# LEARNER GUIDE

# Water Quality

## Level 4



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| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Title:** | | **Manage Water Quality Parameters** | | | | | |
| **Applied Title:** | | **Manage Water Quality Parameters** | | | | | |
| **Field:** | | Agriculture and Nature Conservation | | | | | |
| **Sub-Field:** | | Primary Agriculture | | | | | |
| **SETA (SGB):** | | AgriSETA | | | | | |
| **Skills Area:** | | Water Quality | | | | | |
| **Context:** | | Citrus Production | | | | | |
| **US No:** | 116322 | **Level:** | 4 | **Credits:** | 3 | **Notional Hours:** | 30 |
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Supported by:

**Unit standard alignment and assessment tool development:**
Cabeton Training and Development

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# Directions

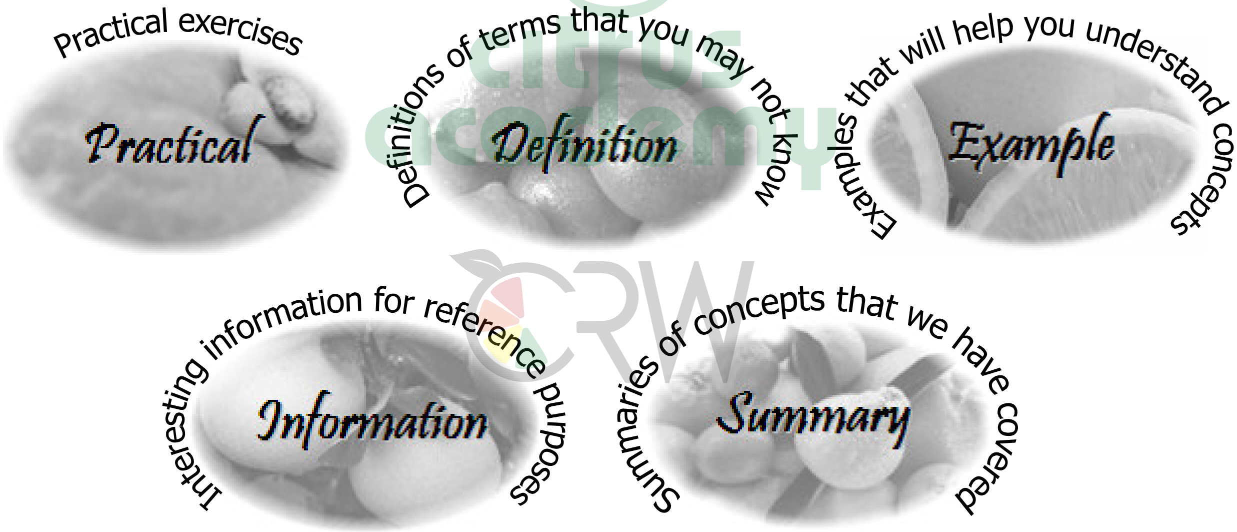
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

The learner guide is accompanied by a Learner Assessment Guide. Please ensure that you have access to this guide as well.

The learner guide was designed to be used by a learner during the presentation of a skills program based on the unit standard, and to be kept afterwards by the learner for reference purposes. The learner assessment guide was designed to be completed during and after the presentation of the skills program, and forms part of the assessment process.

Although this learner guide contains all the information required for attaining competency in this unit standard, references to additional resources, both printed and electronic, are provided for further study by the learner.

Information in boxes is indicated by tags that show:



# Introduction

## 1. Purpose

The learner achieving this unit standard will be able to maintain water quality and adjust systems to ensure appropriate water quality. In addition they will be well positioned to extend their learning and practice into other areas of agriculture and water management.

Learners will gain specific knowledge and skills in maintenance of water quality and will be able to operate in an animal and plant production environment implementing sustainable and economically viable production principles.

They will be capacitated to gain access to the mainstream agricultural sector, in animal and plant production, impacting directly on the sustainability of the sub-sector. The improvement in production technology will also have a direct impact on the improvement of agricultural productivity of the sector.

