor: Mr L.H Van Schoor

May 2001

Declaration

I, the undersigned, hereby declare that the work contained in this dissertation is entirely my own original research and that it has not at any time, either partly or fully, been submitted to any university for the purposes of obtaining a degree.

Signed:.. Date 20 July 2001

ABSTRACT

This study is an integral part of a multidisciplinary research programme that was started as a result of a lack of information on the disposal practices of winery effluent in South Africa. The objective of this study was to investigate the environmental impacts of winery effluent applied in different ways on different types of soils so that guidelines for the identification and selection of suitable combinations of disposal methods and soil types for land disposal of winery effluent could be developed, and also to propose alternative management strategies which comply with national and international legislation.

Ten wineries were selected for the study. The soil and effluent samples were collected at each winery on a monthly basis and analysed. From the results it was clear that different wineries use different disposal methods and on different soils. The study confirmed that winery effluents pose definite pollution problems. The biggest problem when winery effluent is applied to soil is the high organic matter levels in the effluents during the winemaking period. Most of the soils do not retain it and it leaches straight to a water table at the bottom of the soil profile and from there seeps through to nearby streams or ground water bodies, thereby polluting the environment.

In the study it was found that there are many similarities between wineries but there are also major differences between them such that general recipe cannot be used. From the study it was also clear that deep, highly permeable, sandy soils (especially those with E horizons) are not suitable for disposal of winery effluents, either by means of irrigating pastures or ponding.

ACKNOWLEDGEMENTS

I would like to express my sincere thanks to the following:

Prof M.C. Laker and Mr L.H. van Schoor for their assistance, guidance, patience and support with this study and with the preparation of the dissertation.

Mr P.J.E. Louw for his assistance and constructive criticism.

The Agricultural Research Council (ARC) for making this study possible and for permission to use the results for dissertation purposes.

The staff of the Soil Science Section of the ARC – Fruit, Vine and Wine Research Institute for technical assistance.

All wineries which participated in the study. Without their co-operation the study would not have been possible.

Winetech for financial assistance.

Dorah Mulaudzi for her patience and support.

My mother for her support over the years.

My heavenly Father for His grace, power and strength, without which this dissertation would not have been possible.

CONTENTS

CHAPTER 1 - INTRODUCTION

CHAPTER 2 - LITERATURE REVIEW

CHAPTER 3 - RESEARCH METHODOLOGY

CHAPTER 4 - RESULTS AND DISCUSSION PER WINERY

CHAPTER 5 - INTEGRATED COMPARATIVE DISCUSSION ON THE COMPOSITION OF WINERY EFFLUENTS

CHAPTER 6- INTEGRATED COMPARATIVE DISCUSSION ON THE EFFECTS OF WINERY EFFLUENTS ON SOIL AND POSSIBLE POLLUTION OF WATER BODIES

CHAPTER 7 - FATE OF ORGANIC COMPONENTS OF WINERY EFFLUENTS IN SOILS

CHAPTER 8 - CONCLUSIONS AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1. BACKGROUND

From the time when people first gathered to live in communities the disposal of waste generated by human activities has been an environmental problem (Tchobanoglous, Theisen & Eliassen, 1977). Towns and settlements were often smelly and unhealthy places, due to the fact that solid and liquid wastes were commonly tipped out into the street. These kinds of disposal practices led to water pollution due to transport of the pollutants to water bodies through runoff or leaching during rains (Try & Price, 1995). Land application of wastes often led to the accumulation of toxic concentrations of various pollutants in soils.

Water is an important though often underrated resource. South Africa is a relatively arid country with an average annual rainfall of less than 500 $mm.a^{-1}$ (DEAT, 1997), compared with the world average of 860 $mm.a^{-1}$. With this kind of situation water availability and quality are of paramount importance to the socio-economic growth in South Africa (Duncan, Brady & Stoll, 1994). South Africa, especially the Western Cape, has very limited arable land. Degradation of good quality soils, e.g. through pollution, can, therefore, not be afforded.

Wine production is a very important and growing part of South Africa's economy, being of paramount importance to the economy of the Western and Northern Cape. Wine production in South Africa has increased over the past decade and this growth increases pressure on the natural resources such as water, soil and vegetation (Van Schoor, 2000). The wine industry in South Africa comprises a group of closely related industrial operations engaged in the production and processing of grapes to a variety of alcoholic and non-alcoholic products (Robertson & Kirsten, 1993).

The wine industry produces a large quantity of wastewater associated with washing operations during grape harvesting, pressing and the first fermentation phases of wine processing. The problem of handling winery wastewater has been part of winery management for years (Shephard & Grismer, 1997).

The rapid growth in wine production and intensification of land use in most wine making regions of the world during the last decade needs to be matched with greater emphasis on minimizing the impact of winery operations on the natural and human environment (Gajdos, 1998). Wastewater treatment and disposal has become a major component of policymaking because of growing awareness of environmental quality issues (Huruvf, 1998). As a result the disposal of effluent from the wine industry has become an increasing cause for concern to both the industry and the controlling bodies responsible for effluent management (Strohwald, 1993).

Very little monitoring of winery effluent characteristics and impacts on the environment has been done in the past. In South Australia it started only after the Environment Protection Act came into effect in 1995 (Hazell, 1998).

Chapman (1995a) indicated that the South Australian wine industry disposes of its wastewater primarily by evaporation, irrigation, land application and direct discharge into watercourses at times of high flow. Malodours and other problems associated with anaerobic conditions caused by the high organic loading of the wastewater have led to these methods of disposal becoming environmentally and aesthetically unacceptable. Problems associated with anaerobic decomposition are by far not the only problems caused by winery effluents, however. Virtually no systematic studies on the composition and environmental impacts of winery effluents have been conducted in South Africa.

The focus of this dissertation is on land disposal of winery effluents. Ten wineries, distributed throughout the Western and Northern Cape, were included in the study. These wineries use different methods of disposal on different soil types. The study examined the cumulative impacts of the procedures used for disposal of winery effluents on different types of soil in the Western and Northern Cape Provinces.

The compatibility between different disposal methods and different soil types has been determined. These were used to develop guidelines for the selection of suitable disposal method/soil type combinations. It can serve to put acceptable waste management practices in place and indicate policy areas needing improvement or change.

Various other related aspects regarding the disposal of winery effluents and quality are addressed in the multidisciplinary studies at the University of Stellenbosch and the Nietvoorbij campus of the ARC – Institute for Fruit, Vine and Wine.

1.2. PROBLEM FORMULATION AND OBJECTIVE OF THE STUDY

The study followed a multidisciplinary study that started as a result of a lack of information on the disposal practices of winery effluents in South Africa.There is great concern that these effluents may have negative environmental impacts, especially if disposed on soils inappropriately, and that wineries may become liable to heavy penalties enforced by legislation.

Objectives of the study

- To investigate the environmental impacts of winery effluents applied in different ways on different types of soil.
- To develop guidelines for the identification and selection of suitable combinations of disposal methods and soil types for land disposal of winery effluents.
- To propose alternative management practices or strategies which comply with the national and international legislation.

1.3. STRUCTURE OF THE DISSERTATION

A literature review on the environmental impact of winery effluents is presented in Chapter 2. This chapter also includes a review of the production and composition of winery effluents, their characteristics and disposal methods. Chapter 3 outlines the research methodologies used. It describes how the wineries were selected, soil and effluent sampling and also the analytical methods that were used. Chapter 4 gives results and discussions per winery. This is done so that each participating winery can later be given a clear picture of its specific situation. Chapter 5 gives an integrated comparative discussion on the composition of winery effluents. Chapter 6 gives an integrated comparative discussion on the effects of winery effluents on soil and possible pollution of water bodies. Chapter 7 gives a discussion on the fate of the organic components of winery effluents in soils. Chapter 8 gives conclusions and recommendations.

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^3 water originating from the production of wine cellars, he/she must register as a water user and up to 500 m^3 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^3 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 erodable 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 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 sewered 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.

CHAPTER 3

RESEARCH METHODOLOGY

3.1. SITE SELECTION

Ten wineries from the Western and Northern Cape were included in the study. The wineries were selected from all the main wine production areas in these two provinces. Only wineries that were willing to participate voluntarily were included in the study.

Because of the sensitivity of the data the names of the wineries are not given. A code numbering system will only be used to identify them. The code number, code name and disposal method used at each winery is given in Table 3.1.

Table 3.1: Code numbers, code names and disposal methods of wineries included in the study

Code number	**Code name**	**Disposal method**
Paa1	Paarl 1	Irrigation
Paa 2	Paarl 2	Irrigation
Paa 3	Paarl 3	Ponding
Stell	Stellenbosch	Irrigation
Rob 1	Robertson 1	Irrigation
Rob 2	Robertson 2	Ponding
Worc	Worcester	Irrigation
Berg	Berg river	Irrigation
Olif	Olifant river	Ponding
Oran	Orange river	Ponding

3.2. EFFLUENT SAMPLING AND ANALYSIS

Effluent samples were collected from each winery on a monthly basis from December 1999 to July 2000. The effluent was collected from the ponds or tanks where it was stored before being disposed onto the land disposal area. Samples of 200ml and 700ml respectively were collected each time. The 200ml samples were sent to CSIR for COD analysis, using the 5220 B open reflux method (Clesceri, Greenberg & Eaton, 1998). BOD was not determined. The 700ml samples were sent to ARC-Infruitec for the analysis of pH, Electrical conductivity, Na, K, Ca, Mg, Fe, Cl and B. The elements were determined on an ICP spectrometer (Association of Official Analytical Chemists, 1990).

3.3 SOIL INVESTIGATIONS AND ANALYSES

3.3.1 Soil sampling

Soil sampling was done with a soil auger at each winery on a monthly basis from December 1999 to July 2000. The samples were taken from the areas where the effluent is disposed. The soil was sampled at three depths, i.e. 0-30, 30-60 and 60-90 cm. The soil samples for **May** were sampled differently from other months due to soil classification. ***Samples were collected in profile pits and not by auger and sampling depths differed from the other months.***

A control site was selected outside the disposal area in soil closely related to that at the disposal site. It was sampled once at each winery at depths of 0-30, 30-60 and 60-90 cm.

3.3.2. Soil analysis

The soil samples for each winery were prepared and sent to ARC-Infruitec for analysis on a monthly basis. The soil samples were analysed for pH, electrical resistance, stone%, P, Na, K, Ca, Mg, Cu, Zn, Mn and B. pH was determined in a 1: 2,5 soil:1M KCl suspension. The Ammonium Acetate (1 mol.dm^{-3}, pH 7) method was used to extract Ca, Mg, K and Na. They were determined by either flame emission or atomic absorption spectroscopy.

The Di-Ammonium EDTA method was used to extract the micro-elements (Cu, Mn and Zn), which were determined in the extracts by means of ICP. Boron was extracted with 0.02M $CaCl_2$ and determined in the extracts by means of ICP. The Bray 1 method (The Non-affiliated Soil Analysis Work Committee, 1990) was used to determine plant-available phosphorus. Electrical resistance was determined by means of the soil paste method.

3.3.3. Bulk density determinations

Bulk density sampling was done once at each winery. It was done on the top and subsoil on the area where the effluent is disposed and also on the control sites. Undisturbed core samples were collected by means of sampling rings. After removing the samples from the rings, they were dried in an oven at 105^0C for 7 hours, allowed to cool and weighed.

The Bulk density was calculated using the following equation:

Bulk density = Mass of dry soil (grams)/ Total volume (cm^3).

This was then converted to the conventional expression of bulk density in $kg.m^{-3}$.

3.3.4. Soil classification

Modal soil pits were located at representative sites. One profile pit was dug at each winery in the area where the effluent is disposed. The soil classification was done during May 2000 at 8 wineries. The two wineries where classification was not done are Paarl 3 and Robertson 2. These wineries dispose their effluent into evaporation dams that are in very rocky areas.

Profiles were described and classified according to the taxonomic soil classification system for South Africa (Soil Classification Working Group, 1991). Each master horizon of each modal profile was sampled separately. The samples were sent to the laboratory of ARC-Infruitec to be analyzed for pH, electrical resistance, P, K, Na, Ca, Mg, Zn, Mn, B and particle size distribution. pH, electrical, P, K, Na, Ca, Mg, Cu, Zn, Mn and B were determined according to the methods described in Section 3.3.2. Particle size distribution was determined according to the hydrometer method.

3.3.5 Sampling of black soil layers

During the studies of the modal profiles, black soil layers were found at certain depths in the soils of the disposal sites at Robertson 1, Stellenbosch, Olifants River and Orange River wineries. The water dispersibility of the organic matter in these samples was determined in the laboratory by means of addition of distilled water to the samples in beakers, stirring and decantation. This step was repeated until all black material was removed from the soil.

CHAPTER 4

RESULTS AND DISCUSSION PER WINERY

4.1 GENERAL REMARK

Because of the sensitive nature of some of the data, names of wineries will not be given here. Wineries are indicated by area codes only. Readers must not confuse the regional/area names used here with the names of specific wineries that may have similar names. As was mentioned in the literature, wineries should comply with the legislation when they dispose of their wastewater. Wineries should comply with all criteria. If for example the pH of the wastewater is acceptable, but the COD is outside the legal norms, the winery may not dispose of the effluent by means of land application.

4.2 PAARL 1 WINERY

4.2.1 Main types of wines produced and chemicals used in the cellar

Both white and red wines are produced by this winery. Bulk filter and sheet filter with diatomaceous earth is used to filter the wines. Bentonite is also used for protein stabilization. The Q45 soaps and caustic soda are used to wash equipment in the cellar. Chlorine is also used to kill fungi.

4.2.2 Disposal method and soil description

This winery disposes of its effluent by means of irrigating kikuyu grass through conventional overhead sprinklers.

The soil of the disposal area was classified as belonging to the Hermon family of the Sterkspruit form (Soil Classification Working Group, 1991). This indicates that the soil is characterized by strongly structured subsoil with poor physical conditions. Most importantly its infiltration rate and hydraulic conductivity can be expected to be very low. This could cause a danger of ponding and eventually runoff and overflow of effluent into the adjacent channel. A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.1.

4.2.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis from December 1999 to June 2000 (except May 2000) are given in Tables 4.1 and 4.2.

Table 4.1: pH, COD, SAR, EC and Na data for effluent samples from Paarl 1 winery (From: Van Schoor & Mulidzi, 2001)

Month	**pH**	**COD (mg/l)**	**SAR**	**EC (mS/m)**	**Na (mg/l)**
December	6.4	2299	5.7	-	206
January	2.7	5296	1.8	-	61
February	5.1	2700	1.2	82	33
March	5.1	3373	4.4	109	152
April	5.0	7802	1.6	386	85
June	4.5	4458	1.8	170	66

At this winery the effluent **pH** of 6.4 for December 1999 is above the minimum acceptable pH of 6 specified in the General Authorizations in terms of Section 39 of the National Water Act, 1998 (Act No.36 of 1998) and should not pose a problem (Table 4.1).

The effluent pH dropped dramatically as soon as the wine making season started in January, however. The source of the low pH is probably citric acid (Van Schoor, 2000). According to the Department of Water Affairs and Forestry (1996) acidification of soil by applying water with a pH less than 6 may in the long-term lead to the availability of several micro or macronutrients in toxic concentrations. High availability of these nutrients has serious health and environmental implications.

The low pH also increases problems with corrosion of metal or concrete components of irrigation systems. The effluent pH of only 2.7 for January 2000 was the lowest recorded at any stage for any of the wineries studied. Thereafter it stabilized at a much higher, but still unacceptably low, level for the rest of the study period.

The effluent from this winery was characterized by moderate **COD** values of less than 5000 mg/l, which is the maximum acceptable to limited for irrigation of 50 m^3/d (Act

No.36 of 1998), for most of the study period. During January the COD of the effluent from this winery was just slightly above the maximum permissible level of 5000 mg/l, while in April it was significantly above this level. Thus, the disposal of the January and April effluents prior to treatment is not acceptable according to the South African environmental standards.

(Sodium adsorption ratio) **SAR** of the effluent for December was above 5, which is the maximum permissible value (Act No. 36 of 1998). In all other months the SAR values were acceptable according to the South African Water Act standards for irrigation. However it must be pointed out that the SAR value for March approaches the danger level, which indicates that if there is no improvement in the wastewater management sodicity problems may develop in the long term. Like SAR, **sodium** is higher in the December and March effluents.

Electrical conductivity (**EC**) was above the South African standard of 200mS/m for any disposal (Act No.36 of 1998) only for the April effluent.

Table 4.2: K, Ca, Fe, Mg, B and Cl contents of effluents from the Paarl 1 winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	57	-	1.07	0.11	-
January	32	60	5.30	0.63	-	98
February	125	39	3.13	0.44	0.10	173
March	65	64	1.85	0.66	0.11	130
April	336	185	7.25	1.00	0.37	132
June	211	75	6.27	0.64	0.27	116

None of the **nutrient elements** analysed had values that are unacceptably high at any stage, indicating that these do not pose toxicity hazards at this stage (Table 4.2). The April effluent showed elevated, but not unacceptable, K, Ca, Fe and B levels. Mg levels were very low throughout.

4.2.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.3). Some of these are inconsistent and could perhaps be related to sampling/analytical problems (e.g. the very high Zn level in the March 2000 topsoil sample). Others may be cause for concern in regard to possible problems which may develop over the long term, especially when viewed in conjunction with similar trends at the other wineries studied.

Exchangeable sodium percentage **(ESP)** values of the effluent treated soil were low to moderate, but consistently higher than those for the control in the 0-30 cm and 30-60 cm layers. During December, when irrigation was done with effluent with a somewhat higher SAR, the ESP rose to between about 7.0 and 8.5% throughout the profile. Thereafter it dropped sharply, but started increasing again from March (when the effluent again had a slightly higher SAR) to May.

During May ESP values up to over 9.0% were found throughout the profile. Even though these values are not excessively high, and lower than those for most of the other wineries, problems may develop on the highly dispersive soil on which the effluent is disposed of at this winery. It must be pointed out that though the ESP does not seem to be a problem now, there are signs that it is building up such that in a long term it may become a problem. During soil classification in May, it was noted that there is a large amount of dispersed washed in clay in the B1 horizon, which may clog macro-pores. It is expected that continuous application of effluent on this soil will adversely affect the infiltration rate and hydraulic conductivity of the soil and aggravate the problem of runoff and overflow into the channel.

The topsoil **phosphorus** (P) levels in the December and January samples from the effluent treated site are a matter for concern since they are much higher than the levels that Eloff & Laker (1978) found to suppress crop yield (Table 4.3). Eloff & Laker (1978) found that for the Olsen method, which gives values similar to the Bray 1 method, any P values above 45 mg.kg^{-1} suppress yields. The values for the other months were not in this grossly excessive range, but still very high. The sharp decrease in topsoil P levels after January is difficult to explain since subsoil P levels do not indicate P leaching. Unfortunately P data are not available for the effluents. Although indications are that in the long term excessive P levels may worsen to become a severe problem, the situation is better than at most of the other wineries studied.

During April and May the subsoil **potassium** (K) levels were very high compared to the control site (Table 4.3). During these months topsoil K levels were also higher than the control site. The high potassium values can be attributed to the K-H- bitartrate that occurs in both the must and the wine (Van Schoor, 2000).

The fact that the K levels were so high throughout the profile, even to deeper than 1 metre, and that topsoil K decreased from April to May while subsoil K increased during the same period, points to a high mobility of K in the soil. This is in contrast to the situation with P. The elevated K levels in the topsoil **and** the subsurface layer (30-60cm) during December and January (of which the source is not clear), followed by very low levels during February and March, further strengthen the idea of high K mobility. The apparent high K mobility may lead to leaching of K from the soil into water bodies, where it may become an eutrophication concern. At the moment this is speculation, but warrants follow-up work.

Topsoil **pH** values at the disposal site were acceptable, but subsoil pH levels were low to very low, especially in the deeper subsoils (60-90 cm). These values were not lower than those of the control site, however.

Table 4.3: Soil analyses for Paarl 1 Winery

Months	Depth	pH	Resistance	P	K	Na	K	Ca	Mg	S-value	Cu	Zn	Mn	B	ESP(%)
	(cm)	(KCl)	(ohm)	(mg/kg)	(mg/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
December	0 – 30	4.7	1880	104.00	199.00	0.73	0.51	3.95	1.20	8.57	2.35	3.30	12.40	0.36	8.52
December	30 - 60	4.2	1300	50.00	106.00	0.81	0.27	4.70	1.70	11.49	1.06	1.40	7.10	0.43	7.05
December	60 - 90	3.9	770	23.00	47.00	0.76	0.12	3.19	2.00	10.43	0.49	0.60	1.80	0.16	7.29
January	0 – 30	4.8	1880	131.00	289.00	0.33	0.74	4.84	1.62	9.53	2.92	3.20	14.60	0.34	3.46
January	30 - 60	4.6	2470	122.00	106.00	0.37	0.27	3.92	1.42	7.90	1.99	1.80	8.60	0.28	4.68
January	60 - 90	4.5	1360	66.00	70.00	0.59	0.18	4.46	2.45	10.73	0.56	2.00	6.40	0.25	5.50
February	0 – 30	5.0	1450	46.00	27.00	0.10	0.07	0.45	0.25	2.68	1.24	3.80	9.10	0.29	3.73
February	30 - 60	5.0	1310	22.00	8.00	0.11	0.02	0.39	0.28	3.47	0.50	1.00	4.30	0.24	3.17
February	60 - 90	4.6	640	8.00	4.00	0.10	0.01	0.28	0.28	2.40	0.31	1.00	2.20	0.19	4.17
March	0-30	5.9	1330	55.00	47.00	0.06	0.12	0.56	0.20	0.94	1.72	44.60	12.80	0.26	6.38
March	30-60	5.1	1510	28.00	20.00	0.09	0.05	0.40	0.18	2.76	1.41	13.50	7.10	0.21	3.26
March	60-90	4.6	650	6.00	8.00	0.09	0.02	0.32	0.26	3.91	0.30	7.50	2.20	0.07	2.30
April	0-30	5.0	1170	73.00	223.00	0.47	0.57	4.65	1.78	8.73	1.44	8.10	9.90	0.18	5.38
April	30-60	4.4	1500	33.00	215.00	0.62	0.55	4.36	1.80	9.85	0.66	2.30	4.40	0.13	6.29
April	60-90	4.0	1070	9.00	211.00	0.41	0.54	3.10	1.80	8.37	0.18	0.70	1.80	0.04	4.90
May	0-10	5.7	0	62.00	196.00	0.66	0.50	4.67	1.53	7.36	1.38	12.30	11.00	0.23	8.97
May	10-50	4.6	0	76.00	160.00	0.47	0.41	3.74	1.33	5.95	2.23	5.10	9.70	0.18	7.90
May	50-80	4.0	0	5.00	235.00	0.49	0.60	3.39	2.02	6.50	0.31	1.80	2.10	0.08	7.54
May	80-100+	4	0	2.00	239.00	0.52	0.61	2.44	2.06	5.63	0.14	0.40	0.70	0.05	9.24
Control	0-30	5	2560	62.00	145.00	0.22	0.37	5.64	1.28	8.69	1.73	1.20	16.70	0.42	2.53
Control	30-60	4.2	1830	26.00	66.00	0.17	0.17	4.07	1.13	7.66	0.59	0.40	4.30	0.27	2.22
Control	60-90	3.9	1090	7.00	35.00	0.25	0.09	2.42	1.02	5.04	0.14	0.10	0.10	0.12	4.96

The **bulk densities** of both the topsoil and subsoil of the effluent treated site were lower than those for the control site (Table 4.4). The value of 1 400kg/m^3 for the treated site is quite low and favourable. It seems as if the effluent applied on the soil did not bring about any problems as far as the soil structure is concerned. This is unexpected in view of the dispersed clay observed during the profile description.