## 2. Learning Assumed to Be in Place

It is assumed that the learner has successfully completed the unit standards listed below:

| ***NQF Level*** | ***Unit Standard Number*** | ***Unit Standard Description*** |
|---|---|---|
| NQF3 | Literacy and Numeracy | |
| 3 | 116212 | Maintain water quality parameters |
| 2 (F) | 116064 | Recognise and identify the basic functions of the ecological environment |
| 3 | 116275 | Apply routine maintenance and servicing plans and procedures |

# Revision of Level 3

## 1. Quality Assurance Systems

- Quality management involves identifying the factors that impact on quality, determining the ideal value for each factor, putting in place systems to maintain the factors, and monitoring the factors.
- The level of quality management depends on how critical quality is and the given quality of what is being managed.
- Water quality management systems are a comprehensive approach to water quality management.
- In citrus production large volumes of water are used and water quality requirements are neither extremely specific nor extremely critical to successful production.
- Water quality management in citrus focuses on measuring and monitoring water quality.
- In citrus production, the most important equipment that relates to water quality management is the irrigation system.
- Recordkeeping for water quality management must keep track of the current water quality, historical water quality, actions to improve water quality, schedules for those actions, and the outcome of those actions.
- Improvements to the water quality management system are made to the administration of the system, and by integrating new technology where appropriate.

## 2. Critical Control Points

- The three major critical control points in a water quality management system are where water is received on the farm, where water is used on the farm, and where water leaves the farm.
- The quality of the water received on the farm is measured to determine what steps can be taken to improve the quality, and monitored to detect changes in the quality.
- Three minor critical control points are involved where water is used on the farm, being storage, filtration and irrigation.
- Water must be protected from contamination while in storage.
- The effectiveness of the filtration process must be measured and monitored as this prevents clogging of emitters and protects the irrigation system.
- The effectiveness of the irrigation system is measured mostly through ensuring that the delivery rate of emitters is within the prescribed limits, which is an indication of the degree of clogging.
- The quality of water leaving the farm must not be worse than that of the water that was received on the farm. Every water user has the responsibility of ensuring that the water quality of the waterway is maintained.

## 3. Water Quality Factors

- Physical water quality is determined by the suspended solids that is in water, which is made up of clay, silt, sand and organic debris, aquatic plants and animals, rust and scales, waste and debris, and lubricant residues.

- Physical water quality impacts on the performance of the irrigation system, because the material that is suspended in water clogs emitters and pipes.
- In a micro-irrigation system, the emitters that are commonly used are drippers and micro-jets. The emitters have very small openings that can be clogged easily by any suspended solid.
- In a macro-irrigation system, seeds and silt is the most significant suspended material.
- Physical water quality is improved through filtration, which removes the suspended solids from the water by trapping it in the filter system.
- Chemical water quality refers to those invisible attributes of water that can only be measured through analysis.
- Chemical factors that impact on the quality of water for agricultural use include total soluble salts (TDS), pH, calcium, magnesium, sodium, chloride, bicarbonates, boron, and iron, manganese and sulphides.
- This is the most important of all the chemical water quality factors, because the total dissolved salts influences plant production, soil productivity, and irrigation system efficiency.
- pH is a measurement of the level of acidity or alkalinity of water. The optimum pH of soils for optimal citrus production is 6.5 to 7 as measured in a soil-water suspension.
- Citrus can tolerate a fair amount of sodium (Na) in the water. The negative effect of sodium is more severe in the soil and affects citrus indirectly.
- Chemical water quality affects plant production, the sustainability of soil productivity, and the efficient operation of the irrigation system.
- The affect of water quality factors on production can be seen in suboptimal yields, decreasing fruit size, erratic blossom, and a decrease in the number of fruit.
- The most important soil characteristics that can be caused or affected by water quality are salinity, crusting, and leaching.
- Salinity is caused mostly by high TDS in water. Salinisation is the second biggest cause of the loss of productive soils after erosion.
- Crusting refers to when the top few millimetres of the soil becomes much harder and more brittle than the soil immediately underneath it, and inhibits water penetration.
- The leaching requirement is the extra volume of water required to leach salts left from the previous irrigation from the root-zone.
- The efficiency of an irrigation system is determined by the degree of corrosion, the deposits, or scale, in the piping, and the blockages of the emitters.
- Managing chemical water quality focuses on monitoring over time in order to detect deterioration in the water quality.
- Biological quality of water usually refers to the dissolved organic carbon (DOC) content and its effect on living organisms in the water or on those that consume water.
- The biological factors and processes that influence water quality are photosynthesis, the nitrogen cycle, decomposition, and organic load.
- The main impact of biological water quality on the irrigation system is the clogging of emitters.

- There are not many water quality requirements for citrus production and the ranges for these parameters are very broad.

- Compared to other crops citrus can tolerate more salts in the water.

## 4. Recordkeeping

- Monitoring and recording water quality is an essential part of water quality management.

- The physical attributes of a waterway can be an indicator of the water quality.

- Physical water quality is measured by assessing the emitter delivery rate and suspended solids.

- The delivery rate is measured as the number of litres water passed through an emitter in one hour, which varies depending on the type and size of the emitter. The expected delivery rate is specified for all commercial emitters.

- Measuring the suspended solids in irrigation water is done by taking water samples before and after the filter system, filtering the samples through filter paper, and weighing and inspecting the residue after it has been dried.

- Results of delivery rate and suspended solid measurements are recorded and compared with previous results.

- Chemical water quality is measured by taking water samples and conducting tests and analysis.

- Water quality information is interpreted in conjunction with other production information.

- Abnormalities in water quality data may be the result of contamination.

- Water contamination is mostly caused by leaching, poor waste management and poor sewerage disposal.


**Micro-Jets and Drippers**

Micro-jets and drippers are devices developed to deliver small volumes of water over a limited area in order to improve the efficiency of water usage. Micro-jets and drippers are the **emitters** in the irrigation system.

**Salts**

Salts not only refer to table salt (sodium chloride), but any compound of acids and bases, such as calcium sulphate, potassium nitrate, magnesium chloride, etc. In these salts, calcium, potassium and magnesium are bases, and the salts are formed when acids like sulphuric acid, nitric acid and hydrochloric acid are added. Water with a high salt concentration, also referred to as high total dissolved salts (TDS), is referred to as **saline**.

**pH**

pH indicates the acidity or alkalinity of any substance, in this case water, on a scale of 1 to 14. pH can range from 1 (extremely acidic) to 14 (extremely alkaline). A pH value of 7 is neutral. Plant sap has a pH of 5.8 and the pH of human blood is almost 7. A substance with a low pH is called **acidic**. A substance with a high pH is called **alkaline**.

**Half-Life**

The half-life of a chemical is the time taken for it to lose half their strength, or the period of time that must elapse for an agrochemical to lose half of its original toxicity.

**Reverse Osmosis**

A water treatment process whereby dissolved salts, such as sodium, chloride, calcium carbonate, and calcium sulphate may be separated from water by forcing the water through a semi-permeable membrane under high pressure.

**Distillation**

The purification of salt or brackish water by removing the dissolved salts though allowing the water to evaporate and then condensate against a smooth surface, such as glass, from where it is collected again.

**Deionisation**

Removal of ions from water by exchange with other ions associated with fixed charges on a resin.

**Fertigation**

Fertigation refers to the practice of applying fertilisers through the irrigation system. Drip irrigation systems are most suited to fertigation.

**Electrical Conductivity (EC)**

The electrical conductivity of water refers to its ability to conduct electrical current. The more salts dissolved in the water, the higher the ability to conduct current, and hence the EC value.

**Demineralised Water**

Demineralised water refers to water from which the dissolved salts (minerals) have been removed. Car battery water is for example demineralised. In chemical laboratories, all water that is used, even for washing the equipment, is demineralised.

**Chemigation**

Chemigation is the process whereby water-soluble chemicals, such as fertilisers, pesticides, cleaning agents and even herbicides, are applied through the irrigation system.

**Critical Control Point**

A critical control point is a physical point in a system, in this case the water delivery system, that is critical to the overall performance of the system, and at which the performance can be measured and controlled.

**Sodium Adsorption Ratio (SAR)**

The sodium adsorption ratio (SAR) is a measurement of the relation between sodium and calcium plus magnesium in the water, as well as in an extract of the soil.

The higher this value, the more sodium is present and the greater the hazard of degradation of the physical properties of the soil. Soils with a high SAR (12 to 15) have low permeability and are unsuitable for plant growth.

| |
|---|
| **Osmosis**<br><br>Osmosis is the flow of water and other liquids through a semi-permeable membrane, such as the thin membrane underneath the shell of an egg, from an area with a low concentration of dissolved matter, such as salts, to an area with a high concentration of dissolved matter, to gradually even out the concentration imbalance. |
| **Osmotic Potential**<br><br>A measure of the ability of a cell to attract water into itself through the mechanism of osmosis. |
| **Electrolyte**<br><br>Any substance which, when in solution, will conduct an electric current. Acids, bases, and salts are common electrolytes. |

# Chapter 1

After completing this chapter, the learner will be able to:

**Correctly assess, analyse and evaluate data and decide on corrective actions within operational technical systems independently to well-defined but possibly unfamiliar problems.**

## 1. Introduction

The majority of the data required in a management system to assess, analyse and evaluate water quality management is gathered and generated on the farm. Analyses by outside facilities are limited to the analyses of water samples and sometimes of deposits found in the system. These analyses are mostly used to confirm on-farm analyses and observations.