Table 4.4: Bulk densities of the soils at Paarl 1 winery

Soil depth	**Treated plot**	**Control**
Topsoil	1400 kg/m^3	1600 kg/m^3
Subsoil	1400 kg/m^3	1700 kg/m^3

4.2.5 General evaluation

Overall the effluents from this winery are of a better quality than those from almost all the other wineries studied and seem to pose the least threat of negative environmental impacts. Some aspects are unacceptable and need attention, however. Most serious are the moderately high COD and EC values of the April effluent.

The extremely low pH and slightly higher than acceptable COD in the January effluent also needs attention and the general low pH values are unacceptable. Aspects that are acceptable according to the water quality standards but need attention with a view to long-term sustainability include the P, K and Na levels during some periods.

Disposal is done on a low potential soil, but it seems to be a much more suitable soil for effluent disposal than those used at by far the majority of other wineries studied.

4.3 PAARL 2 WINERY

4.3.1 Main types of wines produced and chemicals used in the cellar

This winery produces both red and white wines. The bulk filter, vacuum filter and drum filter with diatomaceous earth are used during the filtration of wine.

Bentonite is used for protein stabilization. Q5 special soaps are used to wash the tanks. Caustic soda is also used to remove the tartaric acid.

It was found that this winery uses water from a borehole that has high chloride content. From the results of this study, it appears that the water has high sodicity as well as salinity.

4.3.2 Disposal method and soil description

This winery disposes of its effluent through irrigating kikuyu grass by means of conventional overhead sprinklers.

The soil of the disposal area was classified as belonging to the Ermelo family of the Longlands form (Soil Classification Working Group, 1991). This soil is characterized by high chroma red and yellow mottles in a light gray matrix in the B-horizon, indicating alternating reducing and oxidizing conditions caused by a fluctuating water table. A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.2.

4.3.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis (except May 2000) from December 1999 to July 2000 are given in Tables 4.5 and 4.6.

Table 4.5: pH, COD, SAR, EC and Na data for effluent samples from Paarl 2 winery (From: Van Schoor & Mulidzi, 2001)

Month	pH	COD (mg/l)	SAR	EC (mSm)	Na (mg/l)
December	7.6	364	7.5	-	261
January	7.4	233	7.8	-	305
February	4.4	8520	6.3	269	269
March	4.6	6190	7.06	311	311
April	4.8	2257	10.04	448	448
June	5.3	3514	11.98	513	513
July	6.0	1968	11.2	313	446

At this winery the **pH** values of 7.6, 7.4 and 6.0 for December 1999, January 2000 and July 2000 are acceptable values for irrigation according to the General Authorisations in terms of Section 39 of the National Water Act, 1998 (Act No.36 of 1998) and is therefore not regarded as a problem (Table 4.5). The effluent pH decreased dramatically as soon as the wine making process started in February. Application of effluent with a pH of less than 6 may lead to the acidification of soil and also in the long term can lead to the availability of several micro and macro nutrients in toxic concentrations (Department of Water Affairs and Forestry, 1996). The low pH also increases problems with corrosion of metal or concrete components of irrigation systems.

The effluent from this winery was characterized by **COD** values slightly to moderately higher than the maximum permissible level of 5000 mg/l (when irrigating up to 50 m^3/d) in February and March (Act No.36 of 1998). In all other months the effluent from this winery was characterized by COD values that do not pose problems according to legislation. It is only the effluent in February and March that needs to be treated prior to any form of disposal.

SAR (sodium adsorption ratio) of the effluent is very high in all months. It is above the maximum permissible value of 5 for any disposal (Act No.36 of 1998). From the soil analyses and observations in the field (Section 4.3.4) it is evident that this effluent is causing sodicity problems in this area. The effective management of the effluent to eliminate the sodicity problem should be a priority to avoid any degradation of the soil. Similar to SAR, **sodium** values are high in all months. It is assumed that the high amount of sodium is due to the caustic soda used in the cellar and possibly the borehole water used.

Electrical conductivity **(EC)** was high and above the South African Standard of 200 mS/m for any disposal (Act No.36 of 1998) in all months. The use of water from the borehole could also be the reason for the high Na and EC of the effluent throughout all months at this cellar.

Table 4.6: K, Ca, Fe, Mg, B and Cl contents of effluents from Paarl 2 winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	39	-	32	-	-
January	163	46.2	0.08	41.9	0.2	285.99
February	267.7	64.5	14.1	62.5	0.49	869
March	313.7	65.7	11.96	67.6	0.48	760
April	113.7	32.3	0.13	46.7	0.25	470
June	244.8	63	6.94	52.2	0.31	704

Chloride shows unacceptably high values in February (869 mg/l), March (760 mg/l) and June (704 mg/l). The reason for the high chloride is that this winery uses chloride rich water from a borehole and they also use chlorine. None of the other **nutrient elements** analysed had values that were unacceptably high at any stage, indicating that these did not pose toxicity hazards (Table 4.6).

4.3.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.7).

Exchangeable sodium percentage **(ESP)** values of the effluent treated soil were much higher than those for the control at all depths (Table 4.7). This reflects the influence of the high SAR and sodium levels of the effluent of this winery (Table 4.5). The degree to which this soil has already been affected by the sodic and saline effluent from this winery was evident when soil classification was done during the dry period of early May 2000. Extensive accumulation of sodium chloride precipitates was observed in the wall of the drainage ditch below the effluent application area, indicating leaching of salts from the area. These will subsequently be transported from the ditch to the streams into which it flows, with detrimental effects on the quality of the water downstream.

The **phosphorus** levels in all months' samples from the effluent treated site were not very high, although they were slightly excessive in December and April. Phosphorus levels follow the normal trend as for most cultivated soils, viz. decreasing P levels with depth. Only in February there was an anomalous situation where phosphorus was low in the top two layers and somewhat higher in the lower subsoil (60-90 cm). This may indicate slight mobility of P in this soil and may be related to the higher COD of the effluent in February. During December and May the subsoil **potassium** levels were very high compared to the control site (Table 4.7). Potassium showed similar trends at the other wineries.

Soil **pH** values at the disposal site were high to very high and fluctuated from significantly above the values for the control site at corresponding depths to significantly below it. A striking feature is the much higher subsoil pH levels (even in the deeper subsoil) at the disposal site than at the control site during February, March and April. This is in contrast with what would be expected in view of the low effluent pH during these months.

Bulk density of both the topsoil and subsoil of the effluent treated site and those for the control site are similar (Table 4.8). All the values are extremely high and should inhibit root development very severely. The organic fraction of the effluent did not improve the bulk density of the soil, as it did at Paarl 1 winery (Table 4.4). In literature (Chapman, 1995a) it is also postulated that the organic fraction of cellar effluents should be beneficial to the physical conditions of soils. The high sodium content of the effluents from this cellar however might have negated this.

Table 4.8 Bulk density analyses for the soils of Paarl 2 Winery

Soil depth	**Treated site**	**Control**
Topsoil	1800 kg/m^3	2000 kg/m^3
Subsoil	2000 kg/m^3	1800 kg/m^3

Table 4.7 Soil analyses for Paarl 2 winery

Months	Depth	pH	Resistance	P	K	Na	K	Ca	Mg	S-value	Cu	Zn	Mn	B	ESP(%)
	(cm)	(KCl)	(ohm)	(mg/kg)	(mg/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
December	0-30	6.7	1870	53.00	156.00	0.54	0.40	0.65	0.53	2.12	0.35	1.00	1.40	0.21	25.47
December	30-60	6.3	540	54.00	481.00	1.16	1.23	1.82	2.52	6.73	0.42	1.10	5.90	1.01	17.24
December	60-90	6.4	340	6.00	555.00	2.44	1.42	3.12	6.83	13.81	0.28	0.30	1.60	1.02	17.67
January	0-30	5.8	690	93.00	207.00	0.72	0.53	1.96	0.95	4.16	0.41	2.00	2.40	0.30	17.31
January	30-60	5.9	1410	31.00	82.00	0.21	0.21	0.84	0.42	1.68	0.23	0.30	0.60	0.12	12.50
February	0-30	7.5	810	14.00	23.00	0.11	0.06	0.20	0.20	0.57	0.57	1.90	4.60	0.32	19.30
February	30-60	7.2	1200	12.00	12.00	0.08	0.03	0.11	0.13	0.35	0.22	0.40	1.70	0.26	22.86
February	60-90	7	970	37.00	16.00	0.10	0.04	0.14	0.18	0.46	0.28	0.50	2.30	0.32	21.74
March	0-30	8.8	480	24.00	20.00	0.06	0.05	0.13	0.12	0.36	0.44	1.90	4.30	0.23	16.67
March	30-60	8.1	750	3.00	12.00	0.04	0.03	0.07	0.05	0.19	0.19	0.20	1.20	0.10	21.05
March	60-90	7.8	900	3.00	8.00	0.04	0.02	0.07	0.08	0.21	0.21	0.30	1.20	0.13	19.05
April	0-30	7.2	730	49.00	94.00	0.35	0.24	1.12	0.76	2.47	0.23	1.30	2.00	0.19	14.17
April	30-60	7.4	660	23.00	55.00	0.36	0.14	0.70	0.42	1.62	0.15	0.30	2.70	0.16	22.22
April	60-90	7.6	580	19.00	55.00	0.40	0.14	0.73	0.42	1.69	0.13	0.30	2.70	0.13	23.67
May	0-15	7.2	400	14.00	86.00	0.43	0.22	0.81	0.70	2.16	0.20	0.30	1.00	0.22	19.91
May	15-30	7.5	750	9.00	74.00	0.37	0.19	0.69	0.61	1.86	0.19	0.10	1.10	0.14	19.89
May	30-40	6.7	0	1.00	590.00	2.05	1.51	3.82	4.80	12.18	0.14	0.10	6.80	0.85	16.83
May	40-120+	6.9	0	1.00	895.00	2.51	2.29	3.85	7.57	16.22	0.11	0.30	2.00	0.64	15.47
Control	0-30	7.3	1040	5.00	129.00	0.32	0.33	6.00	0.98	7.63	1.29	1.40	4.30	0.53	4.19
Control	30-60	6.2	1920	2.00	90.00	0.18	0.23	1.82	0.55	2.78	0.16	0.10	0.00	0.38	6.47
Control	60-90	6.2	830	2.00	258.00	0.37	0.66	3.64	1.39	6.06	0.19	0.10	0.00	0.58	6.11

4.3.5 General evaluation

The effluent from this winery is of very poor quality, caused by its **very high** sodicity and salinity **throughout** all the months during which it was monitored. This is a unique feature for this winery, which was not found at any of the other wineries. Most of the other wineries had very limited or no sodicity and salinity problems, or had them for limited periods only. These aspects of the effluent from this winery are unacceptable and need serious attention. The effluent from this winery poses a threat of negative environmental impact, as evidenced by the salt accumulation observed in the drainage ditch below the disposal area. The moderately high COD values for February and March and the low pH values for some of the months are also of concern and require pretreatment of the effluent before disposal.

Changes to some of the practices at the winery may be required in order to eliminate the high sodicity and salinity of the effluent. ***Most importantly, continued use of the water from the present borehole will cause problems and it is imperative that an alternative water source will have to be found urgently.***

Development of a temporary water table during wet periods and strong lateral seepage above the water table are negative features of the soil on which disposal is done at this winery.

4.4 PAARL 3 WINERY

4.4.1 Main types of wine produced and chemicals used in the cellar

The types of wines produced by this winery are white, red, sparkling wine as well as fortified wines. Bulk filtering with diatomaceous earth is used for the filtration of wine. Sheet and membrane filtering with diatomaceous earth are also used in some processes. The types of detergents used to wash equipment in this winery include chlorine with caustic soda. Chlorine is preferred to kill fungi, as was the case with the wineries discussed previously.

4.4.2 Disposal method

This winery disposes of their effluent by means of ponding in a dam. No modal soil profile was studied.

4.4.2 Effluent composition

Analytical data for effluent samples taken at this winery on a monthly basis (except May 2000) from December 1999 to June 2000 are given in Tables 4.9 and 4.10.

Table 4.9: pH, COD, SAR, EC and Na data for effluent samples from Paarl 3 winery (From: Van Schoor & Mulidzi)

Months	**pH**	**COD (mg/l)**	**SAR**	**EC (mS/m)**	**Na (mg/l)**
December	5.6	582	0.58	-	8.8
January	4.4	3676	0.53	-	10.7
February	4.8	996	3.17	60	77.7
March	4.5	7262	0.79	137	29.6
April	5.3	7802	0.77	175	13.7
June	3.7	859	0.86	52	11.3

At this winery the effluent **pH** was below the minimum acceptable pH of 6 for irrigation specified in the South African General Authorization in terms of Section 39 of the National Water Act, 1998 (Act No.36 of 1998) during all months. According to Department of Water Affairs and Forestry (1996), acidification of soil by applying water with pH less than 6 may in the long-term lead to the availability of several micro and macronutrients in toxic concentrations.

The effluent from this winery was characterized by **COD** values of less than 5 000 mg/l, which is acceptable to any form of disposal provided not more than 50 m^3 is applied per day (Department of Water Affairs and Forestry, 1993), for most of the study period. During March and April, the COD of the effluent was somewhat above the maximum permissible level of 5 000mg/l (Table 4.9).

The disposal of the March and April effluents prior to treatment is not acceptable according to the South African environmental standards. It is however important to realise that all parameters (pH, COD, SAR and EC) must be complied with and irrigation may only occur when all criteria fall within the legal limits.

Sodium adsorption ratio **(SAR)** of the effluent is very low. All values in all months are far below the maximum permissible value of 5 (Act No.36 of 1998) and will not pose any environmental risk. (Table 4.9). Like SAR, **sodium** is also low throughout.

The Electrical conductivity **(EC)** was below the South African Standard of 200 mS/m for irrigation (Act No.36 of 1998) in all months' effluents.

Table 4.10: K, Ca, Fe, Mg, B and Cl contents of effluents from Paarl 3 winery (From: Van Schoor & Mulidzi, 2001)

Months	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	15	-	1.6	-	-
January	40.3	25.7	8.2	3.3	0.08	98
February	15.3	30.5	0.16	9.1	0.06	96
March	334.1	90.4	1.29	8.8	0.29	54
April	290.6	14.3	2.6	6	0.45	58
June	85.4	10.9	0.6	1.3	0.02	27

None of the **nutrient elements** analysed had values that are unacceptably high at any stage, indicating that these do not pose toxicity hazards at this stage (Table 4.10). The March and April analyses, however showed slightly high amounts of potassium.

4.4.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.11).

Exchangeable sodium percentage **(ESP)** values of the effluent treated soil were much higher than those of the control site. The subsoil ESP values of the effluent treated site were high to very high (Table 4.11). ESP is a real problem at this winery. This is very strange in view of the very low SAR and Na values of the effluents. At first it was speculated that a problem water source, similar to the borehole at Paarl 2, might have been used in the past, but the cellar manager did not give this as a possible explanation.

The **phosphorus** levels at the effluent treated site are lower than those of the control site and P is concentrated in the topsoil. **Potassium** is fairly high, but not excessive, in the top two soil layers (0-30 and 30-60cm) in both December and January. The high K level in the lower subsoil (60-90cm) in April (Table 4.11) indicates high mobility of K in the soil upon application of the March and April effluents with their high K contents (Table 4.10). This is a matter of concern as it points to the possibility that K could leach into streams and cause eutrophication of water bodies. High K mobility was also observed in soils at other wineries.

At this winery the exceptional situation is found that the **pH** values of the soil at the control site range from moderately acid in the topsoil to very strongly acid in the subsoil, but at the disposal site it is strongly alkaline in the topsoil in all months and during February, March and April also in the upper subsoil (30-60 cm depth). This is in sharp contrast to what would be expected upon application of the acid effluent, although the use of caustic soda may play a role. Quality of irrigation water depends on the collective water quality of the pond, which can be characterized by a combination of different cellar processes.

4.4.5 General evaluation

Overall the effluent from this winery is of better quality than the effluent from the other wineries studied. The slightly high COD in March and April necessitates treatment of these effluents before disposal, however. The elevated K levels in the March and April effluents, combined with the high K levels in the deeper subsoil in April also points to a situation that may need attention from an environmental point.

Table 4.11: Soil analyses for the soil at Paarl 3 winery

Months	Depth (cm)	pH (KCl)	Resistance (ohm)	H (cmol/kg)	Klip Vol%	P (mg/kg)	K (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	S-value (cmol/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	B (mg/kg)	ESP(%)
December	0-30	8.1	1080	0.00	0.00	33.00	325.00	0.46	0.83	13.63	0.25	15.17	1.33	3.60	6.60	0.60	3.03
December	30-60	5.1	160	0.00	0.00	14.00	180.00	4.26	0.46	2.26	1.48	8.46	0.42	1.00	0.70	0.73	50.35
December	60-90	4.1	110	0.00	0.00	24.00	20.00	6.33	0.05	0.98	2.11	9.47	0.39	0.50	0.00	0.25	66.84
January	0-30	8.1	1150	0.00	22.00	25.00	168.00	0.12	0.43	7.08	0.50	8.13	2.11	4.90	10.00	0.53	1.48
January	30-60	5.3	180	0.52	31.00	6.00	164.00	2.30	0.42	2.67	1.96	7.87	0.54	1.20	1.40	0.74	29.22
January	60-90	3.7	100	3.05	2.00	4.00	35.00	5.51	0.09	1.47	4.21	14.33	0.32	0.90	0.00	0.72	38.45
February	0-30	8.1	1520	0.00	0.00	2.00	16.00	0.06	0.04	0.29	0.12	0.51	1.19	2.50	4.70	0.26	11.76
February	30-60	8.0	890	0.00	0.00	2.00	31.00	0.12	0.08	0.17	0.16	0.53	0.25	0.80	0.60	0.27	22.64
February	60-90	4.8	120	0.00	0.00	93.00	4.00	0.56	0.01	0.14	0.48	2.37	0.06	0.40	0.10	0.37	23.63
March	0-30	8.2	620	0.00	0.00	41.00	39.00	0.03	0.10	0.80	0.06	0.99	8.97	27.20	16.00	0.39	3.03
March	30-60	8.5	500	0.00	0.00	3.00	23.00	0.09	0.06	0.20	0.09	0.44	0.61	1.90	0.90	0.22	20.45
March	60-90	4.4	170	1.81	0.00	2.00	0.00	0.53	0.00	0.12	0.39	2.85	0.47	1.50	0.50	0.20	18.60
April	0-30	7.5	570	0.00	0.00	61.00	184.00	0.17	0.47	5.68	0.31	6.63	5.57	22.10	21.80	0.36	2.56
April	30-60	8.3	340	0.00	0.00	13.00	59.00	1.69	0.15	4.28	1.50	7.62	1.49	6.00	4.70	0.54	22.18
April	60-90	4.0	110	2.44	0.00	16.00	465.00	5.92	1.19	1.55	3.97	15.07	1.24	4.70	1.60	0.27	39.28
Control	0-30	4.5	980	0.94	14.00	94.00	199.00	0.08	0.51	2.03	0.64	4.20	0.71	4.00	6.40	0.40	1.90
Control	30-60	4.1	1240	0.94	17.00	74.00	109.00	0.07	0.28	1.55	0.54	3.38	0.45	7.00	2.80	0.33	2.07
Control	60-90	3.3	740	4.01	27.00	25.00	51.00	0.26	0.13	3.80	2.93	11.13	0.20	3.30	0.10	0.44	2.34

4.5 STELLENBOSCH WINERY

4.5.1 Main types of wines produced and chemicals used in the cellar

Both red, white and fortified wines are produced at this winery. Bulk filtering with diatomaceous earth is used for the filtration of wine. Filtration varies between different months and also on the availability of wine. Bentonite is also used for protein stabilization. The types of soaps used to wash equipment include PRO 41 for outside tanks. Caustic soda is also used.

4.5.2 Disposal method and soil description

This winery disposes of their effluent through irrigating kikuyu grass by means of conventional overhead sprinklers.

The soil of the disposal area was classified as belonging to the Waterton family of the Fernwood form (Soil Classification Working Group, 1991). It has a thick layer of undecomposed organic matter on the surface. A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.3.

4.5.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis (except May 2000) from December 1999 to June 2000 are given in Tables 4.12 and 4.13.

Table 4.12: pH, COD, SAR, EC and Na data for effluent samples from Stellenbosch winery (From: Van Schoor & Mulidzi 2001)

Months	pH	COD (mg/l)	SAR	EC (mS/m)	Na (mg/l)
December	5.3	3321	2.39	-	61
January	6.6	2372	4.9	-	86.3
February	4.3	14160	4.4	150	127.9
March	5	8175	9.1	170	251.5
April	3.1	12238	2.09	143	60.1
June	4.4	3394	3.59	74	58.8

At this winery the effluent **pH** of 6.6 for January is higher than the minimum acceptable pH of 6 specified in the South African General Authorisations in terms of Section 39 of the National Water Act, 1998 (Act No. 36 of 1998). pH was moderately low to very low in other months and there is a sharp decrease in pH in April.

As discussed previously, acidification of soil by applying water with pH less than 6 may in the long-term lead to the availability of several micro or macronutrients in toxic concentrations. High availability of these nutrients as well as other heavy metals, also have serious health and environmental implications. The low pH also increases problems with corrosion of metal or concrete components of irrigation systems.

The effluent from this winery was characterized by moderate **COD** values of less than 5 000 mg/l, which is acceptable provided that application does not exceed 50 m^3/day (Act No.36 of 1998), for most of the study period (when excluding other parameters). During February, March and April the COD of the effluent from this winery was significantly above the maximum permissible level (for irrigation) of 5 000 mg/l (Table 4.12), with the values for February and April being particularly high. Thus, the disposal of the February, March and April effluent prior to treatment is not acceptable according to the South African environmental standards.

Sodium Adsorption Ratio **(SAR)** values of the effluent for five months were low to very low and falls within the South African environmental standards (Table 4.12).

Only in March the SAR value was above the maximum permissible level of 5 (Act No. 36 of 1998). Like SAR, **sodium** is high in the March effluent.

Electrical conductivity **(EC)** was below the South African Standard (for irrigating crops) of 200 mS/m for irrigation (Act No.36 of 1998) in all months.

Table 4.13: K, Ca, Fe, Mg, B and Cl contents of effluents from Stellenbosch winery (From: Van Schoor & Mulidzi, 2001)

Months	K (mg/l)	Ca (mg/l)	Fe (mg/l)	Mg (mg/l)	B (mg/l)	Cl (mg/l)
December	-	41	-	5	-	-
January	61.7	17.8	0.29	3.4	0.12	63.26
February	356.7	48.3	7.8	9.4	0.43	133
March	333.2	40.6	3.6	10.2	0.4	42
April	97	53.4	8.98	5.4	0.16	66
June	64.9	15.3	1.4	3	0.11	55

Of the **nutrient elements** analysed Mg, Ca, Fe and B were low throughout (Table 4.13). **Potassium** was very high in February and March. The high levels of potassium in the effluent for some months are a similar to the trend shown by other wineries during the study period. Chloride values were very high in February (Table 4.13).

4.5.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.14).

Exchangeable sodium percentage **(ESP)** values of the effluent treated soil were in all months higher than those for the control site (Table 4.14). Some of the values are very high, exceeding 10 and even 15. The highest ESP values were found in the subsoils. During May a high value was also found in the thin surface layer sampled separately, probably due to capillary rise from the shallow water table. The high ESP is a matter of concern. Considering the fact that it is a soil and landscape with intensive lateral subsurface leaching, sodium can leach to the groundwater and streams.

The **topsoil phosphorus** levels in December and January were very high – far above the maximum acceptable limits for optimum crop growth (Eloff & Laker, 1978). They decreased to slightly higher than acceptable levels in February and March, but increased in April and May again. Subsoil P values are generally in the acceptable range. There are some indications of the possibility of limited P leaching, which may cause some concern in terms of possible eutrophication of water bodies. This can be seen from the following: P was very high in the 30– 60 cm layer during December, with elevated P levels in this layer also in January and February. During February and March there were also clearly elevated P levels in the deep subsoil (60-90 cm).

The topsoil and subsoil **potassium** levels of the effluent treated site were very high in December, January, April and May when compared to the control site. In contrast the K levels at all depths were exceptionally low in February and March, even much lower than at the control site. This is an anomaly, because these were the months with the very high effluent K levels. Although this winery showed the highest soil potassium values, other wineries also showed high potassium values. The high potassium levels in the subsoil may lead to the leaching of potassium from the soil into water bodies, causing eutrophication of the latter, as explained previously.

The very high **Cu** and **Zn** levels recorded at some periods, especially in topsoils, but also in some subsoils (Table 4.14), are reasons for major concern in terms of pollution.the source of these elements, however are not certain as these are not associated with any cellar activities.

Soil **pH** levels at the disposal site are generally acceptable. Topsoil pH levels are of the same order as those for the control site, except in April, when it is distinctly lower than the value for the control site. It is notable that this was the month with the high available Cu and Zn levels. Topsoil pH levels at this winery respond to effluent pH values, as indicated by the moderate drop in topsoil pH in February and the sharp drop in April. Subsoil pH values at the disposal site are throughout higher than at the control site.

Table 4.14: Soil analyses for the soil of Stellenbosch Winery

Months	Depth (cm)	pH (KCl)	Resistance (ohm)	P (mg/kg)	K (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	S-value (cmol/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	B (mg/kg)	ESP(%)
December	0-30	5.6	550	185.00	387.00	0.64	0.99	4.14	0.40	6.17	6.91	27.90	1.50	1.14	10.37
December	30-60	5.8	1340	119.00	207.00	0.52	0.53	1.83	0.10	2.98	4.56	12.60	0.90	0.73	17.45
December	60-90	5.9	1000	25.00	422.00	0.87	1.08	2.93	0.26	5.14	1.59	3.80	0.40	1.27	16.93
January	0-30	6.0	780	143.00	524.00	0.53	1.34	7.45	0.82	10.14	8.28	45.00	4.00	1.64	5.23
January	30-60	5.9	1340	63.00	301.00	0.25	0.77	2.70	0.30	4.02	4.10	11.60	0.60	0.86	6.22
January	60-90	5.9	1170	53.00	348.00	0.30	0.89	2.53	0.25	3.97	2.84	7.90	0.60	1.00	7.56
February	0-30	5.4	1590	69.00	39.00	0.11	0.10	0.40	0.13	2.00	15.92	26.10	1.50	0.73	5.50
February	30-60	6.1	1510	53.00	27.00	0.09	0.07	0.43	0.13	0.72	10.16	53.80	3.10	0.44	12.50
February	60-90	6.0	1770	96.00	27.00	0.09	0.07	0.30	0.13	0.59	5.56	18.90	1.50	0.59	15.25
March	0-30	6.3	890	84.00	63.00	0.04	0.16	0.30	0.06	0.56	10.52	29.60	2.40	0.51	7.14
March	30-60	6.5	1460	18.00	47.00	0.04	0.12	0.16	0.03	0.35	1.69	6.60	0.80	0.34	11.43
March	60-90	5.8	620	62.00	59.00	0.06	0.15	0.51	0.06	0.78	16.22	40.40	2.10	0.67	7.69
April	0-30	4.6	120	275.00	551.00	1.05	1.41	6.46	1.10	12.77	81.01	129.60	10.80	1.54	8.22
April	30-60	5.4	540	41.00	239.00	0.46	0.61	3.07	0.39	5.08	12.93	24.50	2.20	0.78	9.06
April	60-90	5.6	950	22.00	141.00	0.30	0.36	1.50	0.22	2.38	4.64	7.30	0.80	0.63	12.61
May	0-10	0.0	0	259.00	156.00	1.80	0.40	8.78	3.08	14.06	18.74	89.30	17.80	0.20	12.80
May	10-40	5.6	680	97.00	242.00	0.38	0.62	5.88	0.48	7.36	9.90	42.80	4.90	0.70	5.16
May	40-75	6.2	810	28.00	109.00	0.25	0.28	1.74	0.13	2.40	2.26	10.90	0.20	0.32	10.42
May	75-100+	7.1	1660	24.00	66.00	0.19	0.17	1.37	0.13	1.86	1.35	6.10	0.80	0.17	10.22
Control	0-30	5.9	1370	50.00	78.00	0.08	0.20	8.87	1.11	10.26	1.44	4.60	10.80	1.01	0.78
Control	30-60	5.3	1690	27.00	74.00	0.06	0.19	3.79	1.32	6.30	0.23	0.80	1.20	0.88	0.95
Control	60-90	5.1	1740	14.00	125.00	0.09	0.32	2.88	1.50	6.05	0.28	0.60	1.00	0.92	1.49

The **bulk densities** of both the topsoil and subsoil of the effluent treated site were much higher than those for the control site (Table 4.15), especially in the subsoil. The values for the effluent treated soil are so high that root growth will be impeded. This indicates that the effluent has negatively impacted the structure of the soil, causing soil compaction.

Table 4.15: Bulk densities for the soil at Stellenbosch winery

Soil depth	**Treated site**	**Control**
Topsoil	1700 kg/m^3	1600 kg/m^3
Subsoil	1900 kg/m^3	1300 kg/m^3

4.5.5 General evaluation

Overall the effluents from this winery showed similarities with those from most other wineries. The main problem, that needs serious attention, is the high COD in February, March and April. This is not only an extended period, but also the February and April values are very high. The high SAR and Na in March also need to be addressed. If measures are not taken to correct the above-mentioned aspects, this effluent will pose a serious threat of negative environmental impacts.

The biggest problem at this winery is that effluent disposal is done on a soil that is totally unsuitable for the disposal of this type of effluent. The main issue is that this soil is unable to retain pollutants, thus causing a major potential for eutrophication of the adjacent stream. Leaching of organic pollutants into the stream has been clearly observed at this winery (Chapter 7). There are major similarities between the situation at this winery and that at Robertson 1 winery (Section 4.6).

4.6 ROBERTSON 1 WINERY

4.6.1 Main types of wines produced and chemicals used in the cellar

The types of wines produced by this winery include white, red, full sweet wines as well as grape juice. Bulk filter powder with diatomaceous earth is used for filtration. Bentonite is used for protein stabilization in the white wine, but sometimes also in red wines. Quatrammonium, Idofore, Bacteriax and iodine soaps are used to wash equipment. Caustic soda is also used to remove tartaric acid.

4.6.2 Disposal method and soil description

This winery disposes of their effluent through irrigating kikuyu grass by means of conventional overhead sprinklers.

The soil of the disposal area was classified as belonging to the Penicuik family of the Fernwood form (Soil Classification Working Group, 1991). This indicates that the soil is characterized by light gray, highly leached, structureless sandy subsoil. The infiltration rate and hydraulic conductivity of this soil are both excessive. A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.4.

4.6.2 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis from December 1999 to April 2000 are given in Tables 4.16 and 4.17.

Table 4.16: pH, COD, SAR, EC and Na data for effluent samples from Robertson 1 winery (From: Van Schoor & Mulidzi, 2001)

Months	pH	COD (mg/l)	SAR	EC (mSm)	Na (mg/l)
December	6.1	2241	29.03	-	692
January	7	3399	33.05	-	677.8
February	3.7	5788	1.94	60	35.1
March	3.7	11270	4.49	144	130.5
April	4.3	10614	1.74	90	38

At this winery the effluent **pH** of 6.1 and 7 for December 1999 and January 2000 are above the minimum acceptable pH of 6 specified in the General Authorisations in terms of Section 39 of the National Water Act, 1998 (Act No.36 of 1998) and should not pose problems (Table 4.16). The effluent pH decreased sharply to very low levels as soon as the winemaking season started in February.

As explained previously, acidification of soil by applying water with a pH less than 6 may in the long-term lead to the availability of several micro and macronutrients in toxic concentrations. High availability of these nutrients, as well as other heavy metals, also has serious health and environmental implications. The low pH also increases problems with corrosion of metal or concrete components of irrigation systems.

The effluent from this winery was characterized by low **COD** values of less than 5 000 mg/l, which is acceptable to irrigate crops provided, that not more than 50 m^3/day is applied (Act No.36 of 1998), during December 1999 and January 2000. During February the COD value increased to slightly over 5000 mg/l and it became higher than 10 000 mg/l in March and April. The disposal of the February, March and April effluents prior to treatment is not acceptable according to the South African environmental standards.

The sodium adsorption ratio (**SAR**) of the effluent was very high in December and January (Table 4.16). The SAR values in these two months are far above 5, which is the maximum value permissible for irrigating crops (Act No.36 of 1998). Irrigation of soil with effluent having a SAR value of above 5 can lead to sodicity problems. During February, March and April the SAR of the effluent was very low, posing no danger to the environment.

Table 4.17: K, Ca, Fe, Mg, B and Cl contents of effluents from Robertson 1 winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	25.0	-	6.7	-	-
January	107.1	22.2	1.8	5.8	0.31	55
February	93.1	16.8	1.4	8.1	0.17	86
March	298.5	30.3	1.2	18.3	0.46	166
April	79.6	17.8	1.9	11.1	0.31	141

Table 4.18: Soil analyses for soil from Robertson 1 Winery

Months	Depth (cm)	pH (KCl)	Resistance (ohm)	P (mg/kg)	K (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	S-value (cmol/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	B (mg/kg)	ESP(%)
December	0-30	5.9	380	116.00	414.00	0.93	1.06	1.35	0.44	3.78	2.18	4.80	0.90	0.67	24.60
December	30-60	5.7	1680	46.00	168.00	0.46	0.43	0.48	0.14	1.51	1.57	1.30	1.00	0.26	30.46
December	60-90	8.3	830	81.00	145.00	0.50	0.37	5.13	0.41	6.41	1.50	0.60	3.70	0.28	7.80
January	0-30	7.4	470	39.00	469.00	1.25	1.20	1.87	0.65	4.97	2.89	4.60	1.00	0.56	25.15
January	30-60	7.0	570	25.00	364.00	0.87	0.93	1.14	0.51	3.45	2.79	4.30	1.00	0.46	25.22
January	60-90	7.5	1200	17.00	184.00	0.39	0.47	0.64	0.24	1.74	1.28	1.20	0.00	0.16	22.41
February	0-30	5.4	1870	27.00	20.00	0.07	0.05	0.26	0.16	1.09	8.46	8.80	3.20	0.35	6.42
February	30-60	5.7	2560	120.00	8.00	0.07	0.02	0.12	0.12	0.33	2.23	2.50	0.70	0.21	21.21
February	60-90	8.7	1200	81.00	16.00	0.07	0.04	0.31	0.16	0.58	2.97	1.20	9.20	0.26	12.07
March	0-30	5.4	610	16.00	35.00	0.04	0.09	0.43	0.15	1.97	19.13	17.70	3.80	0.15	2.03
March	30-60	6.1	1230	16.00	20.00	0.02	0.05	0.11	0.04	0.22	4.04	3.50	0.40	0.19	9.09
March	60-90	6.6	990	44.00	20.00	0.02	0.05	0.11	0.05	0.23	1.82	1.00	1.60	0.24	8.70
April	0-30	5.0	1310	36.00	66.00	0.11	0.17	1.29	0.49	2.69	1.79	4.00	2.30	0.20	4.09
April	30-60	6.5	1330	56.00	0.00	0.11	0.00	1.46	0.25	1.82	1.57	1.10	3.50	0.14	6.04
April	60-90	8.4	1260	170.00	86.00	0.11	0.22	5.34	0.69	6.36	1.28	0.40	24.40	0.18	1.73
May	0-25	6.0	1240	33.00	16.00	0.30	0.04	2.13	0.50	2.97	2.31	2.40	1.40	0.32	10.10
May	25-60	5.4	1160	21.00	70.00	0.17	0.18	0.79	0.24	1.62	2.66	0.80	0.60	0.14	10.49
May	60-100	5.5	1170	24.00	55.00	0.19	0.14	0.68	0.18	1.35	2.05	0.50	0.40	0.09	14.07
May	100-120+	5.3	340	105.00	90.00	0.17	0.23	1.06	0.74	2.51	0.46	0.20	8.10	0.11	6.77
Control	0-30	7.6	1430	43.00	86.00	0.16	0.22	5.18	1.48	7.04	5.35	10.60	1.50	0.36	
Control	30-60	8.0	1950	42.00	102.00	0.14	0.26	6.19	1.50	8.09	2.50	2.50	1.50	0.29	
Control	60-90	7.7	1670	68.00	86.00	0.12	0.22	4.80	1.26	6.40	5.41	3.90	1.30	0.25	
Control	90+	8	3030	37.00	51.00	0.10	0.13	2.37	0.69	3.29	2.51	2.30	0.70	0.19	

Electrical conductivity **(EC)** was below the South African Standard of 200 mS/m for irrigation (Act No.36 of 1998) in all months.

None of the **nutrient elements** analysed had values that pose toxicity hazards at this stage, but potassium was high in March (Table 4.17).

4.6.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.18).

Exchangeable sodium percentage **(ESP)** values of the effluent treated soil were exceptionally high to a depth of 60 cm in December and moderately high in the 60-90 cm layer (Table 4.18). In January the ESP values were exceptionally high throughout the whole soil depth sampled (i.e. to 90 cm depth). The high ESP values in the soil during December and January are due to the extremely high SAR values and even more extreme Na levels in the effluent during these months (Table 4.16).

During February the ESP of the topsoil decreased sharply to a fairly low level, while that of the 30-60 cm layer remained extremely high. The value for the 60-90 cm layer was much lower than in January, although high. During March and April the ESP values were very low to moderate in all layers. During February, March and April the SAR values and Na levels of the effluents were low to very low (Table 4.16).

The ESP patterns show clearly that the high amounts of sodium, which accumulated in the soil in December and January, were leached from the soil during February, March and April. This ensures on-site sustainability, but the fact that the sodium is leached laterally to a nearby stream is a matter for concern. A study is needed to determine how much the leachate is diluted in the stream, especially since this leaching is at the end of the dry summer when the flow in the stream will probably be very low. In May the ESP values became high throughout the soil profile again, but unfortunately no effluent analyses are available for this month.

In December the topsoil **phosphorus** level at the effluent treated site was very high. A major concern is the high to very high subsoil phosphorus levels, especially in the deeper subsoils (Table 4.18). This was most noticable in April and May. Combined with the much lower P levels in layers higher in the soil profile, this points to massive leaching of P in this soil. This is not a normal phenomenon for P, but can be related to the sandy nature and lack of iron oxides in this soil. This has a major pollution potential through eutrophication of water bodies into which the P is leaching laterally from the soil. Algal growth is a prominent feature in the drainage ditch which drains the effluent treated site into the nearby stream, supporting the concern about eutrophication.

The **potassium** values at the effluent treated site were very high in the topsoil and high in the subsoil during December and January (Table 4.18). From February to May it dropped drastically, even to highly deficient values during February and March. This points to intensive leaching of K from this disposal site, posing an additional eutrophication danger to the nearby stream.

At this winery the soil at the control site showed an extremely high **pH** values at all depths. At the disposal site only the deeper subsoil (60-90 cm depth) had such high pH values throughout all months studied. The topsoil and upper subsoil at the disposal site had **much** lower pH values than those at the control site. These values are favourable and not too low at this stage. It is interesting to note how the topsoil pH levels fluctuate monthly according to the fluctuations in effluent pH levels, indicating the poor buffering capacity of this highly leached sandy soil.

The **bulk densities** of the topsoils of the effluent treated and control sites were equal (Table 4.19). The subsoil of the effluent treated site shows a very high bulk density, indicating a severe compaction problem.

Table 4.19: Bulk densities for soil at Robertson 1 winery

Soil depth	**Treated soil**	**Control**
Topsoil	1600 kg/m^3	1600 kg/m^3
Subsoil	1800 kg/m^3	1600 kg/m^3

4.6.5 General evaluation

The effluent from this winery was of poor quality and is posing a threat of serious negative environmental impacts. Problem aspects include high COD, low pH, high SAR and high sodium. Phosphorus and potassium pollution are additional problems. Improved and efficient effluent management is needed in this winery.

The biggest problem at this winery is that effluent disposal is done on a soil that is **totally** unsuitable for the disposal of this poor quality effluent. It is a sandy, bleached soil with no clay or iron oxides that can retain any of the pollutants in the soil. Apart from the observed subsoil compaction there is no long-term on-site land degradation, but major off-site degradation due to leaching of pollutants into adjacent streams. The latter also includes pollution by organic substances (Chapter 7).

In all respects the problems at this winery, from poor quality effluent to disposal on similar unsuitable soils and off-site pollution, are almost identical to the problems at the Stellenbosch winery (Section 4.5). They even have the same subsoil compaction trend.

4.7 ROBERTSON 2 WINERY

4.7.1 Main types of wine produced and chemicals used in the cellar

The types of wines produced by this winery include: white, red, sparkling as well as fortified wines. This winery uses bulk filtering with diatomaceous earth to filter the wines. Bentonite is also used for protein stabilization. They use caustic soda to wash equipment. Chlorine is also used to kill fungi.

4.7.2 Disposal method

This winery disposes of their effluent by means of ponding in a dam. No study of a modal profile was made.

4.7.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis from December to April 2000 are given in Tables 4.20 and 4.21.

Table 4.20: pH, COD, SAR, EC and Na data for effluent samples from Robertson 2 winery (From: Van Schoor & Mulidzi, 2001)

Month	**pH**	**COD (mg/l)**	**SAR**	**EC (mS/m)**	**Na (mg/l)**
December	4.4	1517	1.89	-	59
January	5.7	6561	1.80	-	61.12
February	4.9	1174	2.01	544	71.1
March	4.6	3770	2.06	92	66.4
April	6.1	448	2.36	177	80.2

At this winery the effluent **pH** is moderately lower than the minimum acceptable pH of 6 specified in the South African General Authorizations for crop irrigation in terms of Section 39 of the national Water Act (ACT NO.36 of 1998) in all months except April. As mentioned previously, acidification of soil by applying water with a pH less than 6 may in the long-term lead to the availability of several micro and macro nutrients.

The effluent from this winery was characterized by **COD** values of less than 5 000 mg/l, which is acceptable to crop irrigation, provided not more than 50 m^3/day is irrigated (ACT NO.36 of 1998), for most of the study period (Table 4.20). Only during January the COD of the effluent from this winery was slightly above the maximum permissible level of 5 000 mg/l.

Sodium adsorption ratio **(SAR)** of the effluent was low during all months, all values being below the maximum permissible level of 5 (ACT NO.36 of 1998). **Sodium** was also very low throughout the sampling period (Table 4.20).

Electrical conductivity **(EC)** was only for February above the South African Standard of 200 mS/m for crop irrigation (ACT NO.36 of 1998).

Table 4.21: K, Ca, Fe, Mg, B and Cl contents of effluents from Robertson 2 winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	34	-	12	-	-
January	137.5	39.7	4.02	15	0.38	76.62
February	95.1	31.9	0.15	14.3	0.1	66
March	89.9	32.8	0.99	13.5	0.12	87
April	48.7	27.3	0	12.2	0.02	45

None of the **nutrient elements** analysed had values that are unacceptably high at any stage, indicating that these do not pose toxicity hazards at this stage (Table 4.21)

4.7.4 Soil analyses

Soil analysis data for this winery are given in Table 4.22.

The exchangeable sodium percentage (**ESP**) was moderately low throughout. The low ESP values in the soil was not surprising as the effluent from this winery has very low SAR and sodium values. **Phosphorus** was very low and **potassium** was very high in April. **Manganese** was very high throughout the sampling period and cause negative environmental impacts (Table 4.22). Soil **pH** was extremely high throughout the sampling period.

4.7.5 General evaluation

Overall effluent from this winery was of a reasonable quality, (much better than those from almost all other wineries studied), and does not seem to pose a big threat to the environment. The only major concern is the high amount of manganese throughout. As it was sampled only in the topsoil due to rocks, it is difficult to say whether manganese is a problem in the sense that it is leaching to the groundwater. Its source is unknown because it could not be related to cellar processes. The effluent from this winery requires only little treatment prior to disposal, unlike the situation at the other wineries studied. From the effluent point of view, it is only high COD in January and high EC in February that are problems. Out of the 10 wineries studied, this winery seems to be the one that has the best effluent management.

Table 4.22: Soil analyses for Robertson 2 Winery

Months	Depth	pH	Resistance	P	K	Na	K	Ca	Mg	S-value	Cu	Zn	Mn	B	ESP(%)
	(cm)	(KCl)	(ohm)	(mg/kg)	(mg/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
February	0-30	8.5	340	38.00	70.00	0.14	0.18	1.41	0.40	2.13	1.46	1.60	131.60	0.43	6.57
March	0-30	8.6	300	25.00	82.00	0.13	0.21	1.47	0.44	2.25	1.22	1.40	127.10	0.49	5.78
April	0-30	8	350	31.00	555.00	1.22	1.42	13.01	4.51	20.16	1.34	1.70	143.70	0.69	6.05

4.8 WORCESTER WINERY

4.8.1 Main types of wine produced and chemicals used in the cellar

The types of wines produced by this winery include: white, semi-sweet white, red as well as sparkling wine. Bulk filtering method with diatomaceous earth is used for filtration of wine. Bentonite is also used for protein stabilization. Caustic soda is used to wash equipment.

4.8.2 Disposal method and soil description

This winery disposes of their effluent through irrigating kikuyu grass by means of conventional overhead sprinklers.

The soil of the disposal area was classified as belonging to the Mtamvuna family of the Dundee form (Soil Classification Working Group, 1991). The soil is characterized by black spots with high organic matter contents in the light coloured alluvial layered materials of the C2 horizon. A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.5.

4.8.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis from December 1999 to April 2000 are given in Tables 4.23 and 4.24.

Table 4.23: pH, COD, SAR, EC and Na data for effluent samples from Worcester winery (From: Van Schoor & Mulidzi, 2001)

Month	pH	COD (mg/l)	SAR	EC (mS/m)	Na (mg/l)
December	2.8	2595	0.71	-	5
January	4.7	4545	7.06	-	107.2
February	4.1	18044	3.46	65	59.2
March	3.6	6627	6.53	66	107.9
April	5.4	1117	2.33	44	24.9

At this winery the effluent **pH** of all months was very low. It was lowest in December month wherein winemaking processes have not yet started (Table 4.23). The pH trend in this winery is different from the other wineries studied, because in the other wineries effluent pH values were relative high in December (and in some cases even in January) and decreased when COD values increased when the winemaking period started.