Although methods vary in the degree of sophistication, the results from various observations, tests and analyses are of equal importance in the process. A simple observation, such as feeling the grittiness of the deposits in the pipelines, is of no less importance than determining the concentration of sodium in water using laboratory equipment costing a million rand.

Usually, the water quality manager has little say in the quality of the water received on the farm. The water quality is assessed simply as being good, marginal or poor. The task of the water quality manager is to improve those water quality factors that can be improved cost-effectively, and manage the others to minimise their impact. The challenge is to decide when to take action to improve or eliminate factors and when to manage the impact. The framework for all these decisions is the profitability of production in a sustainable environment.

## 2. The Impact of Water Quality

In general, water quality impact on the irrigation system, soil productivity and crop production. Water quality factors are classified as physical, chemical or biological.

The impact of physical, chemical and biological water quality factors on the effectiveness of the irrigation system, soil productivity, and crop production varies. In table 1.1 below, the hazard according to the Department of Water Affairs of various physical, chemical and biological water quality factors on the irrigation system in terms of the clogging of emitters are shown.

| ***Factor*** | ***Unit*** | ***Low Hazard*** | ***High Hazard*** |
|---|---|---|---|
| **Physical Water Quality** | | | |
| Suspend solids | mg per litre | <50 | >100 |
| **Chemical Water Quality** | | | |
| pH | | <6 | >8 |
| Bicarbonates | me per litre | <1.64 | >3.28 |
| | mg per litre | <100 | >200 |
| Calcium | me per litre | <0.50 | >2.50 |
| | mg per litre | <10 | >50 |
| Manganese | mg per litre | <0.10 | >1.50 |
| Iron | mg per litre | <0.20 | >1.50 |

| *Factor* | *Unit* | *Low Hazard* | *High Hazard* |
|---|---|---|---|
| Sulphide | mg per litre | <0.20 | >2.00 |
| Total dissolved solids (TDS) | mg per litre | <500 | >2,000 |
| EC | mS per m-1 | <75 | >300 |
| **Biological Water Quality** | | | |
| Total bacteria | Numbers per ml | <10,000 | >50,000 |

**Table 1.1: Water Quality Hazards for the Irrigation System**

## 2.1. The Impact of Physical Water Quality

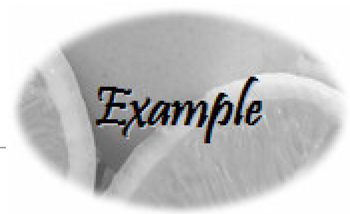
The main impact of the physical water quality is blocking or clogging of emitters. The standard set by the Department of Water Affairs and Forestry (DWAF, 1996) for the clogging hazard of water is as follows:

| *Rating* | *Suspended Solids per Litre Water (mg)* |
|---|---|
| Minor hazard | less than 50mg |
| Moderate hazard | 50mg to 100mg |
| Severe hazard | more than 100mg |

**Table 1.2: DWAF Standards for Suspended Solids**

The effects of clogged emitters are so devastating on production that even water classified as having a Low Clogging Hazard according to the tables above still needs treatment, because some of these factors have a cumulative effect on the irrigation system.

Filtration is used as a standard treatment for improving physical water quality by removing suspended solids from water. Apart from the initial analysis of the water, continuous monitoring of the suspended solids in the piping and emitters, and of the effectiveness of the filter system, is essential. The classification in the table above needs adjustment based on the hazard that can be caused by the accumulation in the pipes. Such an assessment is done as in the example below:




**Assessing Clogging Hazards**

| *Suspended Solids* | *Assessment* | *Actions* | *Comments* |
|---|---|---|---|
| <50mg per litre and 50-100mg per litre | Minor clogging hazard but can accumulate, requires action. | Filtration | Suspended solids will accumulate in the piping and will eventually cause emitters to clog[*]. |
| >100mg per litre | Needs action | Sedimentation, cyclones, filtration | Techniques and level of physics and engineering fall outside the scope of this material. Seeks specialised advice. |

* The rate of accumulation of suspended solids and the agglomerating effect of the bacteria depend on a number of factors, including temperature and the flow rate in the pipes. The requirement should be included in the specifications for the filtration system. This forms part of irrigation system design and a filtration system with the capacity to handle the load of solids for the specific water should be installed.