Effluent from this winery was characterized by moderate **COD** values of less than 5 000 mg/l, which is acceptable for crop irrigation as disposal method, provided not more than 50 m^3/day is irrigated (ACT NO.36 of 1998). During February the COD of the effluent from this winery was very high, however, and far above the maximum permissible level of 5 000mg/l, while in March it was just slightly above this level. The disposal of the February and March effluent prior to treatment is not acceptable according to the South African environmental Standards.

Sodium adsorption ratio **(SAR)** of the effluent was high in January and March, when the SAR value was above 5 mg/l, which is the maximum permissible limit for irrigation (ACT NO.36 of 1998) provided that other criteria are also met. Although in all other months the SAR value was below the maximum permissible level, it must be pointed out that if there is no improvement in the wastewater management, sodicity problems may develop in the soil of the disposal site.

Electrical conductivity **(EC)** was low and below the South African Standard of 200 mS/m for irrigation (ACT NO.36 of 1998).

Table 4.24: K, Ca, Fe, Mg, B and Cl contents of effluents from Worcester winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	4.3	-	1.27	-	-
January	100.8	9.6	2.9	1.26	0.06	49.89
February	127.2	9.8	6.14	6.5	0.12	19
March	124.6	11.3	2.94	4.3	0.04	27
April	19.5	4.8	0.01	2.5	0	73

None of the **nutrient elements** analysed had values that are unacceptably high at any stage, indicating that these do not pose toxicity hazards at this stage (Table 4.24).

4.8.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.25).

Exchangeable sodium percentage **(ESP)** values of this winery were high (in the 0-30 cm and 30-60 cm layers) to very high (in the 60-90 cm layer) in December and moderately high in February. When comparing the ESP of the effluent treated site with the control site, it is clear that the soil of the effluent treated site has higher ESP values than the control site. The very high ESP in the lower subsoil (60-90 cm) in December is a matter of great concern, especially in view of the increase in ESP from the topsoil to the upper subsoil (30-60 cm) and the sharp increase from the latter to the lower subsoil.

Such a sharp increase in ESP with depth and such a high ESP in the lower subsoil were not found at any of the other wineries, except Paarl 3 with extremely high ESP values at any stage of the sampling period. Since the effluent in December had low SAR and sodium levels, the high ESP levels must be due to sodium rich effluent from the preceding month(s). Such lag effect has been observed for various elements at various wineries during the study. The very low ESP in January, following the low SAR in the December effluent, and the relatively high ESP in February, following the high SAR of the January effluent further illustrate this. The ESP values at all depths of the soil the of disposal site were very low for all the other months. This shows that long term on-site sodification is not a real concern here. Combined with the ESP pattern found for December it does, however, indicate major leaching of sodium, applied in effluent, from this soil. Off-site sodification of water bodies or other areas into which leaching occurs from this site is, therefore, a major concern.

The topsoil **phosphorus** levels in the December and January samples of the effluent treated site were very high compared to the control site. It is also very high at the 30–60 cm depth during December, January and April. Phosphorus was extremely high in the 60–90 cm layer in April (Table 4.25).

These trends indicate that (a) large amounts of P are added to the disposal site and (b) leaching of large amounts of phosphorus through and from this soil occurs. The latter indicates that a major eutrophication danger for streams can be expected.

The winery does not show high amounts of **potassium** in the soil of the effluent treated site. The potassium values were even lower than those at the control site during January and February. The potassium values at this winery are different compared to the other wineries studied, because the other wineries showed high potassium values in the soils of the effluent treated sites.

At this winery there were no differences between the **pH** values of the soils at the control and disposal sites and all were in the optimum pH range.

The **bulk densities** of both the topsoil and subsoil of the effluent treated site were equal to those for the control site (Table 4.26). The effluent applied on the soil did not bring about any change in the soil structure.

Table 4.26 Bulk densities for soils at the Worcester winery

Soil depth	Effluent treated site	Control
Topsoil	1500 mg/m^3	1600 mg/m^3
Subsoil	1700 mg/m^3	1600 mg/m^3

Table 4.25 Soil analyses for Worcester Winery

Months	Depth	pH	Resistance	P	K	Na	K	Ca	Mg	S-value	Cu	Zn	Mn	B	ESP(%)
	(cm)	(KCl)	(ohm)	(mg/kg)	(mg/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
December	0-30	5.1	2080	164.00	59.00	0.33	0.15	1.62	0.42	2.52	1.75	3.40	3.50	0.16	13.10
December	30-60	5.1	5190	142.00	55.00	0.31	0.14	0.95	0.19	1.59	0.98	1.10	1.10	0.06	19.50
December	60-90	5.1	11870	60.00	31.00	0.28	0.08	0.47	0.11	0.94	0.31	0.40	0.10	0.03	29.79
January	0-30	5.2	3060	121.00	63.00	0.05	0.16	1.99	0.63	3.35	1.44	3.00	4.30	0.12	1.49
January	30-60	5.0	4910	125.00	51.00	0.04	0.13	1.36	0.37	2.60	0.67	0.80	1.00	0.07	1.54
January	60-90	4.8	8600	68.00	27.00	0.03	0.07	0.83	0.24	1.69	0.22	0.20	0.00	0.02	1.78
February	0-30	5.7	3560	57.00	12.00	0.06	0.03	0.24	0.17	0.50	1.51	3.00	4.10	0.21	12.00
February	30-60	5.4	5320	30.00	20.00	0.07	0.05	0.13	0.14	1.02	0.41	0.70	0.60	0.13	6.86
February	60-90	5.4	4760	4.00	16.00	0.07	0.04	0.10	0.12	0.80	0.20	0.30	0.30	0.17	8.75
March	0-30	5.2	2620	39.00	4.00	0.01	0.01	0.16	0.06	1.03	1.76	2.90	5.20	0.03	0.97
March	30-60	5.5	4970	72.00	0.00	0.00	0.00	0.12	0.03	0.78	0.74	1.30	2.20	0.02	0.00
March	60-90	5.8	4960	76.00	12.00	0.00	0.03	0.10	0.03	0.16	0.35	0.40	0.80	0.03	0.00
April	0-30	5.0	3970	54.00	47.00	0.03	0.12	1.21	0.40	2.47	1.68	2.60	4.30	0.03	1.21
April	30-60	5.1	4600	101.00	31.00	0.02	0.08	1.01	0.22	1.88	0.76	1.50	1.50	0.03	1.06
April	60-90	5.4	3480	191.00	31.00	0.02	0.08	1.07	0.23	1.87	0.36	0.60	1.00	0.02	1.07
May	0-27	5.1	3220	35.00	70.00	0.07	0.18	1.85	0.59	3.40	1.72	3.80	7.10	0.04	2.06
May	27-55	5.0	7890	44.00	27.00	0.04	0.07	1.31	0.23	2.28	0.76	1.50	0.80	0.02	1.75
May	55-100+	5.0	19990	19.00	8.00	0.01	0.02	0.40	0.05	0.72	0.18	0.20	0.00	0.00	1.39
Control	0-30	5.4	4800	40.00	47.00	0.06	0.12	2.44	0.38	3.31	1.49	3.60	1.70	0.17	1.81
Control	30-60	5.2	9620	11.00	27.00	0.03	0.07	1.43	0.25	2.17	0.31	1.70	0.10	0.09	1.38
Control	60-90	5.4	9890	6.00	35.00	0.04	0.09	1.78	0.26	2.56	0.24	0.20	0.20	0.10	1.56

4.8.5 General evaluation

A number of problems were identified at this winery. The first important aspect that needs attention is the very high COD in February, the highest recorded in any month at any of the eight Western Cape wineries. This makes this effluent totally unfit for any form of disposal without pretreatment. The COD of the March effluent was also slightly high.

Secondly there seems to be a definite sodicity problem at this cellar. It is not an on-site problem, but an off-site problem due leaching of quite large amounts of sodium from the disposal site. The main source of sodium appears to be effluent that is applied in early summer (before December). This aspect will have to be studied in more detail in future. The SAR of the effluent was also above the South African environmentally acceptable standard in January and March.

The third worrying factor from this winery is the high amount of phosphorus that is added to the soil at the disposal site and the very clear indication that virtually all this phosphorus is leached from the soil. This poses a severe eutrophication hazard for the stream into which this phosphorus is leached. As was the case with the sodium, it seems that the P does not pose any on-site pollution hazard, but a severe off-site hazard.

Overall improved effluent management including cleaner production strategies in the cellar is needed so that an acceptable effluent quality should be achieved. The disposal is done on a soil that appears to be unable to retain important pollutants like sodium and phosphorus.

4.9 BERG RIVER WINERY

4.9.1 Main types of wine produced and chemicals used in the cellar

The types of wines produced by this winery include: white, red, dessert wine and grape juice. The bulk filter with diatomaceous earth material for filtration is used. Bentonite is used for protein stabilization and Q45 (biodegradable) and caustic soda are used for cleaning of equipment.

4.9.2 Disposal method and soil description

This winery disposes of their effluent through irrigating kikuyu grass by means of conventional overhead sprinklers.

The soil of the disposal area was classified as belonging to the Riebeeck family of the Swartland form (Soil Classification Working Group, 1991). This indicates that the soil is characterized by subsoil with strongly developed blocky structure. A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.6.

4.9.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis (except May 2000) from December 1999 to June 2000 are given in Tables 4.27 and 4.28

Table 4.27: pH, COD, SAR, EC and Na data for effluent from the Berg river winery
(From Van Schoor & Mulidzi, 2001)

Month	pH	COD	SAR	EC (mS/m)	Na (mg/l)
December	5.6	1494	1.23	-	24
January	3.5	14229	0.53	-	15.7
February	4.3	10120	0.62	95	15.7
March	3.8	6389	0.48	76	10
April	5.1	2805	0.27	184	6.2
June	3.6	1205	0.35	110	8.3

At this winery the effluent **pH** was low to very low in all months and below the minimum acceptable pH of 6 specified in the South African General Authorizations in terms of Section 39 of the National Water Act, 1998 (ACT NO.36 of 1998) and should pose a problem. The effluent pH decreased as soon as the wine making season started in January. The low pH may in the long-term lead to the availability of several micro or macronutrients in toxic concentrations. High availability of these nutrients, as well as other heavy metals also have serious health and environmental implications. The low pH also increases problems with corrosion of metal or concrete components of irrigation systems.

The effluent from this winery was characterized by **COD** values of less than 5 000 mg/l in December, April and June, which are acceptable for irrigation, provided that not more than 50 m^3/day is irrigated (ACT NO.36 of 1998). During January the COD level was the second highest recorded at any of the Western Cape wineries in any month and far above the maximum permissible level of 5 000 mg/l (Table 4.27). The February effluent also had a high COD level, while the March effluent's COD also exceeded the permissible level. This winery was one of those with an extended (three month) peak period and its total COD for this peak period was second only to the very poor Stellenbosch winery. The disposal of the January, February and March effluent prior to treatment is not acceptable according to the South African environmental Standards.

Sodium adsorption ratio **(SAR)** of the effluent is very low in all months and far less than 5, which is the maximum value permissible for disposal (ACT NO.36 of 1998). Like SAR, **sodium** is also very low throughout (Table 4.27).

Electrical conductivity **(EC)** was low and below the South African standard of 200 mS/m for irrigation (ACT NO.36 of 1998) in all months, provided that the other criteria for irrigation are also met.

Table 4.28: K, Ca, Fe, Mg, B and Cl contents of effluents from the Berg river winery (From: Van Schoor & Mulidzi, 2001)

Month	K (mg/l)	Ca (mg/l)	Fe (mg/l)	Mg (mg/l)	B (mg/l)	Cl (mg/l)
December	-	25	-	1.85	-	-
January	264.96	48.6	4.93	10.6	0.5	126.5
February	279.9	36.2	2.84	7.3	0.3	63
March	242.5	24.9	0.84	5.2	0.2	43
April	311.6	34.6	0.22	3.3	0.16	28
June	279.7	35	6.1	4.4	0.15	27

Potassium remained high throughout the sampling period. It is a unique situation when compared to all the other "normal" wineries, excluding the totally abnormal Olifants River winery. The other **nutrient elements** are acceptably low throughout.

4.9.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.29)

The exchangeable sodium percentage **(ESP)** values for the effluent treated soil were, with the exception of two months quite low during the sampling period (Table 4.29). The topsoil values were throughout the sampling period even lower than those for the control site. The low ESP values in the soil of the disposal area are in line with the very low sodium contents and SAR values of the effluents from this winery. This absence of indications of sodicity, even in the soil samples taken in December, is a unique feature of this winery amongst the wineries in this study.

The topsoil **phosphorus** levels in December, January and April samples of the effluent treated site were not only very high compared to the control site, but far above the acceptable maximum P level for optimum plant growth (Eloff & Laker, 1978). In the other months, P contents were low to moderate even in the subsoil, indicating that it is not leaching into the subsoil or through it to the groundwater or streams.

This site has structured subsoil, which could have low permeability, and the possibility of lateral leaching in the topsoil above this layer cannot be ruled out totally, because there are sharp decreases in topsoil P levels over short time periods. This will require more detailed study.

The **potassium** levels in the 0-30 cm and 30-60 cm layers of the soil at the effluent treated site of this winery were in all months much higher than those for any of the other normal wineries (excluding the Olifants River winery). During December and January the potassium levels were extremely high in the effluent treated soil. It was also very high in April and May. The high amount of potassium in the effluent treated soil was caused by high amount of K in the effluent, which is a unique feature of this winery, as indicated earlier. The high amount of potassium in the subsoil is a worrying factor as it indicates that the K can possibly leach out to the groundwater or streams, creating a eutrophication hazard.

This winery is one of only two at which high levels of all three trace elements/heavy metals, **copper, zinc** and **manganese**, were found at all depths in the soil at the disposal site. The other one is the Orange River winery. This is disconcerting because it indicates both on-site pollution and potential off-site pollution by these metals. The high availability of these above trace metals is unexpected in view of the fact that the **pH** levels of the soil at the disposal site were high to very high and availability of the trace elements would be expected to be low. A possible explanation is given in Section 6.5.

Bulk density of the topsoil of the effluent treated site was acceptable, unlike the abnormally high bulk density at the control site, indicating a severe compaction problem at that site (Table 4.30).

Table 4.30: Bulk densities for soils at the Berg River winery

Soil depth	**Effluent treated site**	**Control**
Topsoil	1600 kg/m^3	2100 kg/m^3

4.9.5 General evaluation

A number of serious problems are found at this winery. The first is the high COD values in the January, February and March effluents, which pose a worse situation than at most of the Western Cape wineries studied. Secondly there is the unique situation of the high potassium levels in the effluent in all months, leading to very high soil K levels. Thirdly very high soil P levels were found at the disposal site. Fourthly this winery is one of only two with high copper, zinc and manganese levels at all soil depths in all months at the disposal site. As indicated, some of these problems are more serious than at the vast majority of wineries studied.

On the positive side the low SAR of the effluent and low ESP of the effluent treated soil indicate that sodicity is not a problem at this winery. In this regard it is better than almost all the other wineries studied.

It seems as if that disposal of effluent is done on a more suitable soil than at most of the other wineries. During soil classification nothing unusual (e.g. black layers in the soil, lateral seepage, etc.) was observed. The higher clay content of this soil than at most of the other wineries is probably the most important advantage. The site is on a fairly steep slope and off-site investigations will have to be made to verify whether lateral seepage through the topsoil did not occur.

Table 4.29: Soil analyses for the Berg River winery

Months	Depth	pH	Resistance	P	K	Na	K	Ca	Mg	S-value	Cu	Zn	Mn	B	ESP(%)
	(cm)	(KCl)	(ohm)	(mg/kg)	(mg/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
December	0-30	5.7	830	137.00	1028.00	0.47	2.63	4.60	0.82	8.52	23.71	29.70	56.60	1.17	5.52
January	0-30	6.3	400	130.00	1685.00	0.42	4.31	10.45	2.40	17.58	38.63	65.50	75.30	2.08	2.39
January	30-60	6.8	750	62.00	981.00	0.17	2.51	4.99	1.13	8.80	14.22	18.00	63.80	0.87	1.93
February	0-30	7.2	590	22.00	129.00	0.09	0.33	0.91	0.27	1.60	19.25	27.90	97.40	1.01	5.63
February	30 60	8	680	47.00	109.00	0.07	0.28	0.47	0.18	1.00	6.28	8.00	82.60	0.53	7.00
March	0-30	8	840	27.00	117.00	0.02	0.30	0.51	0.11	0.94	25.07	32.90	52.00	0.88	2.13
March	30-60	8	810	3.00	176.00	0.02	0.45	0.42	0.21	1.10	5.29	4.00	73.90	0.40	1.82
March	60-90	5.1	560	2.00	94.00	0.10	0.24	0.32	0.78	1.60	2.13	1.70	51.40	0.37	6.25
April	0-30	6.4	570	85.00	598.00	0.29	1.53	5.46	1.16	8.44	19.59	31.40	50.90	0.69	3.44
April	30-60	7.5	820	8.00	520.00	0.21	1.33	2.76	1.22	5.52	3.28	1.60	61.30	0.31	3.80
May	0-15	6	0	16.00	301.00	0.14	0.77	3.28	0.76	4.95	7.84	10.40	57.70	0.41	2.83
May	15-50	6.7	0	32.00	348.00	0.16	0.89	3.16	0.63	4.84	5.12	2.70	64.40	0.50	3.31
Control	0-30	4.8	1590	1.00	160.00	0.41	0.41	2.36	1.97	5.46	1.15	0.40	13.50	0.36	7.51
Control	30-60	4.8	2000	0.00	102.00	0.25	0.26	2.20	4.64	7.90	0.88	0.20	4.50	0.46	3.16
Control	60-90	5	1470	4.00	59.00	0.26	0.15	1.75	8.70	11.10	0.42	0.30	7.60	0.33	2.34

4.10 OLIFANTS RIVER WINERY

4.10.1 Main types of wine produced and chemicals used in the cellar

The types of wines produced by this winery include: white, red, grape juice as well as fortified wines. Bulk filtering with diatomaceous earth is used for the filtering of wine. Bentonite is used for protein stabilization. Parsan soaps with caustic soda are used for the cleaning of equipment.

4.10.2 Disposal method and soil description

This winery disposes of their effluent by means of keeping it in a pond for evaporation. The pond is small, shallow and not lined. During soil classification, it was difficult to classify this type of soil. A description and analysis for a modal profile from the disposal area are given in Appendix 4.7.

4.10.3 Effluent composition

Analytical data for effluent samples taken at this winery on a monthly basis (except May 2000) from December 1999 to June 2000 are given in Tables 4.31 and 4.32.

Table 4.31: pH, COD, SAR, EC and Na data for effluents from the Olifants River winery (From: Van Schoor & Mulidzi, 2001)

Month	**pH**	**COD (mg/l)**	**SAR**	**EC (mS/m)**	**Na (mg/l)**
December	4.6	37739	5.8	-	252
January	7.1	1462	10.83	-	322.6
February	4	23872	1.5	524	51.6
March	4	47024	2.3	1008	97.1
April	4.5	58812	2.79	2340	109.7
June	4.8	70683	0.98	2570	90.4

At this winery the effluent **pH** was consistently low except in January, when it was acceptable (Table 4.31). The pH values of the effluent were lower than the minimum acceptable pH of 6 specified in the South African General Authorizations in terms of Section 39 of the national Water Act (ACT NO.36 of 1998), except in January.

The effluent from this winery was characterized by very high **COD** values of up to an order of magnitude higher than 5 000 mg/l, which is unacceptable for irrigation during all months except January (Table 4.31). The disposal of effluent from this winery prior to treatment is not legal.

Sodium adsorption ratio **(SAR)** for four months was low. The SAR value for December and January are the only values, which are above the maximum permissible value of 5 for irrigation (ACT NO.36 of 1998). **Sodium** is also very high in December and January. In other months sodium is at an acceptable level (Table 4.31).

Electrical conductivity **(EC)** was very high in all months and even up to an order of magnitude above the South African Standard of 200 mS/m for irrigation (ACT NO.36 of 1998).

Table 4.32: K, Ca, Fe, Mg, B and Cl contents of effluents from Olifants river winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	103	-	47	-	-
January	388.7	40.7	0.54	16.2	0.69	48.11
February	1448.6	103.7	8.72	124	7.59	158
March	4119	150.5	15.29	156.9	10.4	86
April	5577.6	155.9	23.32	166.7	11.7	134
June	6896	265.5	17.5	230.4	14	0

Potassium is high in January and very high from February to June, especially from March to June (Table 4.32). Boron is also very high from February to June and is pointing towards toxic levels. Magnesium and calcium were very high in the June sample. The sources for B are however, unknown at this stage because it cannot be related with cellar activities.

4.10.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.33).

Exchangeable sodium percentage **(ESP)** values of the effluent treated soil were very high during December and January throughout the whole soil depth sampled. The high ESP values in the soil during December and January are due to the high SAR values and even more related to the extremely high sodium levels in the effluent during these months (Table 4.31). During February and March, the ESP of the topsoil and subsoil dropped to acceptable levels, in response to lower SAR values and Na levels in the effluent during these months.

During April ESP increased in both the topsoil and subsoil to very high levels, even higher than in December and January. In May the ESP was still relatively high in the topsoil, but it became low in the subsoil. An important question is where the sodium goes to during the periods when the ESP values drop. Plants cannot remove it because disposal is in a pond and not on an irrigated area. It cannot evaporate into the air, neither can it be fixed into non-extractable forms. The only possibility is leaching of this soluble cation to off-site areas. The answer may be found in the ESP data for the control site. The values for the control site were high, with the subsoil value being exceptionally high. Since the control site was only 50 metres **downslope** from the disposal pond, this may indicate massive downslope lateral seepage of sodium.

Table 4.33: Soil analyses for Olifants River Winery

Months	Depth	pH	Resistance	P	K	Na	K	Ca	Mg	S-value	Cu	Zn	Mn	B	ESP(%)
	(cm)	(KCl)	(ohm)	(mg/kg)	(mg/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(cmol/kg)	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)	
December	0-30	7.1	60	692.00	6100.00	6.18	5.60	6.85	4.94	33.57	6.99	15.70	264.50	9.75	18.41
December	30-60	8.8	60	872.00	6983.00	6.53	7.86	7.76	3.65	35.80	9.68	35.90	25.00	3.03	18.24
December	60-90	4.7	150	572.00	2057.00	1.29	5.26	3.69	1.85	13.92	6.02	14.30	24.60	4.05	9.27
January	0-30	6.9	70	227.00	3648.00	3.93	9.33	4.17	1.77	19.20	10.73	23.80	11.40	3.69	20.47
January	30-60	6.5	70	395.00	4145.00	3.09	10.60	5.56	2.47	21.72	8.14	14.00	43.00	2.62	14.23
February	0-30	9.4	50	457.00	716.00	0.17	1.83	0.64	0.51	3.15	4.39	9.20	100.20	8.47	5.40
February	30-60	9.2	90	3173.00	454.00	0.22	1.16	1.00	0.51	2.89	4.85	11.40	83.40	5.65	7.61
March	0-30	8.1	50	313.00	485.00	0.12	1.24	0.60	0.97	2.93	3.00	11.70	55.50	7.64	4.10
March	30-60	9.4	140	138.00	297.00	0.04	0.76	1.17	0.32	2.29	0.00	0.00	10.90	2.94	1.75
March	60-90	9.5	170	126.00	282.00	0.04	0.72	1.00	0.20	1.96	0.00	0.00	43.30	1.96	2.04
April	0-30	7.6	10	549.00	9548.00	15.60	24.42	6.91	6.52	53.45	1.50	15.80	55.90	7.51	29.19
April	30-60	8.7	20	858.00	5353.00	7.05	13.69	4.08	4.06	28.88	2.47	9.10	120.80	4.72	24.41
May	0-15	6.7	350	137.00	297.00	0.67	0.76	2.12	1.21	4.76	5.94	10.30	4.50	0.30	14.08
May	15-17.5	6.9	0	40.00	39.00	0.38	0.10	2.00	0.88	3.36	5.91	19.00	3.30	0.38	11.31
May	17.5-30	6.3	0	133.00	149.00	1.14	0.38	14.61	3.91	20.04	9.43	29.50	10.30	3.23	5.69
May	30-47	7.3	0	626.00	1310.00	0.88	3.35	12.39	2.06	18.68	2.15	3.00	103.00	1.53	4.71
May	47-100+	8.1	0	124.00	649.00	0.50	1.66	17.27	1.83	21.26	0.00	0.00	43.40	0.86	2.35
Control	0-30	8.7	160	23.00	821.00	3.92	2.10	14.89	1.62	22.53	0.26	0.60	27.70	2.48	17.40
Control	30-60	8.6	20	33.00	751.00	14.31	1.92	15.36	3.91	35.50	0.25	0.30	14.40	13.20	40.31

The **phosphorus** levels in the soil at the effluent treated site were very high to exceptionally high throughout the profile in all months. P is in most cases higher in the subsoil than in the topsoil. The P levels are high enough to be toxic to plants. Fortunately it does seem as if the P remains in the impounded area, since the control site does not have high P levels.

The **potassium** levels at both the effluent treated site and the control sites were very high throughout the profile. Some of the K levels in the soil at the effluent treated site are terribly high. This is not strange in view of the horribly high K levels in the effluent from this winery. The high levels of potassium in the subsoil of the disposal site, combined with the abnormally high K levels at the control site, is a worrying factor as it indicates lateral leaching of the K, which could end up in groundwater and cause environmental pollution.

Manganese and **zinc** are also high in the topsoil in some of the months. High manganese in the subsoil in April is a worrying factor as it may indicate the possibility of leaching to the groundwater or streams, resulting in environmental problems (Table 4.33).

The **bulk density** of the topsoil of the effluent treated site was lower than for the control site (Table 4.34). The value for the topsoil of the effluent treated site was abnormally low. This is not strange, since it was evident during soil classification that the topsoil layer was replaced by a man made layer of diatomaceous earth. The subsoil of the effluent treated site and that of the control site showed normal low bulk densities, indicating that effluent is not causing problems in terms of compaction.

Table 4.34: Bulk densities for soils at the Olifants River winery

Soil depth	**Effluent treated site**	**Control**
Topsoil	500 kg/m^3	1700 kg/m^3
Subsoil	1400 kg/m^3	1500 kg/m^3

4.10.5 General evaluation

The effluent from this winery is of **exceptionally** poor quality and is posing a threat of serious negative environmental impact if the evaporation pond should break or spill over. Compared with the other wineries studied, it is difficult to understand how this winery succeeds in producing such a bad quality effluent. Problem aspects include high COD and potassium levels for almost all months, low pH, high SAR and high sodium. Soil analyses indicated high phosphorus levels, while zinc and manganese pollution are additional problems. A special problem associated with the high COD will be discussed in Chapter 7.

Although not lined, an advantage at this winery is that the disposal pond was made in a soil with a dense clay and/or dorbank (duripan) subsoil, which limits seepage from the pond. (It was difficult to sample and classify it properly.) The sandy topsoil which overlies the clay and dorbank in the subsoil may lead to lateral leaching if the walls of the pond are not sealed properly with clay. Indications are that such seepage is occurring to some extent, not only in regard to the earlier mentioned results at the control site, but also in the form of observation of a wet patch in a depression downslope from the pond when the soil classification was done in May 2000.

In conclusion it can be said that big improvements in effluent management need to be done **very urgently** at this winery.

4.11 ORANGE RIVER WINERY

4.11.1 Main types of wine produced and chemicals used in the cellar

White, red, semi sweet, fortified, sparkling wines and grape juice are produced at this winery. Bulk filtering with diatomaceous earth is used to filter the wine. The SS cleaner and caustic soda soaps are used to clean the equipment. Bentonite is also used for protein stabilization. Chlorine is used to kill fungi.

4.11.2 Disposal method and soil description

This winery disposes of their effluent by means of ponding in shallow unlined ponds covering a much larger area than at the Olifants River winery.

The soil of the disposal area was classified as belonging to the Hopefield family of the Fernwood form (Soil Classification Working Group, 1991). A description and particle size analyses for a modal profile from the disposal area are given in Appendix 4.8. Augering immediately outside the pond area showed that the natural soil of the area has a typical sandy red apedal B horizon. The bleaching if the soil in the ponded area is ascribed to a "podzolization" effect in which the iron has been chelated by the organic matter in the winery effluent and transported deep into the profile together with it, thus stripping the red colour from the sand grains. (See also Chapter 7.)

4.11.3 Effluent composition

Analytical data for the effluent samples taken at this winery on a monthly basis (except May 2000) from December 1999 to July 2000 are given in Tables 4.35 and 4.36.

Table 4.35: pH, COD, SAR, EC and Na data for effluents from the Orange River winery (From: Van Schoor & Mulidzi, 2001).

Month	pH	COD (mg/l)	SAR	EC (mS/m)	Na (mg/l)
December	6.6	1176	1.22	-	40
January	4.1	3043	1.7	-	55.14
February	5.1	4000	1.65	88	53.2
March	4	23571	9.49	253	387
April	4.4	24752	0.94	125	28.7
June	5.8	574	0.99	67	29
July	5.7	980	1.4	62	41.5

At this winery the effluent **pH** of 6.6 for December 1999 is above the minimum acceptable pH of 6 specified in the South African General Authorizations in terms of Section 39 of the National Water Act, 1998 (ACT NO.36 of 1998) and should not pose a problem (Table 4.35). The effluent pH decreased when the wine making season started in January.

The effluent from this winery was characterized by low to moderate **COD** values of less than 5 000 mg/l, which is acceptable for irrigation (ACT NO.36 of 1998), for most of the study period. During March and April the COD of the effluent from this winery was extremely high and way above the maximum permissible level of 5 000 mg/l, however. These values were far higher than any obtained for any of the Western Cape wineries, but lower than the terrible values for the Olifants River winery.

The disposal of March and April effluent prior to treatment is not acceptable according to the South African environmental standards.

Sodium adsorption ratio **(SAR)** of the effluent is not very high, with the values for six months being very low (Table 4.35). It is only in March where the SAR value of 9.49 was above the maximum permissible level of 5 (ACT NO.36 of 1998). All values in all other months were still below the South African Water Act standards for disposal. Like SAR, **sodium** was only high in the March effluent.

Electrical conductivity **(EC)** was high and above the South African standard of 200mS/m acceptable for irrigation (ACT NO.36 of 1998) only for the March effluent.

Table 4.36: K, Ca, Fe, Mg, B and Cl contents of effluents from the Orange River winery (From: Van Schoor & Mulidzi, 2001)

Month	**K (mg/l)**	**Ca (mg/l)**	**Fe (mg/l)**	**Mg (mg/l)**	**B (mg/l)**	**Cl (mg/l)**
December	-	58	-	14	-	-
January	48.7	41.3	1.9	23.3	0.15	126.5
February	75.1	40.3	3.6	23.1	0.13	105
March	295.9	71.8	6.3	32.8	0.6	456
April	103.9	39	12.1	19	0.32	46
June	19.2	37.7	0.4	16.1	0.03	46

None of the **nutrient elements** analysed had values that are unacceptably high at any stage, indicating that these do not pose toxicity hazards at this stage (Table 4.36), except the March effluent, which had high levels of K and Cl.

4.11.4 Soil analyses

The soil analyses showed some important differences between the control and the site irrigated with effluent (Table 4.37).

The exchangeable sodium percentage **(ESP)** values of the effluent treated soil were high in December throughout the whole soil depth sampled (i.e. to 90 cm depth) and increased with increasing depth. In February the ESP values were also high, but decreasing with increasing depth. In April the ESP values were somewhat high throughout the whole soil depth.

The high ESP levels in April can be due to the high sodium and SAR values in the effluent in March. In May the subsoil ESP values were very low, being amongst the indications of intensive leaching of sodium from this highly permeable soil.

The topsoil **phosphorus** levels in the December, January and April samples from the effluent treated soil were high. Subsoil P levels were not very high, but generally higher than optimal. Subsoil P levels were much higher at the disposal site than in the control, indicating definite P leaching to lower soil layers. In December the P level in the deeper subsoil (60-90 cm) was very high.

The **potassium** levels were very high in January, April and May samples of the effluent treated soil and also on the control site (Table 4.37). The high amount of K in the subsoil is a matter of concern as it can leach into water bodies and cause eutrophication.

Zinc, copper and **manganese** levels were very high at all depths throughout the profile. This was one of only two wineries where levels of all three these elements were high at all depths, the other one being the Berg River winery.

At this winery there are clear indications of lowering of the **pH** of the soil pH in the 60-90 cm layer at the disposal site. In contrast the deep sampling in May indicated elevated pH levels of over 8 below 150 cm depth, just above the water table.

Table 4.37: Soil analyses for the Orange River winery

Months	Depth (cm)	pH (KCl)	resistance (ohm)	P (mg/kg)	K (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	S-value (cmol/kg)	Cu (mg/kg)	Zn (mg/kg)	Mn (mg/kg)	B (mg/kg)	ESP(%)
December	0-30	6.4	390	103.00	23.00	0.09	0.06	0.77	0.33	1.25	19.56	22.90	4.80	0.49	7.55
December	30-60	6.5	1220	84.00	23.00	0.08	0.06	0.29	0.20	0.63	9.58	6.00	2.90	0.24	10.99
December	60-90	6.4	1000	145.00	35.00	0.09	0.09	0.30	0.21	0.69	8.44	3.30	3.80	0.26	13.44
January	0-30	6.3	1080	136.00	266.00	0.22	0.68	5.28	1.52	7.70	13.04	28.10	24.70	0.74	2.86
January	30-60	6.1	1340	70.00	242.00	0.25	0.62	3.56	1.61	6.04	5.16	1.70	24.60	0.30	4.14
January	60-90	5.6	1560	49.00	192.00	0.21	0.49	2.97	1.59	5.26	1.53	0.80	35.40	0.18	3.99
February	0-30	6.1	360	64.00	47.00	0.08	0.12	0.33	0.17	0.70	3.01	1.80	13.20	1.85	11.43
February	30-60	7.7	490	64.00	66.00	0.08	0.17	0.51	0.18	0.94	5.68	1.60	35.60	2.49	8.51
February	60-90	4.9	210	42.00	63.00	0.11	0.16	0.28	0.18	1.91	17.51	4.90	6.10	1.68	5.76
March	0-30	7.0	1020	83.00	27.00	0.02	0.07	0.39	0.14	0.62	10.42	24.70	10.90	0.31	3.23
March	30-60	6.7	980	62.00	23.00	0.02	0.06	0.26	0.13	0.47	4.39	1.80	11.40	0.15	4.26
March	60-90	6.0	960	45.00	16.00	0.02	0.04	0.22	0.13	0.41	2.59	3.30	15.00	0.09	4.88
April	0-30	5.5	120	230.00	289.00	0.63	0.74	7.19	2.28	11.55	38.62	55.50	16.40	0.49	5.45
April	30-60	6.7	370	90.00	192.00	0.34	0.49	3.97	1.53	6.33	21.67	25.10	7.20	0.16	5.37
April	60-90	6.3	520	81.00	203.00	0.33	0.52	3.77	1.67	6.29	11.09	7.40	6.20	0.13	5.25
May	0-25	5.6	1080	49.00	184.00	0.14	0.47	1.38	0.60	2.59	0.00	0.00	0.00	0.20	5.41
May	25-50	5.1	1700	70.00	250.00	0.05	0.64	1.59	0.34	2.93	1.26	0.80	2.50	0.14	1.71
May	50-88	5.0	2540	55.00	192.00	0.05	0.49	1.61	0.35	2.74	1.37	0.60	2.90	0.13	1.82
May	88-120+	4.3	2910	61.00	227.00	0.06	0.58	0.91	0.34	2.52	1.16	0.50	4.80	0.11	2.38
May	150-175	8.3	460	23.00	391.00	0.05	1.00	10.16	0.31	11.52	1.31	0.50	29.20	0.20	0.43
May	175+	8.4	710	20.00	309.00	0.10	0.79	15.32	0.57	16.78	1.30	0.50	48.00	0.23	0.60
May	0-50	8.0	2430	7.00	133.00	0.15	0.34	4.52	1.15	6.16	0.33	0.30	9.60	0.09	2.44
Control	0-30	6.4	1260	45.00	364.00	0.11	0.93	2.97	1.19	5.20	0.38	0.60	6.80	0.54	2.12
Control	30-60	6.6	1270	31.00	266.00	0.16	0.68	3.14	1.35	5.33	0.30	0.10	3.30	0.65	3.00
Control	60-90	7.0	1500	10.00	141.00	0.17	0.36	3.11	1.31	4.95	0.28	0.30	14.10	0.41	3.43

The **bulk density** of the topsoil of the effluent treated site was very low (Table 4.38). It was, in fact, abnormally low, due to the presence of large quantities of diatomaceous earth. The topsoil of the control site had a very high bulk density. The subsoils of both the effluent treated and control sites had very high bulk densities, indicating compaction problems.

Table 4.38: Bulk densities for soils at the Orange River winery

Soil depths	**Effluent treated site**	**Control**
Topsoil	900 kg/m^3	1900 kg/m^3
Subsoil	1800 kg/m^3	1700 kg/m^3

4.11.5 General evaluation

The March effluent from this winery was of very poor quality in just about every possible respect, including exceptionally high COD and high K, Na, Cl, SAR and EC values, and is posing a threat of serious negative environmental impact when contained in an unlined pond system. The April effluent also had an extremely high COD. The very high COD is the main effluent problem at this winery, as will be discussed in more detail in Chapter 7. Soil analyses indicated P, Zn, Cu and Mn as potentially serious pollution problems.

The biggest problem at this winery is that effluent disposal is done on a soil that is unsuitable for the disposal of this effluent by means of ponding. It is a sandy soil with little clay that can retain pollutants in the soil. It also is a deep soil with high permeability. The effluent therefore leaches quickly through the soil until it reaches the water table at about two metres depth. The high pH levels, lower electrical resistance and high K levels found below 150 cm depth during the soil classification in May are indications of this. This aspect will also be elaborated further in Chapter 7.

CHAPTER 5

INTEGRATED COMPARATIVE DISCUSSION ON THE COMPOSITION OF WINERY EFFLUENTS

5.1 INTRODUCTION

From Chapter 4 it is clear that the composition of winery effluent differs widely from one winery to the other, but there are also some similarities in trends. These differences are assumed to be due to differences in the winemaking processes in different wineries, as well as differences in chemicals, soaps, etc. used to wash the tanks, equipment and floors. Water management in a winery also has an influence on the quality and quantity of effluent.

5.2 EFFLUENT pH

According to the literature, winery effluent is characterized by pH of less than 5.5 (Levay, 1995). In the present study the effluent from all cellars had pH values lower than 5.5 for the whole winemaking period (Table 5.1). In a number of cases the pH values dropped to below 4.0 and in a few even below 3.0. In other words the pH values of the effluents of all the wineries studied are below, in most cases far below, the minimum pH of 6 allowed by the South African Water Act (ACT NO.36 of 1998). For many wineries a sharp decrease in pH coincided with a marked increase in COD. (Compare Tables 5.1 and 5.2) The low pH of winery effluents can, to a large extent be ascribed to citric or tartaric acid used to neutralise the alkali (Van Schoor, 2000).

It is clear that the effluents of all wineries have pH values far below the acceptable levels for most of the year, and that all wineries must take appropriate measures to correct this problem before disposal of the effluent. Except for a few cases of minor reductions in soil pH levels, there does not seem to be indications of acidification of the soils due to effluent application. In a few cases there were even increases in soil pH to high levels. It was not determined how the wineries manage the counteraction of soil acidification, but most of them seem to be doing a good job of it.

According to the literature, the best method is addition of calcium hydroxide slurry at the point where the effluent leaves the storage dam for irrigation (Hazell, 1997).

Table 5.1: pH values of effluents from different wineries (From: Van Schoor & Mulidzi, 2001).

Mon	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	6.4	7.6	5.6	5.3	2.8	4.4	6.1	5.6	4.6	6.6
Jan	2.7	7.4	4.4	6.6	4.7	5.7	7	3.5	7.1	4.1
Feb	5.1	4.4	4.8	4.3	4.1	4.9	3.7	4.3	4	5.1
Mar	5.1	4.6	4.5	5	3.6	4.6	3.7	3.8	4	4
Apr	5	4.8	5.3	3.1	5.4	6.1	4.3	5.1	4.5	4.4
Jun	4.5	5.3	3.7	4.4	-	-	-	3.6	4.8	5.8
Jul	-	6	-	-	-	-	-	-	-	5.7

5.3 COD LEVELS OF EFFLUENTS

From Table 5.2 it is clear that all wineries have COD values above 5 000 mg/l (which is the maximum acceptable value for crop irrigation) at some stage during their winemaking periods. The period of exceedance of the acceptable limit usually lasts for two or three months and usually includes February, March and/or April. In a few cases it starts in January and in no case did it apparently go beyond April. Unfortunately no data were collected during May, but by June COD levels have decrease to low or very low values. There was no possible explanation for the odd high December value for the abnormal cellar from the Olifants River region. Citric acid, grape solids, lees, grape juice, wine and tartrate increases COD of wastewater (Van Schoor, 2001b).

Table 5.2: COD values of effluents from different Wineries (From: Van Schoor & Mulidzi, 2001).

Month	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	2299	364	582	3321	2595	1517	2241	1494	37739	1176
Jan	5296	233	3676	2372	4545	6561	3399	14229	1462	3043
Feb	2700	8520	996	14160	18044	1174	5788	10120	23872	4000
Mar	3373	6190	7262	8175	6627	3770	11270	6389	47024	23571
Apr	7802	2257	7802	12238	1117	448	10614	2805	58812	24752
June	4458	3514	859	3394	-	-	-	1205	-	574
Jul	-	1968	-	-	-	-	-	-	-	980

The values with which COD exceed the acceptable limit for some wineries (Paarl 1, Paarl 2, Paarl 3, Robertson 2) are low, while others range from high (Stellenbosch, Worcester, Robertson 1, Berg River) to extremely high (Orange River, Olifants River).

Some regional trends were observed: All three cellars from the Paarl region (Paarl 1, 2 and 3) did not exceed the acceptable limit by much. Cellars from further inland, i.e. from the Berg river, Worcester and Robertson regions (Berg River, Worcester, Robertson 1) had high exceedance levels, while both cellars from the dry northern Olifants and Orange river regions had extremely high exceedance levels. Since only a small number of cellars were studied in each region, these cannot be regarded as rules at this stage, but it warrants further investigation. Robertson 2 already does not fit into its group, being much better than the rest of the group in terms of COD. The poor quality effluent from the one Stellenbosch winery can also not be taken as representative of the whole Stellenbosch region.

It is accepted that ethanol and sugars are the main contributors to high COD values in wine cellar effluents (Glaetzer, 1998). Suspended and colloidal organic matter in cellar effluent is usually also a significant contributor to the total pollution load as measured by COD (Levay, 1995). In the present study the organic fractions responsible for high COD values were not determined. It is clear that effluents from all the wineries had COD levels above the acceptable maximum limit for two to three months each year. During these periods the effluent will have to be treated **before** disposal to reduce the COD to acceptable levels.

From the present study it is clear that aerobic decomposition of the organic matter, especially at the wineries with high COD effluents, does not take place in the soil and that the organic substances percolate through the soil to the water table where it undergoes anaerobic decomposition or seeps through to ditches or streams (see Chapter 7). The wineries do not seem to have appropriate, if any, management systems in place to deal with the problems of high COD levels. They may be under the false impression that aerobic decomposition of the organic fraction of the effluents occurs in their soils, which is clearly not the case.

5.4 SAR AND SODIUM

Table 5.3 shows that the effluent from three of the wineries had **SAR** values above 5 (which is the maximum acceptable value for crop irrigation) during December and January. In December an additional winery had effluent with a SAR above the acceptable level, while another one fell in this category in January. Caustic soda is the main source of sodium (Van Schoor, 2000).

The effluents from four wineries had unacceptably high SAR values in March. Two of these did not have such problem in December or January. Although the effluents from the Robertson 1 winery had high SAR values only in December and January, these values were extremely high. The Paarl 2 winery is the only winery of which the effluents had high SAR values throughout all months. This was attributed to the use of poor quality borehole water in the cellar. In contrast the effluents from the Paarl 3, Robertson 2 and Berg River wineries had very low SAR values throughout the whole study period.

Table 5.3: SAR values of effluents from different wineries (From: Van Schoor & Mulidzi, 2001).

Mont	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	5.7	7.5	0.6	2.4	0.7	1.9	29.0	1.2	5.8	1.2
Jan	1.8	7.8	0.5	4.9	7.1	1.8	33.1	0.5	10.8	1.7
Feb	1.2	6.3	3.2	4.4	3.5	2.0	1.9	0.6	1.5	1.7
Mar	4.4	7.1	0.8	9.1	6.5	2.1	4.5	0.5	2.3	9.5
Apr	1.6	10.0	0.8	2.1	2.3	2.4	1.7	0.3	2.8	0.9
Jun	1.8	12.0	0.9	3.6	-	-	-	0.4	1.0	1.0
Jul	-	11.2	-	-	-	-	-	-	-	1.4

It is clear from Table 5.4 that the effluents from certain wineries have high sodium levels in some months. Logically these coincide with the cases with high SAR values.

According to Glaetzer (1995) sodium enters the wastewater stream via the use of cleaning chemicals such as caustic soda (sodium hydroxide) and sodium hypochlorite. As indicated earlier, the biggest problem case in the present study (Paarl 2) was related to the use of poor quality borehole water and not to chemicals used in the cellar. High sodium levels will imbalance the cations and anions present in the soils, leading to a degradation of soil structure and thus permeability. In the present study dispersion of clay and subsoil compaction have been observed as on-site problems caused by sodium in one case. In the two wineries where high sodium is the biggest problem (Paarl 2 and Robertson 1) the biggest concern is about off-site effects of sodium leaching into adjacent streams, causing sodicity problems elsewhere.

Table 5.4: Sodium levels (mg/l) in effluents from different wineries (From: Van Schoor & Mulidzi, 2001).

Mont	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	206	261	8.8	61	5	59	692	24	252	40
Jan	61	305	10.7	86.3	107.2	61.12	677.8	15.7	322.6	55.14
Feb	33	269	77.7	127.9	59.2	71.1	35.1	15.7	51.6	53.2
Mar	152	311	29.6	251.5	107.9	66.4	130.5	10	97.1	387
Apr	85	448	13.7	60.1	24.9	80.2	38	6.2	109.7	28.7
Jun	66	513	11.3	58.8	-	-	-	8.3	90.4	29
Jul	-	446	-	-	-	-	-	-	-	41.5

The wineries where high sodium and SAR levels in the effluent pose problems do not seem to have appropriate management systems in place to counteract this. This can be seen in the relationships between elevated ESP levels in the soils of the disposal sites and effluent SAR values. ESP and SAR both reflect Na:(Ca + Mg) ratios.