## 2.2. The Impact of Chemical Water Quality

Assessing, analysing and evaluating data relating to the chemical water quality and determining the best course for corrective action are much more complicated than is the case with data relating to physical water quality.

Certain chemical factors cannot be improved economically and the water quality manager can only take steps to limit or correct the impact on production and the environment. The type of irrigation system used, being micro-jets or drippers, also has an influence on the actions that can be taken to correct and / or minimise the impact.

The corrective actions in table 1.3 below include those aimed at improving chemical water quality and those aimed at reducing its impact on the environment and on crop production.

| ***Measurement*** | ***Comments*** | ***Assessment*** | ***Actions*** |
|---|---|---|---|
| **pH** | | | |
| <6.00 | Half-life of pesticides depends on pH of spray solution. Buffer solutions available for various pH levels. Consult supplier. | Suitable for most pesticide and nutrient sprays and need no treatment. | None |
| | | Some pesticides and nutrient sprays need higher pH. | Buffer the pH at the desired level |
| | Low pH in combination with low salt increases corrosion potential. The Corrosivity Index (CI) is used to evaluate this. | The corrosion potential of the water is high. Treatments are required. | This is a specialised action. Seeks expert advice. |
| | Nutrient solutions can be formulated without addition of acids, provided added chemicals do not increase the pH. | No need to use acids in drip irrigation systems. | None |
| 6.00-7.00 | Half-life of pesticides depends on pH of spray solution. Buffer solutions available for various pH levels. Consult supplier. | Solutions of some pesticides and nutrient sprays need to be acidified. | Identify the pesticides and nutrients and select the appropriate acid. |
| | Water usually contains Ca, Mg and S which should be incorporated in the formulation of the nutrient solutions. | Acidification of irrigation water used in drip systems is an option. Reduce the pH while adding nutrients and utilise the nutrients already in the water. | Select the most suitable acid or buffer solution. |
| 7.00-8.00 | Half-life of pesticides depends on pH of spray solution. Buffer solutions available for various pH levels. Consult supplier. | Solutions of most pesticides and nutrient sprays need to be acidified. | Select the most suitable acid or buffer solution. |

| Measurement | Comments | Assessment | Actions |
|---|---|---|---|
| | In combination with high Ca levels, scale forming and clogging are possible. Langelier Index is an indicator of the potential for scale formation. Acidification is undertaken on an *ad hoc* basis to clean the system. Water applied through micro-jets is seldom acidified due to the cost of the acids and the lack of proof of benefits. Using nitric and / or phosphoric acid reduce the pH and add nitrogen and / or phosphorus without much change in EC. | Scale is causing clogging of emitters. | Acidify continuously for drippers and *ad hoc* for micro-jets. Acidification of water used in micro-jet systems can possibly be justified during July to November. Acidification of irrigation water used in drip systems is a must to reduce pH, add nutrients and utilise the nutrients already in the water.. |
| > 8.00 | The volume of acids required to reduce the pH might be so much that N and P are over-supplied. Other acids are required. Consult a specialist. | In conjunction with high Ca concentrations scale forming and clogging are a real threat. | Acidify |
| **Electrical Conductivity (EC)** | | | |
| <75 | A leaching requirement (LR) of up to 10% is necessary. | Low salt content. Requires no special attention. | Monitor metal and cement components for signs of corrosion. |
| 75-125 | When the LR of between 10% and 15% is added to the volume of water applied, the salts will not accumulate in the root-zone. | Suitable for most soils and crops. | Apply the LR during each irrigation cycle. |
| 126-200 | When the EC of the water is greater than 150mSm$^{-1}$ plants need energy to utilise the water and production will suffer. | Not suitable for irrigation of citrus with conventional systems. | Consult a specialist. |
| >200 | Plants need large amounts of energy to utilise the water and production will suffer greatly. | Not suitable for irrigation unless specialised equipment and techniques are implemented. | Consult a specialist. |
| **Sodium Adsorption Ratio (SAR)** | | | |
| <1.00 | No sodium hazard | No sodium hazard | None |
| 1.00-3.00 | Crusting slows infiltration rate and free water accumulates on surface. The first sign of detrimental effect of too high sodium content. | Crusting is possible | Monitor the infiltration of water into the soil. If runoff occurs, consider the application of gypsum. |
| >3.00 | Excessive crusting | The sodium hazard needs attention. | Consult a specialist. |