5.5 EC AND CHLORIDE

5.5.1 EC (Electrical conductivity)

Table 5.5 indicates that few wineries have effluents with EC values above 200 mS/m (which is the maximum acceptable value for crop irrigation) at some stage during their winemaking periods. High electrolyte contents in effluents, therefore, do not seem to pose any problem at the vast majority of wineries.

In contrast to this general favourable pattern, two wineries (Olifants River and Paarl 2) have EC values above 200 mS/m in **all** months. Not only did the effluents from these wineries have high electrolyte concentrations throughout the whole period, but the values were very high. In the case of Olifants River the values were extremely high. The implication is that the effluents from both wineries have very definite salinization hazards, both on-site and off-site. Unfortunately EC was not determined on the pre-winemaking samples (December and January), when the values might have been high at more wineries. This will have to be followed up.

Table 5.5: EC values of effluents from different wineries (From: Van Schoor & Mulidzi, 2001).

Mont	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	-	-	-	-	-	-	-	-	-	-
Jan	-	-	-	-	-	-	-	-	-	-
Feb	82	269	60	150	65	544	60	95	524	88
Mar	109	311	137	170	66	92	144	76	1008	253
Apr	386	448	175	143	44	177	90	184	2340	125
Jun	170	513	52	74	-	-	-	110	2570	67
Jul	-	313	-	-	-	-	-	-	-	62

5.5.2 Chloride

From Table 5.6 it is clear that the effluents from the majority of the wineries had acceptable chloride levels, i.e. below 200 mg/l, throughout the study period. There is a unique situation with one winery (Paarl 2), where the effluents had extremely high chloride levels throughout all months, which was also, like the high sodium levels, related to the poor quality borehole water used.

Other wineries that showed high amounts of chloride in effluents in some months are Paarl 1, Stellenbosch and Orange River. It is only Stellenbosch (January) and Orange River (March) that have very high values. The reason for the high amounts of chloride in effluents is not known, but may possible be due to the use of a chemical such as hypochlorite to combat fungal growth.

Table 5.6: Chloride levels (mg/l) in effluents from different wineries (From: Van Schoor & Mulidzi, 2001).

Mont	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	-	-	-	-	-	-	-	-	-	-
Jan	98	286	98	632.6	49.89	76.6	55.24	126.5	48.11	126.5
Feb	173	869	96	133	19	66	86	63	158	105
Mar	130	760	54	42	27	87	166	43	86	456
Apr	132	470	58	66	73	45	141	28	134	46
Jun	116	704	27	55	-	-	-	27	0	46
Jul	-	-	-	-	-	-	-	-	-	-

5.6 POTASSIUM

Table 5.7 indicates that all the wineries, except one (Robertson 2), had effluents characterized by high potassium at some stage during the study period. The effluents from the Berg River winery constantly had high potassium levels throughout the whole study period. The effluents of the winery from the Olifants River region had very high potassium values throughout the sampling period (Table 5.7), in line with the abnormally high levels of all elements analysed for at this winery. At both these wineries the soils at the disposal site are not sandy, as is the case at most other wineries, so the potassium can be retained on adsorption sites in the soil.

Potassium is not toxic to plants, but high potassium levels may upset nutrient balances in the soil, especially K:Mg balances. From the soil data obtained in this study it transpired that there is a lot of leaching of potassium in and from the effluent treated soils at some cellars, creating definite eutrophication hazards for adjacent streams. This is especially the case where the effluent is applied on the light gray, highly leached sandy soils.

Table 5.7: Potassium values (mg/l) for effluents from different wineries (From: Van Schoor & Mulidzi, 2001)

Mont	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	-	-	-	-	-	-	-	-	-	-
Jan	32	163	40.3	61.7	100.8	137.5	107	264.9	388.7	48.7
Feb	125	267.7	15.3	356.7	127.2	95.1	93.1	279.9	1449	75.1
Mar	65	313.7	334.1	333.2	124.6	89.9	298.5	242.5	4119	295.9
Apr	336	113.7	290.6	97	19.5	48.7	79.6	311.6	5578	103.9
Jun	211	244.8	85.4	64.9	-	-	-	279.7	6896	19.2
Jul	-	-	-	-	-		-	-	-	-

CHAPTER 6

INTEGRATED COMPARATIVE DISCUSSION ON THE EFFECTS OF WINERY EFFLUENTS ON SOIL AND POSSIBLE POLLUTION OF WATER BODIES

6.1 GENERAL

It is clear from Chapter 5 that the composition of winery effluents differ from one winery to another and also between different times during the wine making season at any specific winery. The pollution associated with winery effluents will, therefore, also differ from one winery to the other and between different months at any specific winery. The quality of winery effluent will determine the extent of pollution it will cause to the soil it has been disposed on, as well as off-site pollution that it may cause.

The properties, characteristics and qualities of the soil at the disposal site will also affect the on-site impact of the pollution, while these together with the position of the disposal site in the landscape will affect the off-site pollution hazard. These aspects are discussed in more detail in Chapters 4 and 7.

6.2 PHOSPHORUS TRENDS

From Tables 6.1, 6.2 and 6.3 it is clear that phosphorus shows some disconcerting trends at most of the wineries. The topsoils of the vast majority of the wineries show excessive to highly excessive P levels during December and January, before the start of the wine making season (Table 6.1). Taking into account that P level of 45 $mg.kg^{-1}$ is the maximum permissible level for optimum plant growth (for P extracted with the Bray 1 method) such levels are unacceptable.

Thereafter the topsoil P values decrease sharply, to even reach acceptable levels for half of the wineries, until March. In April, just after the wine making season, there is a significant increase in topsoil P to unacceptably high levels at all wineries except the two Robertson wineries.

At the Stellenbosch and Orange River wineries the topsoil P levels during April were extremely high and totally unacceptable – even higher than in December and January. At the Stellenbosch winery this high topsoil P level persisted even during May.

Phosphorus levels are generally higher in the topsoils (0 – 30 cm depth) than in the subsoils (30 – 60 cm and 60 – 90 cm) (Tables 6.1, 6.2 and 6.3). This is a general pattern for P applied to topsoils, since P normally does not move in soils, even in sandy soils under excessive irrigation (Eloff, 1971). In the present study there were some wineries where subsoils contained high to excessive P levels at some stages, indicating P movement in the soil and definite dangers of P leaching from the soil to water bodies, which could cause eutrophication of such water bodies. Most alarming in this regard are the extremely high P levels in the lower subsoil (60 – 90 cm) at the Worcester and Robertson 1 wineries during April (Table 6.3).

The phosphorus levels found in the soil at the Olifants River winery are extremely high, as is the case with most other elements at this winery. It could be argued that this shows that ponding on this dense soil efficiently retained this potential pollutant within the pond.

Unfortunately no P analyses were done on the effluents. Since disposal of effluent is done by means of ponding in the case of two of the wineries with very high P levels in the soil, the effluent is the only possible source of the high P levels. P can get into the effluent by means of washing soaps. It is clear that phosphorus management will have to be improved drastically at almost all the wineries, and especially at the Stellenbosch and Robertson 1 wineries. At these wineries there are not only clear indications of P leaching, but their disposal sites are also close to streams.

Table 6.1 Phosphorus (mg/kg) in topsoil (0 – 30 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	104	53	33	185	164	-	116	137	692	103
Jan	131	93	25	143	121	-	39	130	227	136
Feb	46	14	2	69	57	38	27	22	457	64
Marc	55	24	41	84	39	25	16	27	313	83
Apri	73	49	61	275	54	31	36	85	549	230
May	76	9	-	259	35	-	33	16	133	70
Control	62	5	94	50	40	-	33	1	23	45

Table 6.2 Phosphorus (mg/kg) in upper subsoil (30 – 60 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	50	54	14	119	142	-	46	-	872	84
Jan	122	31	6	63	125	-	25	62	395	70
Feb	22	12	2	53	30	-	120	47	3173	64
Marc	28	3	3	18	72	-	16	3	138	62
Apri	33	23	13	41	101	-	56	8	858	90
May	5	1	-	97	44	-	21	32	626	55
Control	26	2	74	27	11	-	23	0	33	31

Table 6.3 Phosphorus (mg/kg) in lower subsoil P (60 – 90 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	23	6	24	25	60	-	81	-	572	145
Jan	66	-	4	53	68	-	17	-	-	49
Feb	8	37	93	96	4	-	81	-	-	42
Marc	6	3	2	62	76	-	44	2	126	45
Apri	9	19	16	22	191	-	170	-	-	81
May	5	1	-	24	19	-	24	-	124	61
Control	7	2	25	14	6	-	23	4	-	10

6.3 POTASIUM TRENDS

Like phosphorus, potassium levels in the soils at most wineries were high to very high in December and January (Tables 6.4, 6.5 and 6.6). Unlike P these elevated K levels were not confined to the topsoil, but occurred at all soil depths.

Except for the very high December and January K levels at the Berg River winery, none of the values are expected to negatively affect plant growth. The very high K levels in the soil at the Berg River winery is in line with the high K levels in the effluents from this winery, as indicated in Chapter 4. (See also Table 5.7.)

Similar to P the K levels dropped sharply in February and March, in many cases to abnormally low values. Some of the February and March values are so low that they represent deficient K levels for plants. The reasons for these exceptionally low levels during these (the wine making months) are not clear.

During April the topsoil K levels rise sharply again, similar to P. In some cases elevated K levels persisted into May. The high soil K levels in April and May are attributed to the high K contents of the effluents of most cellars in March or April (Table 5.7).

Like with all other elements, the Olifants River winery also showed abnormally high values of potassium, both in the topsoil and in the subsoil. Like with P it could possibly be argued that this indicates efficient ponding, but the fact is that the effluent from this winery had abnormally high K levels in almost all months (Table 5.7).

The indication that at some wineries potassium is leaching from topsoil to subsoil and then probably to groundwater or streams is, a matter for concern. The situation at the Stellenbosch and Robertson 1 wineries, where disposal is done on highly permeable soils with low nutrient retention capacities close to streams, should receive urgent attention in this regard. There should also be much concern about the increase in K levels with depth to a very high level in the lower subsoil (60 – 90 cm) at Paarl 2 in the May samples. K toxicities are not expected, but eutrophication, which could lead to algal growth.

Table 6.4 Potassium (mg/kg) in topsoils (0 – 30 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	199	156	325	387	59	-	414	1028	6100	23
Jan	289	207	168	524	63	-	469	1685	3648	266
Feb	27	23	16	39	12	70	20	129	716	47
Marc	47	20	39	63	4	82	35	117	485	27
Apri	223	94	184	551	47	555	66	598	9548	289
May	196	74	-	242	70	-	16	301	297	184
Control	145	129	199	78	47	-	235	160	821	364

Table 6.5 Potassium (mg/kg) in upper subsoils (30 – 60 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	106	481	180	207	55	-	168	-	6983	23
Jan	106	82	164	301	51	-	364	981	4145	242
Feb	8	12	31	27	20	-	8	109	454	66
Marc	20	12	23	47	0	-	20	176	297	23
Apri	215	55	59	239	31	-	0	520	5353	192
May	235	590	-	109	27	-	70	348	1310	192
Control	66	90	109	74	27	-	242	102	751	266

Table 6.6 Potassium (mg/kg) in lower subsoils K (60 – 90 cm)

Months	Paa 1	Paa 2	Paa 3	Stell	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	47	555	20	422	31	-	145	-	2057	35
Jan	70	-	35	348	27	-	184	-	-	192
Feb	4	16	4	27	16	-	16	-	-	63
Marc	8	8	0	59	12	-	20	94	282	16
Apri	211	55	465	141	31	-	86	-	-	203
May	235	895	-	66	8	-	55	-	649	227
Control	35	258	51	125	35	-	145	59	-	141

6.4 ESP TRENDS

It is clear from Tables 6.7, 6.8 and 6.9 that almost all wineries have unacceptably high ESP levels in the topsoil and/ or subsoil of their effluent disposal sites in some of the months.

At most wineries seasonal trends similar to those for P and K are also found for ESP, viz. highest values in December, January and April. Three wineries (Paarl 2, Paarl 3 and Robertson 1) have remarkably high ESP values in the subsoils of their disposal sites.

In contrast the ESP values of the soil at the Berg River winery are low throughout, whereas a few other wineries also generally do not look too bad. It is a matter of fact that there is sodium pollution at most of the wineries. This could in most cases be clearly related to high sodium levels and SAR values of the effluent. The main sources of sodium in the effluent during wine making include technologies that employ and utilize sodium hydroxides diluted to 5% (better known as caustic soda) (Van Schoor, 2000). At the winery with the worst sodium problem (Paarl 2), the use of sodic borehole water was the main source of sodium.

At Paarl 3 the subsoil has very high sodium levels despite no indication of high sodium in the effluent. The manager of the winery was very cooperative, but could not find any explanation for this situation. (See also Chapter 4.)

According to the literature, high ESP causes the clay to become dispersed and puddle when wet, lowering infiltration, permeability and aeration and forming a hard impermeable crust when dry. In the present study indications of such effect was found at only one winery, probably because effluent disposal was in most cases done on sandy soils. High ESP may also contribute to dispersion of the organic fraction in the effluent and its leaching into the deeper subsoils. (See Chapter 7.)

Table 6.7 ESP of topsoils (0 – 30 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	8.52	25.47	3.03	10.37	13.10	-	24.60	5.52	18.41	7.55
Jan	3.46	17.31	1.48	5.23	1.49	-	25.15	2.39	20.47	2.86
Feb	3.73	19.30	11.76	5.50	12.0	6.57	6.42	5.63	5.40	11.43
Marc	6.38	16.67	3.03	7.14	0.97	5.78	2.03	2.13	4.10	3.23
Apri	5.38	14.17	2.56	8.22	1.21	6.05	4.09	3.44	29.19	5.45
May	7.9	19.89	-	12.80	2.06	-	10.10	2.83	14.08	5.41
Control	2.53	4.19	1.90	0.78	1.81	-	2.28	7.51	17.40	2.12

Table 6.8 ESP of upper subsoils (30 – 60 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	7.05	17.24	50.35	17.45	19.50	-	30.46	-	18.24	10.99
Jan	4.68	12.50	29.22	6.22	1.54	-	25.22	1.93	14.23	4.14
Feb	3.17	22.86	22.64	12.50	6.86	-	21.21	7.00	7.61	8.51
Marc	3.26	21.05	20.45	11.43	0.00	-	9.09	1.82	1.75	4.26
Apri	6.29	22.22	22.18	9.06	1.06	-	6.04	3.80	24.41	5.37
May	7.54	16.83	-	10.42	1.75	-	10.49	3.31	4.71	1.82
Control	2.22	6.47	2.07	0.95	1.38	-	1.73	3.16	40.31	3.0

Table 6.9 ESP of lower subsoils (60 – 90 cm)

Months	Paa 1	Paa 2	Paa 3	Stelle	Worc	Rob 2	Rob 1	Berg	Olif	Oran
Dec	7.29	17.67	66.84	16.93	29.79	-	7.80	-	9.27	13.44
Jan	5.50	-	38.45	7.56	1.78	-	22.41	-	-	3.99
Feb	4.17	21.74	23.63	15.25	8.75	-	12.07	-	-	5.76
Marc	2.30	19.05	18.60	7.69	0.00	-	8.70	6.25	2.04	4.88
Apri	4.90	23.67	39.28	12.61	1.07	-	1.73	-	-	5.25
May	9.24	15.47	-	10.22	1.39	-	14.07	-	2.35	1.82
Control	4.96	6.11	2.34	1.49	1.56	-	1.9	2.34	-	3.43

6.5 MANGANESE, ZINC AND COPPER

Orange river, Olifants river and Berg river wineries have high manganese values even in the subsoil. At these three wineries there are indications that there is leaching from topsoil to subsoil and may therefore even leach to groundwater or streams. Manganese pollution can be expected at these three wineries. Other wineries (Paarl 1, Paarl 3 and Robertson 2) have some indication of high manganese values in the topsoil in one or two months. There is no clear trend shown by manganese as it differs from one winery to the other. The sources of these elements are at this stage unknown because it can not be related to winery processes. Spray drift from vineyards in close proximity during spray could be speculated as possible source but was not measured in this study.

Like manganese, zinc is very high at all depths in the soil at three wineries (Orange river, Olifant river and Berg river). Two other wineries (Stellenbosch and Paarl 3) have high zinc values in the topsoil during certain months.

Most wineries do not have high levels of copper in their soils. Only two wineries (Orange river and Berg river) have high values of copper in most of the months in both the topsoil and subsoil. This is an indication that it may leach to the groundwater or streams, therefore polluting the environment.

6.6 RESPONSE OF MINERAL ELEMENT LEVELS IN SOILS TO ITS LEVELS IN EFFLUENT

As indicated earlier, there is evidence that mineral element levels in soils rise and fall in response to fluctuations in the levels of these elements in the effluent. There is usually a lag in this response, i.e. the increase in the level in the soils is usually in the month following the month in which an elevated level occurred in the effluent. The same holds for sharp decreases in mineral element levels. Sometimes there is a further lag with depth, especially for P, but in the case of the sandy soils the changes occur simultaneously at all depths, due to fast leaching.

These effects are clearly illustrated for K and Na at the Orange River winery (Figures 6.1 and 6.2). For both elements there are sharp increases in their levels in the soil at all depths in April, following their sharply increased levels in the March effluent. Conversely their levels in the soil decreased sharply in February, following their high levels in the soil in January, in response to their low levels in the January effluent. Unfortunately no analyses are available for the December effluent, so that it can only be speculated that the high levels of these elements in the soil in January were due to high levels in the December effluent.

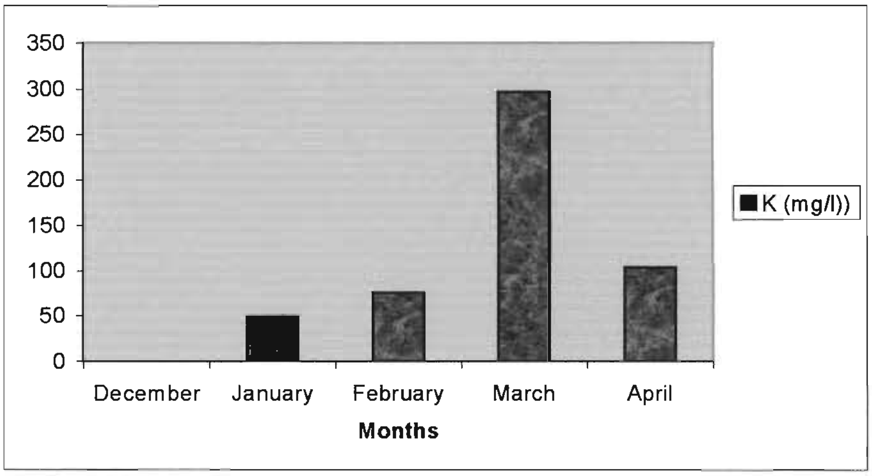

Figure 6.1a: Potassium trend of effluent at Orange river winery

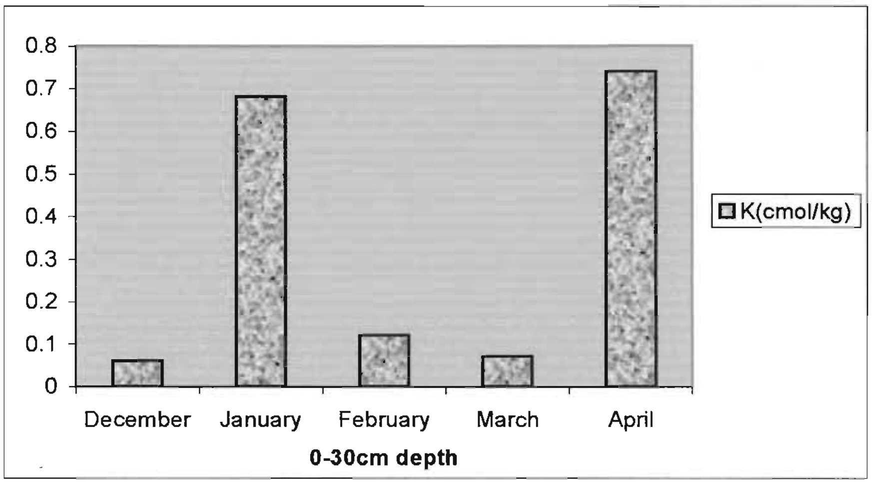

Figure 6.1b: Potassium trend of topsoil (0-30 cm) at Orange river winery

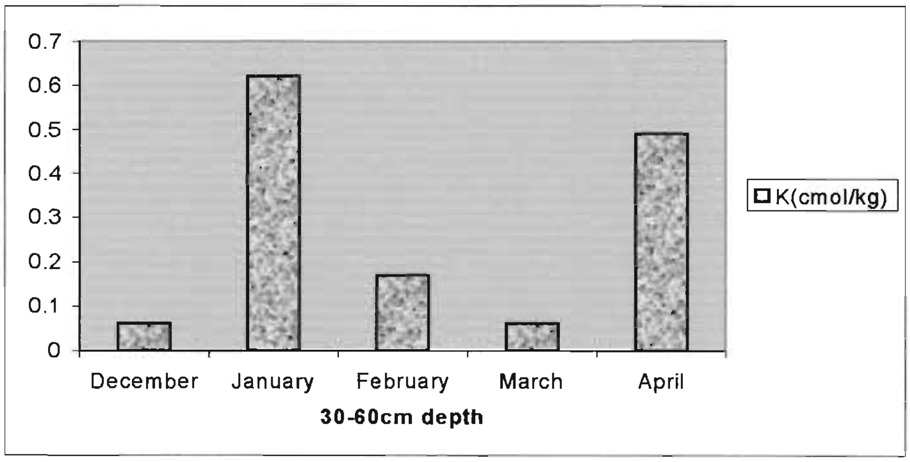

Figure 6.1c: Potassium trend of subsoil (30-60cm) at Orange river winery

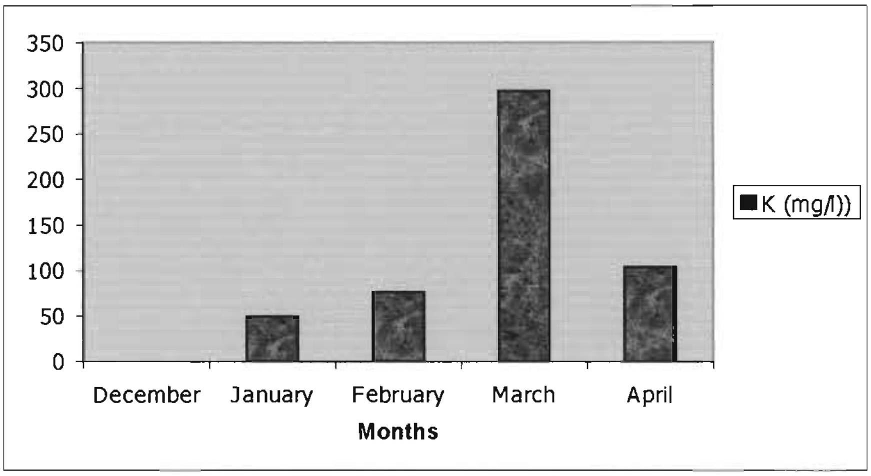

Figure 6.1a: Potassium trend of effluent at Orange river winery

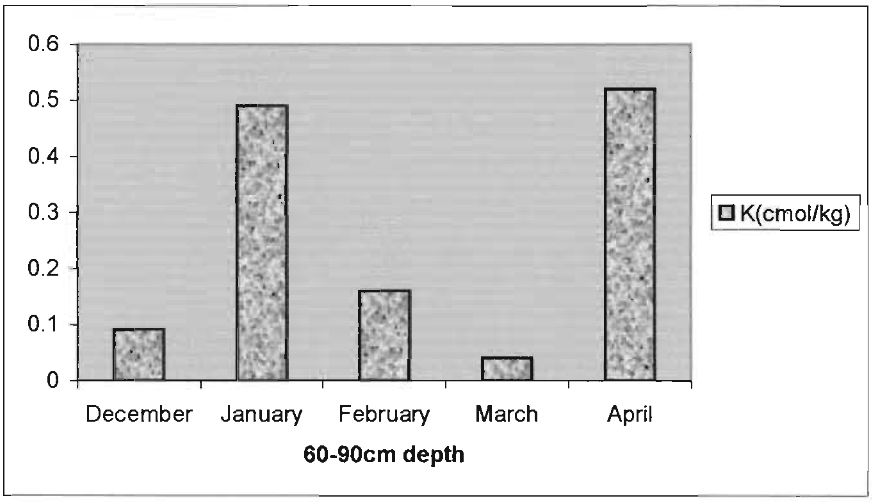

Figure 6.1d: Potassium trend of subsoil (60-90cm) at Orange river winery

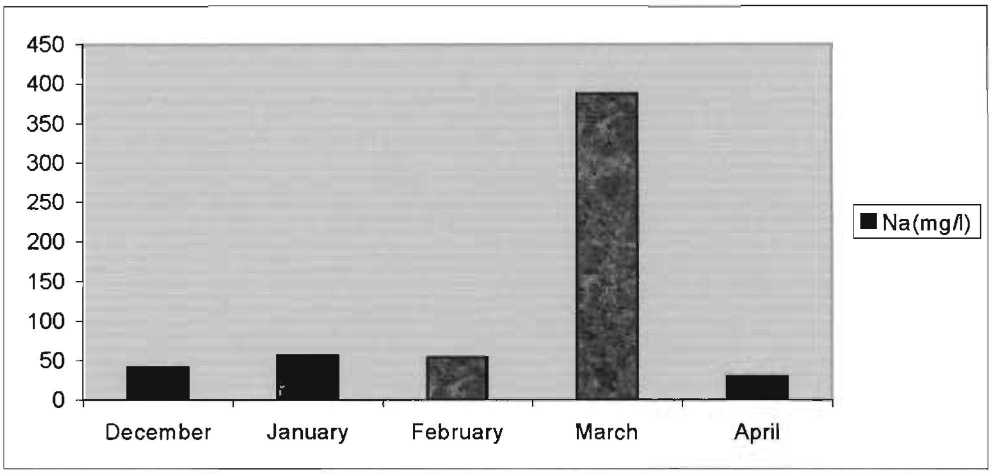

Figure 6.2a: Sodium trend of effluent at Orange river winery

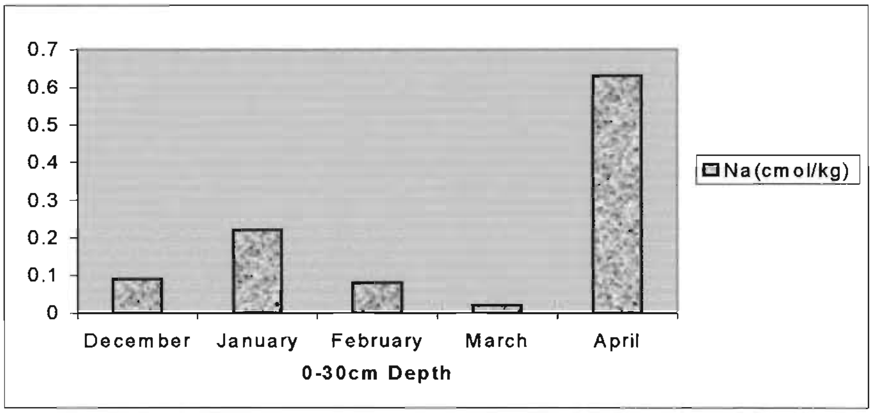

Figure 6.2b: Sodium trend of topsoil (0-30cm) at Orange river winery

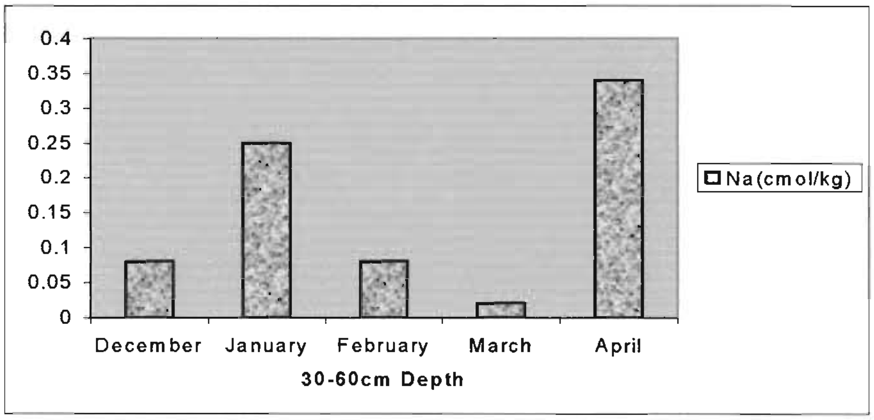

Figure 6.2c: Sodium trend of subsoil (30-60cm) at Orange river winery

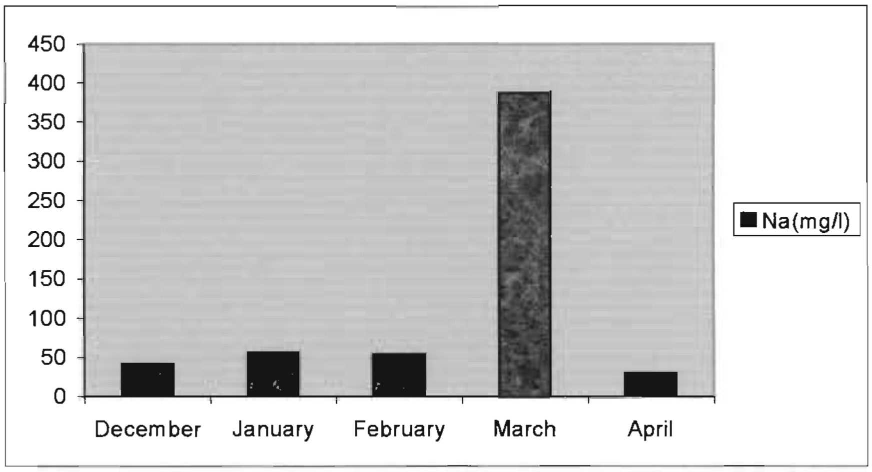

Figure 6.2a: Sodium trend of effluent at Orange river winery

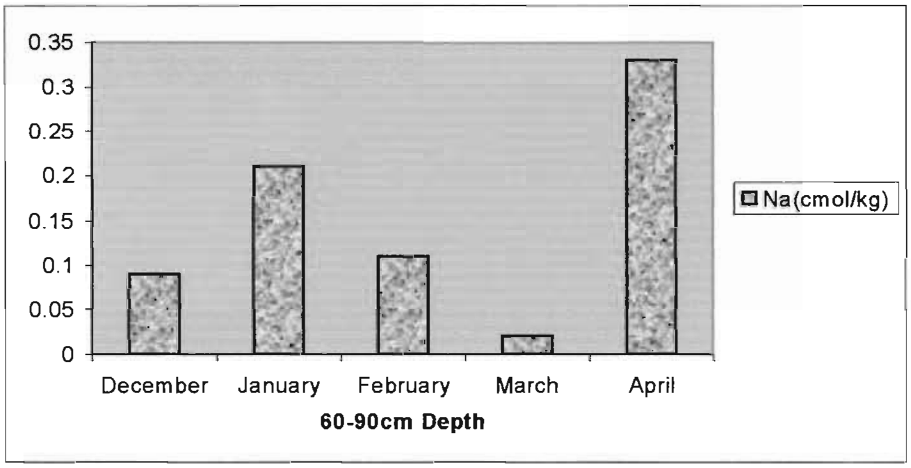

Figure 6.2d: Sodium trend of subsoil (60-90cm) at Orange river winery

CHAPTER 7

FATE OF THE ORGANIC COMPONENTS OF WINERY EFFLUENTS IN SOILS

7.1 GENERAL

The fate of the organic components of winery effluents in soils is discussed as a separate chapter here, because halfway through the study it became clear that the organic components of the effluents may constitute the most important pollutant in the effluents. Reference to the type of problem found in this study was found only in the publication of Levay (1995) and nowhere else in the literature that was available. It also became clear that management of problems caused by the organic fraction of winery effluents leaves a lot to be desired at the wineries studied.

7.2 ORGANIC SUBSTANCES FROM THE WINE MAKING PROCESS

According to Papini (2000) direct land application of stillage from brandy distilleries as irrigation water and as fertilizer has been cited as having the following effects on soil properties:

- Increase in soil pH.
- Increase in water and mineral salt retaining characteristics.
- Restoration and maintenance of soil fertility.
- Increase in soil microflora.

He further indicated that when organic matter is applied to soil, it could be respired as CO_2, converted into humic substances and/or incorporated into the soil biomass through the actions of soil microbes. He indicated that a potential big advantage of humic substances in soils is by means of improving soil structure and making the structure more stable. This will improve soil physical conditions and benefit root growth.

Chapman (1995b) shares the same sentiments as Papini, indicating that the soluble organic carbon in wastewaters produced by the wine industry would be extensively and rapidly removed from the soil solution by processes of adsorption and microbial metabolism. Part of the soluble organic carbon is adsorbed to the surfaces of clay and organic colloids as the wastewater moves through the topsoil during irrigation.

The overall removal of soluble organic carbon during each irrigation with wastewater involves both the removal of the organic substrates added by the wastewater and, to a lesser extent, the removal of soluble organic compounds produced by microbial metabolism.

In the present study no indication was found that the organic matter from winery effluents remained in the soil after irrigation or had any positive effect on soil physical conditions. In the case of five wineries (Olifants River, Stellenbosch, Robertson 1, Paarl 2 and Orange River) results clearly indicate that all organic matter contained in the effluents leaches right through the soil until a water table, which forms on top of an impermeable layer (e.g. a dense clay layer), is reached or until it leaches out of the soil.

This was first identified at the Robertson 1 winery during May 2000 when the profile descriptions were made. The profile was dug to a depth of 1,0 m, where the soil became very wet. Augering was done from the bottom of the profile pit to establish the nature of the underlying limiting layer. At 1,2 m a water table was reached. From the top of the soil to that depth the soil was light gray, almost white, sand. The moment the water table was reached, it abruptly changed to pitch-black sand with a very bad odour. It was clear that **all** the organic matter in the effluent had moved right through into the water table, where it underwent anaerobic decomposition.

During November 2000, i.e. long after the end of the vintage season and shortly before the beginning of the next season, the thickness of this black layer in the soil of the disposal site of the Robertson 1 winery was determined. It was found to stretch from 1,2 m below the surface to 1,8 m below the surface, i.e. it was 60 cm thick. A sample of this black soil was washed in the laboratory by adding water, stirring it and decanting the supernatant liquid. After repeated washing the result was white sand, identical to the soil above the water table, and a black liquid (Plate 7.1)

Plate 7.1: Samples of black soil from the water table at Robertson 1 winery (left) and white sand remaining after washing of a similar sample with water (right)

This clearly indicate that the black substances is water-soluble organic matter from the effluent. Investigations in a drainage ditch at the bottom end of the area on which the effluent is disposed, revealed large amounts of black gel-like organic coagulates in the ditch (Plate 7.2). This indicates removal of the organic matter from the disposal site by lateral subsurface leaching. Since the ditch empties into a nearby stream, this poses a real organic matter pollution hazard to the stream.

Plate 7.2: Samples of black material from the drainage ditch at the disposal site at Robertson 1 winery (left) and normal white soil from the disposal site (right)

The results from the investigations at this site can be summarized as follows:

a. The organic matter in the effluent moved right through the soil into the water table, from where it leached laterally to open water (ditch/ stream), constituting a pollution hazard.

b. Under normal circumstances no bad odour from the anaerobic decomposition was evident. Some smell occured only when the polluted layer was exposed.

c. The thick black layer prevailing in November indicates that the anaerobic decomposition is very slow.

d. The problem was found only beyond 1,2 m depth and was thus not identified during the previous "normal" samplings to 90 cm depth.

At the Stellenbosch winery a similar situation to that at Robertson 1 was found during the May 2000 investigation, but with the water table starting already at 80 cm below the surface. In this case lateral seepage is directly into a stream and not via a drainage ditch. Thick layers of black organic coagulates, similar to that at Robertson 1, but in larger quantities, were found in the stream not only where the water from the disposal site seeped into it, but also some distance downstream from the seepage point. Upstream from the point at which seepage from the disposal site into the stream takes place, none of this material was found in the stream, clearly indicating that pollution was from the disposal site of this winery. This confirmed the off-site pollution potential of this type of situation.

There are various similarities between the Robertson 1 and Stellenbosch wineries:

a. At both the effluent has high COD for certain periods.
b. At both disposal is done by means of sprinkler irrigation on kikuyu grass.
c. At both disposal is done on a bleached sandy soil with low nutrient retention and water storage capacities and excessive permeability.
d. At both the disposal area is near a stream or ditch leading to a nearby stream.
e. At both there is a marked slope towards the stream, favouring lateral seepage to the stream.

It is important to relate various aspects of the situations at the above two wineries to statements in the literature. These can be summarized as follows:

a. According to Chapman (1994) land application systems are ideally suited for the treatment of organic carbon contained in winery effluents, because the water in the soil system transports the organic contaminants to the microbial populations that are supported on a stationary medium. Chapman (1994) also stated that sufficient contact time is allowed for microbial treatment and removal of organic contaminants from the soil solution before it is displaced by the next application of wastewater. Such situations clearly do not prevail in the bleached sandy soils of the disposal sites of these two wineries.

The warning of Levay (1995) should rather have been heeded that highly permeable soils are often unsuitable, except at low application rates, because contaminants may be leached rapidly into groundwater before uptake or breakdown has occurred. This is exactly the situation at these two wineries.

b. According to Chapman (1983) it is essential to allow sufficient time between irrigations for the soil to become aerobic. Most importantly waterlogging must be avoided. None of these conditions are met at these wineries. Apart from the fact that the soils are clearly unsuitable for disposal of this type of effluent, **disposal is done on very small areas of land**. To get rid of all the effluent, much more effluent is applied than can be handled by these soils with their low water holding capacities. Irrigations are clearly too frequent and too much water is applied per irrigation. Chapman (1994) indicated that irrigation of vineyards may be the only option available in many areas due to lack of available land for other forms of effluent disposal on land, such as irrigation of cultivated pastures or ponding.

c. According to EPA (1998) wastewater should not be irrigated onto waterlogged areas or land within 50 metres of streams or wetlands and according to the South African Standards it may not be nearer than 100 metres from a stream. In the case of the Stellenbosch winery the disposal area is right next to a stream. The disposal area of the Robertson 1 winery may be a bit more than 50 metres from the stream, but there is a drainage ditch running from the disposal area into the stream.

d. According to EPA (1998) increases in the median total organic carbon 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. No measurements have been made in the present study, but there is no doubt that this value will be exceeded far in the case of the Stellenbosch winery and probably also for the Robertson 1 winery.

At the Orange River winery, where disposal is done by means of ponding on a deep, well-drained sandy soil, there was no sign of organic matter accumulation to a depth of 2,0 metres. At 2,1 metres a black layer, similar to that found at Robertson 1 was found in a water table. Here the bad smell of the black material was even worse and more intense than at the other sites. The thickness of the layer could not be determined. Again, the odour was no problem as long as the black layer is not exposed. Here the site is not close to a stream, but the water table must be connected to other water bodies, e.g. streams further away or boreholes, that may be polluted by it. This will have to be investigated in future. It must be noted that the effluent from this winery had extremely high COD values at certain times of the year. It may also be somewhat of a misnomer to speak about ponding on this highly permeable soil. Most of the water probably moves right through the soil to where it is "ponded" in the water table at 2,0 metres depth. According to Shelef & Kanarek (1995) one of the disadvantages of ponding is the possibility of groundwater contamination by seepage from the ponds, especially in sandy and loamy soils.

At the Olifants River winery, where disposal is done by ponding on an impermeable soil, the black layer was found in a water table close to the soil surface, immediately below a white, washed out layer of diatomaceous earth. Again this winery had effluents with extremely high COD values.

At Paarl 2 an interesting situation was found: There was no indication of a water table at the disposal site and no black material was observed in the subsoil. In the drainage ditch below the disposal site only an accumulation of salt was observed (as discussed earlier), but no black coagulates. But when investigations were conducted some 50 metres downstream in the stream into which the ditch drains, accumulations of black organic coagulates were unexpectedly found in the stream, instead of the salt accumulations that were expected. The fact that the effluents from this winery do not have high COD's and that no black material was found in the subsoil at the disposal site or in the drainage ditch makes this finding somewhat of an inexplicable mystery at this stage. It will have to be followed up, however.

The results of this study clearly indicate that the organic component of winery effluents is of no benefit to the soil on which it is applied. It is, in fact, not retained by the soil and poses a serious pollution hazard to adjacent water bodies.

It was beyond the scope of this study to determine the composition of the organic fraction, the distance to which pollution takes place in streams from the point where it enters the streams, its influence on aquatic life and measures and technologies to remove the organic material from the effluent before it is applied to the soil.

Aerobic decomposition in aerated ponds may be required. Research on the treatment of winery effluents has been conducted in the Department of Food Science at the University of Stellenbosch, but efforts to obtain copies of the relevant dissertation and other reports on the research have been unsuccessful. Observations at the effluent disposal sites of five brandy distilleries, at which similar unreported studies were conducted together with the studies at the ten wineries, revealed that at those sites the organic matter accumulated on top of the soil surface. The soil surface looked hydrophobic. This is completely opposite to the situation with winery effluents.

7.3 OBSERVATIONS REGARDING DIATOMACEOUS EARTH

No information was found in the literature concerning the disposal of effluent containing diatomaceous earth on soils. Bentonite, which is used for protein stabilization and clarification of wine, and diatomaceous earth, which is used for filtering of wine, are important components of winery wastes and wastewater.

Most of the wineries that dispose their effluent through irrigation usually separate the diatomaceous earth from the liquid waste before the effluent is used for irrigation. The wineries that dispose their effluent through ponding for evaporation release their effluent with the diatomaceous earth still in it.

In the present study effluent containing diatomaceous earth was applied by means of ponding at the Orange River and Olifants River wineries.At both wineries the first observation was that the diatomaceous earth does not enter the soil, but remains on top of the soil and forms a thick white layer. As it always stays on top of the soil and being light, wind can spread it to other areas, resulting in environmental pollution. The second observation was that diatomaceous earth does not retain any of the organic matter originating from the winemaking process.

The most striking example was at the Olifants River winery, where the pure white diatomaceous earth was on top of the soil surface, with the black layer of effluent organic matter directly underneath it. The transition between the two layers was abrupt. At the Orange River winery the white layer of diatomaceous earth was on top of the soil and the black effluent organic matter in the water table at a depth of two metres.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

8.1 CONCLUSIONS

The study confirmed that winery effluents pose definite pollution problems. A few specific cases of year-round problems were found, e.g. the high sodium levels at Paarl 2 winery, high potassium levels at the Berg River winery and the overall abnormal situation at the Olifants River winery, but in general unacceptable levels of pollutants in winery effluents are a seasonal phenomenon. This is not unexpected, in view of the nature of the enterprise. This means that special management and/or pre-treatment techniques will be required only during specific limited periods of the year.

Apart from the special cases mentioned above, the general pattern is that high levels of the main inorganic pollutants (sodium, phosphorus and potassium) occur just before the winemaking season (December/January) and just after it (March/April). In contrast high levels of organic pollutants (as reflected by high COD levels) occur during the winemaking period, as could be expected. This is a two or three month period during February to April. In a few cases it started in January.

When effluent is irrigated on soils, the biggest problem of winery effluents is the high organic matter levels in the effluents during the winemaking period. Most of the soils do not retain it, neither does it undergo aerobic decomposition in the soil, and it leaches through to the water table at the bottom of the soil profile and from there seeps through to nearby streams or groundwater bodies, thereby polluting the environment. This confirms the high off-site pollution potential of the organic matter.

The off-site pollution hazard of both the organic and inorganic pollutants is aggravated by the fact that disposal is in many cases done on highly leached sandy soils with very low nutrient retention, low water storage capacities, and excessive permeabilities.

In addition large volumes are generally disposed on very small areas, causing major over-irrigation, which aggravates leaching. Some of the disposal areas are also closer than the permissible distance to streams. It is clear that in most cases the wineries did not take cognizance of the warnings and guidelines given in literature.

At most of the wineries effluent management is in most respects very poor. A notable exception is the apparently good acidity management at almost all the wineries. Disposal management is poor, including in most cases poor soil and site selection for disposal. At most wineries these problems will have to be addressed **urgently**, especially to combat off-site pollution. The problem is that many of the wineries have little or no other alternatives available in terms of the quality of soil and area (size) of land available for disposal by means of irrigation of cultivated pastures or ponding, and even the locality of the site. Unfortunately this may mean that they will have to change to disposal on larger areas by irrigating vineyards (or other crops), which Chapman (1994) indicates as the only other option available in many areas, or expensive pre-treatment of effluent before its disposal. The possible use of reed beds to purify effluent is presently being investigated at the ARC Institute for Fruit, Wine and Vine.

In the study it was found that there are many similarities between wineries. But it must be emphasized that there are also major differences between them, such that the situation each winery needs to be investigated separately, its specific problems analyzed and appropriate measures identified to counteract or eliminate these problems.

Guidelines can be given or developed for individual factors, but a single overall recipe cannot be prescribed. Good guidelines are available in the literature and it is really not necessary to develop new ones for most of the factors. A notable exception is the lack of information in the literature on the problems associated with the leaching of the (water-soluble) organic fraction of the winery effluents and its off-site pollution potential. Better guidelines and treatment techniques should be developed for this.

From the study it was clear that deep, highly permeable, sandy soils (especially those with E horizons) are not suitable for disposal of winery effluents, either by means of irrigating pastures or by ponding.

8.2 RECOMMENDATIONS

It is recommended that:

a. A copy of this dissertation is made available to the managers of each of the 10 wineries that were willing to cooperate in this study. The mistake is often made not to give feedback to the people who cooperated in a study, thus making them unwilling to cooperate again in future.
b. The code for his/her winery is made known to the manager of each cooperating winery individually and confidentially so that he/she can see what the findings for his/her specific winery was. A discussion session can then be arranged at each winery separately in order to look at weak points and possible solutions for that winery in the form of close consultation with the manager.
c. A practical semi-popular booklet be compiled, for use by winery managers, giving guidelines and suggestions regarding:
    i. Management systems to improve effluent quality.
    ii. Appropriate and sustainable effluent disposal systems.
    iii. Selection of suitable soils and terrain for effluent disposal.

    Guidelines and information from literature, practical knowledge of various persons involved in advising wineries on effluent management and disposal, and information from this study should be used in the compilation of such booklet.
d. Studies of the situation regarding effluent quality, effluent disposal and disposal site characteristics be made at as many wineries as possible as soon as possible. Effluent quality should be monitored on a monthly basis for at least a six month period from December to May. There is an urgent need to study effluent quality at a selection of wineries also for the period June to November.

Phosphorus **must** be included in the determinations made on effluents. If time, manpower and laboratory facilities are problems, it is recommended that soil sampling is done only once and that this is done in **April**. This should be accompanied by a full profile description. In deep sandy soils studies should be done to at least 2,5 m depth unless a limiting layer is found at a shallower depth.

e. A study be undertaken urgently to determine how far downstream the organic pollution spread at the Robertson 1 and Stellenbosch wineries and its influence on the aquatic life. This could serve as indicator of the potential impacts of similar situations at other wineries. The situation at the Orange River winery regarding the organic matter accumulation in the deep subsoil should also be investigated.

f. The apparent regional patterns regarding COD be further investigated and attempts made to identify the reasons for, *inter alia*, (i) the very high COD values found at the Northern Cape wineries and (ii) the relative low COD values for the wineries from the Paarl region.

REFERENCES

ASSOCIATION OF OFFICIAL ANALYTICAL CHEMISTS, 1990. Official methods of analysis. Association of Official Analytical Chemists, Arlington, Virginia.

BATCHELOR, A., 1998. The treatment of septic tank effluent. CSIR Division of Water, Environment & Forestry Technology, Pretoria.

BLOEM, A.A., 1992. Kriteria vir die aanpassing van die ontwerp en bestuur van oorhoofse besproeiingstelsels by die infiltreerbaarheid van gronde. M.Sc. dissertation, Univ.Pretoria.

BOND, W.J., 1998. Effluent irrigation - an environmental challenge for soil science. *Australian Journal for Soil Residues* ***36****, 543-555.*

BRUVOLL, A. & IBENHALT, K., 1997. Future waste generation: Forecasts on the basis of a macro-economic model. *Resource, Conservation and Recycling* ***19****, 137-149.*

CHANG, N. & LIN, Y.T., 1997. An analysis of recycling impacts on solid waste generation by time series intervention modeling. *Resource, Conservation and Recycling* **19**, 165-186.

CHAPMAN, J.A., 1983. *Guidelines for wastewater irrigation*. Environment Protection Authority, Adelaide, South Australia.

CHAPMAN, J.A., 1994. Impact of winery effluent on soil. In: LEE, T.H. (ed.) Proceedings of the Sustainable Wastewater Management Seminar for the Australian Wine Industry, Vol. 1, 29-36. Australian Wine Research Institute, Adelaide. South Australia.

CHAPMAN, J.A., 1995a. Land disposal of winery and distillery wastewaters. Ph.D. thesis. Department of Soil Science, University of Adelaide.

CHAPMAN, J.A., 1995b. Removal of soluble organic carbon from winery and distillery wastewater by application to land. In: LEE, T.H. (ed.). Proceedings of the Sustainable Wastewater Management Seminar for the Australian Wine Industry, Vol. 1, 39-45. Australian Wine Research Institute, Adelaide.

CHAPMAN, J.A., 1996. Cleaner production for wine industry. South Australian Wine & Brandy Ass. Inc., Magill, SA.

CLESCERI, L. S., GREENBERG, A. E. & EATON, A. D., 1998. Standard methods for the examination of water and wastewater (20th ed.). APHA-AWWA-WEF. Washington.

COMMONWEALTH OF AUSTRALIA, 1995. National water quality management strategy: Draft effluent management guidelines for wineries and distilleries. Department of Conservation and Natural Resources: Commonwealth of Australia, Adelaide.

CONOLLY, R., 1975. Development of the Sydney region waste management plan. In: KIROV, N.Y. (ed.) Waste Management, Control, Recovery and Reuse, pp.77-79.Ann Arbor Science, Ann Arbor.

DEPARTMENT OF ENVIRONMENTAL AFFAIRS AND TOURISM, 1997. White paper on environmental management policy for South Africa 385, 18164. DEAT, Pretoria.

DUNCAN, J.R., BRADY, D. & STOLL, A.D., 1994. The use of yeast biomass and yeast products to accumulate toxic and valuable heavy metals from wastewater. Department of Biochemistry and Microbiology, Rhodes University.

ELOFF, J.F., 1971. Studies oor die toeganklike fosforstatus van sekere Vaalharts-gronde. M.Sc.Agric.dissertation, UOFS.

ELOFF, J.F. & LAKER, M.C., 1978. Phosphorus studies on Vaalharts soils. II. The evaluation of method of extraction, by correlation of results with various wheat crop parameters. *Agrochemophysica* **10**, 19-23.

ENVIRONMENTAL PROTECTION AGENCY, 1997. Draft Planning and Environmental Management guidelines for Wineries in South Australia. South Australian Wine and Brandy industry Ass.inc. Magill,SA.

ENVIRONMENT PROTECTION AGENCY, 1998. Environmental management code of practice for wineries and distilleries in South Australia. Consultation draft. South Australia Wine and Brandy Industry Ass. Inc., Magill, SA.

GAJDOS, R., 1998. Bio-conservation of organic waste by the year 2010 to recycle elements and save energy. *Resource, Conservation and Recycling* **23**, 67-87.

GLAETZER, S.J., 1998. Environmental management case study – Winery. Group Environmental Engineer for Mildara Blass Limited, Sturt Highway, Nuriootpa.

HAZELL, P., 1997. Draft planning and environmental management guidelines for wineries in South Australia. Unpublished report. South Australian Wine and Brandy industry Association.inc. Magill, SA.

HAZELL, P., 1998. Monitoring and control of environmental impacts associated with winery effluent in South Australia. *Proc. 2nd International Specialized Conference on Winery Wastewaters, Bordeaux,* pp.53-60.

HURUVF, N., 1998. Wastewater reuse-regional and economic consideration. *Waste Water Management* **23**, 57-66.

JOLLY, D.R.P., 1974. Experience with a winery waste treatment plant. In: KIROV, N.Y. (ed.) Waste Management, Control, Recovery and Reuse, pp.24-27. Ann Arbor Science, Ann Arbor.

LAKER, M.C., 2001. Soil compaction and crusting: Effects and amelioration. Draft paper for SASA symposium on soil compaction, Durban, August 2001.

LAKER, M.C. & VANASSCHE, F.M.G., 2001. Alleviation of soil crusting in a citrus orchard by means of a coal-derived humic product. Programme and Extended Abstracts, Joint Congress 2001, pp.265-266. Soil Sci. Soc. S. Afr., Pretoria.

LEESON, L.D., 1995. Environmental Law. Pitman, London.

LEVAY, G., 1995. Effluent management for wineries and distilleries. The Australian Regulatory Framework and Code of Practice. Ian Wark Research Institute, University of South Australia, Adelaide.

Malher, C.F. & Oliveira, F.J.P., 1998. An environmental monitoring proposal for landfill management. In: SIVAKURA, M. & CHOWDHURRY, R.N. (eds.) Environmental Management: Engineering the water environment and geo-Environment, pp, 47-51. Elsevier, Amsterdam.

MIDDLEBROOKS, E.J., 1995. Upgrading pond effluents: an overview. *Water Science and Technology* **31**, 353-368.

PAPINI, A.G., 2000. Land treatment of grape processing effluents near Robertson, Western Cape. Masters dissertation, Department of Geological Science, University of Cape Town.

PARKES, B., 1974. Disposal of liquid wastes from a large coastal city. In: KIROV, N.Y. (ed.) Waste Management, Control, Recovery and Reuse. Ann Arbor Science, Ann Arbor.

RHOADES, J.D., 1989. Effects of salts on soils and plants. NWC. Newark. Delaware.

ROBERTSON, S. & KIRSTEN., 1993. Water and wastewater management in the Wine industry. WRC Report No. 416/1/99. Water Research Commission, Pretoria.

ROZZI, A., MALPEI, F. & PADOANI, L. 1998. Estimate of polluting loads in effluents of Italian North east wineries. *Proc. 2nd International Specialized Conference on Winery Wastewaters,* Bordeaux, 33-40.

RYDER, R.A., 1995. Aerobic pond treatment of winery wastewater for vineyard irrigation by drip and spray system in California. *Rev. Fr. Oenol.* **152**, 22-24.

SAIDAM, M.Y., RAMADAN, S.A.& BUTLER, D., 1995. Upgrading waste stabilization pond effluents by rock filters. *Water Science and Technology* **31**, 24-27.

SHELEF, G & KANAREK, A 1995. Wastewater treatment by stabilization pond. *Water Science and Technology* **31**, 84-88.

SHEPHERD, H.L. & GRISMER, M.E., 1997. Vineyard and winery management. Constructed wetlands: An alternative for treating winery wastewater**.** Journal Sakonnetis Rooster. Davis.

SOIL CLASSIFICATION WORKING GROUP, 1991. Soil classification: A taxonomic system for South Africa. Memoirs on the Agricultural Natural Resources of South Africa No. 15. Dept. of Agricultural Development, Pretoria.

STEYL, I., 1996. Solid waste in rural Stellenbosch: Nature, extent and handling strategies. Masters dissertation, Department of Geography and Environmental Studies, University of Stellenbosch.

STROHWALD, N.K.H., 1993. An investigation into the application of the Aduf process to fruit processing effluent. Membratek, Pretoria.

TCHOBANOGLOUS, G., THEISEN, H. & ELIASSEN, R., 1977. Solid waste: Engineering principles and management issues. McGraw-Hill, New York.

THE NON-AFFILIATED SOIL ANALYSIS WORK COMMITTEE, 1990. Handbook of standard soil testing methods for advisory purposes. Soil Sci. Soc. S. Afr., Pretoria.

TRY, P.M. & PRICE, G.J., 1995. Sewage and Industrial effluents. In: HESTER, R.E. & HARRISON, R.M. (eds.) Waste treatment and disposal, pp.17-19. The Royal Society of Chemistry, Cambridge.

VAN SCHOOR, L.H., 2000. Bestuursopsies om negatiewe omgewingsimpakte by wynkelders te minimaliseer. *Wynboer,* July 2000, 97-100.

VAN SCHOOR, L. H., 2001a. Omgewingswetgewing in die wingerd- en wynbedryf. *Wynboer,* January 2001, 114-117.

VAN SCHOOR, L. H., 2001b. A formula for quantification and prioritisation of negative environmental impacts in the wine industry. *Wynboer,* May 2001, 100-102.

VAN SCHOOR L.H. & MULIDZI, A.R., 2001. Ondersoek na die omgewingsimpak en gevolglike bestuur van uitvloeisel vanaf brandewyn en spiritus stokerye en wynkelders. Unpublished report, Winetech, Cape Town.

WATER ACT, 1998. General Authorisations in Terms of Section 39 of the National Water Act, 1998 (Act No. 36 of 1998). Government Gazette No. 20526. Department of Water Affairs and Forestry, Pretoria.

WOOD, M.G.; GREENFIELD, P.F.; HOWES, T., JOHNS, M.R. & KELLEY, J., 1995. Computational fluid dynamic modelling of wastewater ponds to improve design. *Water Science and Technology* **31**, 111-118.

APPENDICES

Appendix 4.1a Description for a modal profile from the disposal area at Paarl 1

Classified by: R and L	Date: 11 May 2000	Locality: Paarl 1	Profile no: 1
Terrain morp unit:Foot slope	Slope (%): 2	Slope form: Plain	Aspect: South East

Master horizon	Ap	B1	B2	B3
Depth (cm)	0-10cm	10-50cm	50-80cm	80 - 100+
Colour	7.5YR6/2 (D)	7.5YR4/2 (D)	7.5YR3/2(D)	7.5YR3/2 (D)
Structure	Fine-med weak-modera sub-ang blocky	Coarse-mod prismatic breaking to stro ang blocky	Moderate-strong prismatic-breaking into strong moderat angular blocky	Moderate prisimatic - strong moderate angular blocky
Coarse fragments	None	None	None	Some fine coarse gravel
Transition	Clear-Wavey	Gradual	Gradual	
Diagnostic hor/mat	Orthic A	Prismacutanic B	Prismacutanic B	
Moisture content	Dry	Dry	Dry	
Roots	Abundant massive &turn sharp at bot	Rare	Rare	Dead roots
Mottles	None	None	Dull-yellow(rust muscles in rootchannels)	As for B2
Swelling	None	Strong cracks	None	None
Other features	None	Thick light colour clay skins washed, signs of clay dispersion.		

Soil form: Sterkspruit **Soil family: Hermon**

Appendix 4.1b Particle size distribution of the soil from the disposal area at Paarl 1

Depth (cm)	% Clay	% Silt	%Fine sand	%Medium sand	% Coarse sand	% Stone
0 - 30	18.4	19.6	23.6	16.2	22.2	15.5
30 – 60	25.4	19.2	24.2	14.4	16.8	17.5
60 - 90	17.2	9.8	29.0	17.2	26.8	11.3

Appendix 4.2a. Description for a modal profile from disposal area at Paarl 2

Classified by: R and L	Date: 11 May 2000	Locality: Paarl 2	Profile no: 2
Terrain morp unit:Foot slope	Slope (%): 5	Slope form: Convex	Aspect: South

Master horizon	Ap	E	B1	G
Depth (cm)	2.5-15cm	15 - 30cm	30 - 40cm	40 - 120+
Colour	7.5YR5/4(m) 7/2 (d)	7.5YR5/4(m) 7/2 (d)	10YR 6/3(m) 7.5YR 6/2(d)	
Structure	Single grain	Single grains(moist) and massive(dry)	Massive	
Coarse fragments	Rare small stones	Rare small stones	Rare small stones	
Transition	Clear	Abrupt	Clear	
Diagnostic hor/mat	Orthic A	E- horizon	Soft plinthic	Non diagnostic horizon
Moisture content	Moist	Moist	Wet	
Roots	Frequent(not in good condition)	Frequent poor condition (dead)	Rare	
Mottles	None	None	Abundant chroma mostly red mottle and iron concentration	
Swelling	None	None	None	
Other features	None	None	None	

Soil form: Longlands **Soil family: Ermelo**

Appendix 4.2b Particle Size distribution of the soil from the disposal area at Paarl 2

Depth (cm)	% Clay	% Silt	%Fine sand	%Medium sand	% Coarse sand	% Stone
0 – 30	9.2	5.8	21.2	20.4	43.4	41.6
30 – 60	10.8	4.1	11.8	16.1	57.2	17.4
60 - 90	32.8	3.4	12.4	11.2	40.2	28.8

Appendix 4.3a. Description for a modal profile from the disposal area at Stellenbosch

Classified by: R and L	Date: 15 May 2000	Locality: Stellenbosch	Profile no: 3
Terrain morp unit: Foot slope	Slope (%): 4	Slope form: Concave	Aspect: South

Master horizon	Ap	E1	E2
Depth (cm)	10 - 40cm	40 - 75cm	75cm+
Colour	7.5YR3/2 (m)	7.5YR 5/2(m)	7.5YR 6/1(w)
Structure	Apedal	Apedal	Apedal
Coarse fragments	Few stones	Few fine gravel	Fine gravel
Transition	Abrupt	Gradual	
Diagnostic hor/mat	Orthic/Humic	E	E
Moisture content	Slightly moist	Wet	Wet
Roots	Frequent fine roots	Very rare	Very rare
Mottles	none	None	None
Swelling	none	None	None
Other features	none	None	None

Soil form : Fernwood **Soil family: Waterton**

Appendix 4.3b Particle Size distribution of the soil from the disposal area at Stellenbosch

Depth (cm)	**% Clay**	**% Silt**	**%Fine sand**	**%Medium sand**	**% Coarse sand**	**% Stone**
0 – 30	9.8	11.2	21.6	17.0	40.4	35.6
30 – 60	22.0	7.6	16.6	12.8	41.0	52.9
60 - 90	19.2	6.2	17.4	13.6	43.6	57.9

Appendix 4.4a. Description for a modal profile from the disposal area at Robertson 1

Classified by: R and L	Date: 12 May 2000	Locality: Robertson 1	Profile no: 4
Terrain morp unit: Lower foot slope	Slope (%): 1	Slope form: Plain	Aspect: West

Master horizon	A	E1	E2
Depth (cm)	3 - 25cm	25 - 60cm	60 – 100cm
Colour	7.5YR7/2(d) 5/3(m)	10YR 7/1(d) 10YR 6/2(m)	10YR 5/2 (m)
Structure	Massive single grain	Single grain	Single grains Massive-dry
Coarse fragments	None	None	None
Transition	Gradual	Clear	
Diagnostic hor/mat	Orthic A	E	E
Moisture content	Dry	Moist	Moist
Roots	Rare to frequent	Rare	Very rare
Mottles	None	None	None
Swelling	None	None	None
Other features	None	None	

Soil form: Fernwood **Soil family: Penicuik**

Appendix 4.4b Particle Size distribution of the soil from the disposal area at Robertson 1

Depth (cm)	% Clay	% Silt	%Fine sand	%Medium sand	% Coarse sand	% Stone
0 – 30	5.8	4.0	24.5	48.1	17.6	13.0
30 – 60	3.9	3.6	29.1	48.6	14.8	6.1
60 - 90	2.6	3.0	39.5	47.3	7.6	0.3

Appendix 4.5a. Description for a modal profile from the disposal area at Worcester

Classified by: R and L	Date: 15 May 2000	Locality: Worcester	Profile no: 5
Terrain morp unit: Valley bottom	Slope (%): 1	Slope form: Plain	Aspect: East

Master horizon	Ap	C1	C2
Depth (cm)	0 - 27cm	27 - 55cm	55 - 100+
Colour	5YR3/2(m)	5YR3/2 (m)	7.5YR6/3
Structure	Single grains	Single grains	Single grains
Coarse fragments	Rare small stones	Frequent small to med stones	Abundant fine gravels and stones varying from small-big
Transition	Clear	Clear	
Diagnostic hor/mat	Orthic/Humic	Stratified alluvial	Stratified alluvial
Moisture content	Moist	Moist	Moist
Roots	Abundant in top 10cm	Rare to frequent	Rare to frequent
Mottles	None	None	None
Swelling	None	None	None
Other features	None	None	None

Soil form: Dundee **Soil family: Mtamvuna**

Appendix 4.5b Particle Size distribution of the soil from the disposal area at Worcester

Depth (cm)	% Clay	% Silt	%Fine sand	%Medium sand	% Coarse sand	% Stone
0 – 30	2.8	3.6	30.9	47.3	15.4	2.6
30 – 60	3.1	5.1	31.8	45.6	14.4	4.3
60 - 90	3.6	5.3	19.7	52.6	18.8	2.3

Appendix 4.6a. Description for a modal profile from the disposal area at Berg river

Classified by: R and L	Date: 16 May 2000	Locality: Berg river	Profile no: 6
Terrain morp unit: Lower midslope	Slope (%): 9	Slope form: Convex	Aspect: South

Master horizon	A	B	C1	C2
Depth (cm)	0 - 15cm	15 - 42cm	42 - 70cm	70 – 100+
Colour	10YR 6/3(d)	10YR 6/4 (d)	Predominantly yellow	Predominantly yellow
Structure	Moderate-fine crumb structure	Moderate-strong-fine-medium-angular-sub-angular blocky	As for B. Shale suprolite	Weathering shale
Coarse fragments	Few small stones	Rare to frequent small-medium stones	Some quarts gravel	Quarts gravel
Transition	Clear	Clear	Clear	
Diagnostic hor/mat	Orthic A	Pedocutanic B	Suprolite	Suprolite
Moisture content	Dry	Dry	Dry	Dry
Roots	Frequent unhealthy roots	Frequent dead roots	Very rare	Very rare
Mottles	None	Rare mottles associated with weathering rocks	Frequently bright red mottles associated with weathered shale	Dull yellow and brown associated with weathering shale
Swelling	None	None	None	None
Other features	None	Some indication of washed dispersed clay	None	Dense soft weathered shale

Soil form: Swartland **Soil family: Riebeeck**

Appendix 4.6b Particle Size distribution of the soil from the disposal area at Berg river

Depth (cm)	% Clay	% Silt	%Fine sand	%Medium sand	% Coarse sand	% Stone
0 – 30	**29.2**	**26.4**	**20.8**	**8.2**	**15.4**	**59.2**
30 – 60	**37.4**	**22.4**	**17.0**	**7.0**	**16.2**	**64.2**
60 - 90	**19.6**	**19.0**	**17.0**	**12.2**	**32.2**	**68.7**

Appendix 4.7a. Description for a modal profile from the disposal area at Olifants river

Classified by: R and L	Date: 16 May 2000	Locality: Olifants river	Profile no: 7
Terrain morp unit:	Slope (%):	Slope form:	Aspect:

Master horizon	M1	M2	M3	Suprolite(dorbank that is breaking up)	Weathered shale
Depth (cm)	0 - 15cm	15 - 17.5cm	17.5 - 30cm	30 - 47cm	47 - 1m+
Colour	7.5YR5/2(m)	7.5YR 6/4(w)	7.5YR3/2		
Structure	Apedal	Apedal (single grains)	Apedal		
Coarse fragments	Grape seeds	None	None		
Transition	Abrupt	Abrupt	Clear		
Diagnostic hor/mat	Man made horizon	Man made soil layer	Man made soil layer		
Moisture content	Moist	Wet	Wet		
Roots	None	None	None		
Mottles	None	None	None		
Swelling	None	None	None		
Other features	None	None	None		

Appendix 4.7b Particle Size distribution of the soil from the disposal area at Olifants river

Depth (cm)	**% Clay**	**% Silt**	**%Fine sand**	**%Medium sand**	**% Coarse sand**	**% Stone**
0 – 30	6.0	5.8	62.2	19.8	6.2	2.3
30 - 60	5.6	5.8	52.6	22.8	13.2	14.2

Appendix 4.8a. Description for a modal profile from the disposal area at Orange river

Classified by: R and L	Date: 18 May 2000	Locality: Orange river	Profile no: 8
Terrain morp unit: Flat disposal pond	Slope (%):	Slope form:	Aspect:

Master horizon	A	E1	E2	E3
Depth (cm)	10 - 25cm	25 - 50cm	50 - 88cm	88 - 120+
Colour	5YR3/6(s.m)	5YR5/4(m) 5YR6/3(d)	5YR5/3(m) 5YR6/3(d)	5YR6/2(d) 5YR4/4(m)
Structure	Single grains	Single grains	Single grains	Single grains
Coarse fragments	Rare to frequent coarse gravel	Frequent fine gravel	Some fine gravel	Rare-frequent fine gravel
Transition	Clear	Clear	Gradual	
Diagnostic hor/mat	Orthic	E	E	E
Moisture content	Slightly moist	Moist	Moist	Moist
Roots	Few roots	None	None	None
Mottles	None	None	None	None
Swelling	None	None	None	None
Other features	Pockets of organic matter	None	Some black sports	Some black spots

Soil form: Fernwood **Soil family: Hopefield**

Appendix 4.8b Particle Size distribution of the soil from the disposal area at Orange river

Depth (cm)	% Clay	% Silt	%Fine sand	%Medium sand	% Coarse sand	% Stone
0 – 30	4.3	2.3	42.9	25.8	24.7	17.1
30 – 60	6.7	1.8	35.2	25.9	30.4	18.6
60 - 90	5.6	2.1	28.9	27.0	36.4	48.6