| Measurement | Comments | Assessment | Actions |
|---|---|---|---|
| **Calcium (Ca)** | | | |
| >50mg/litre | In combination with a high pH, high carbonate or bicarbonate concentration will cause clogging. | Clogging of emitters | Consult a specialist. |
| **Magnesium (Mg)** | | | |
| >50mg/litre | Magnesium and potassium act mutually antagonistic, meaning they oppose each other's uptake and functioning. | Continuous use of the water will induce a potassium deficiency in plants. | Monitor the potassium level in the soil and leaves and act accordingly. |
| **Chlorine (Cl)** | | | |
| >50mg/litre | The leaves accumulate the absorbed chlorine until toxic levels are reached. The edges of the leaves can become scorched and leaf drop will occur. | High chloride concentrations in water promote soil salinity in the root-zone and can cause scorching of leaves when the water is used for spraying. | Monitor the chloride levels in the leaves and soil and avoid wetting leaves with the water during irrigation. |
| **Boron (B)** | | | |
| >1.0mg/litre | Symptoms of an excess of boron include yellowing of the leaf-tips, development of chlorotic blotches and premature leaf drop. | Boron toxicity may develop. | Monitor boron concentration in leaves. Consult a specialist. |
| **Nitrogen (N)** | | | |
| >20mg/litre | For proper development of the orange colour of the fruit, little or no nitrogen must be applied during January to June. | Using this water during January to June may result in poor fruit colour. | Monitor the N concentration in the leaves as well as the colour development of the fruit. |

**Table 1.3: Assessment of Chemical Water Quality and Corrective Actions**

*Definition*

**Buffer Solution**

Buffer solutions have the ability to absorb or release protons (hydrogen or acid ions) in a solution in order to keep the pH constant. Buffers have a limited pH range and different buffers must be used to buffer the pH at various levels.

**Chlorosis**

Chlorosis is the yellowing of local areas on a leaf. This is usually the first sign of a detrimental incidence in or on the leaf. The cells are not dead and sometimes the reaction can be reversed.

**Necrosis**

Necrosis is the step following chlorosis when the cell die and brown areas or spots appears on and in the leaf. Necrosis is irreversible.

Apart from the salts in the water that can cause clogging, salts added as fertilisers can aggravate the clogging hazard. This however forms part of the course on soil management and plant nutrition, where fertigation, compatibilities, and order of mixing are discussed.

### 2.3. The Impact of Microbiological and Biological Factors

In citrus production, the impact of microbiological and biological water quality factors is limited to those that promote the growth of bacteria and slimes in the piping after filtration. The bacterial and slime growth act as agglomerating agents to bind other suspended material into lumps that block the emitters. The growth is aggravated by the addition of nitrogen, phosphorus and organic carbon, such as molasses, organic acids or buffers. Applying nutrient solutions through the irrigation system stimulates the growth of the microbes.

Treatment is applied before, during or after filtration. The best results are however obtained when the complete system, being filters, supply lines, laterals and emitters, is disinfected. Drip irrigations systems need continuous disinfection. This decision should be based on historical data and current analyses, including those of the deposits in the piping and emitters.

Although DWAF indicates that less than 10,000 organisms per ml poses a low clogging hazard, the bacteria multiply in the pipes and any number will eventually clog the emitters. The bacteria population in the system must be monitored continuously and action must be taken accordingly. The most effective method to determine the presence of the different microbes is to evaluate the deposits in the pipes when flushing the system. See the table in Chapter 2.

## 3. Principles and Use of Operational Technical Systems

The technical systems involved in water quality management are so closely related to the irrigation and fertigation systems that they are usually also managed by the irrigation manager. Only under extreme conditions will such technical systems be managed by the water quality manager. Operational technical systems refer to acid and disinfectant applicators, or dosing apparatus, and filtration equipment.

### 3.1. Dosing Apparatus

Acidification and disinfection are done by using the same equipment as for applying fertilisers through fertigation. The selection and operation of these systems form part of the irrigation program. The equipment consists mainly of dosing apparatus which will introduce the acid or chlorine into the irrigation water. Two groups of dosing equipment are available (Koegelenberg & Conradie, 2000), being:

- Passive dosing apparatus
- Active dosing apparatus

#### 3.1.1. Passive Dosing Apparatus

Passive dosing equipment is apparatus that sucks the acid or chlorine solution into the stream of water in the pipes. This can be done at the suction end of the irrigation pump, through a venturi system, or through a pressure tank connected to the irrigation system.

##### 3.1.1.1. Irrigation Pump

The reservoir with acid or chlorine is connected to the intake end and the chemicals are sucked into the system in the same way as the water. The volume can be regulated by a tap. This is a simple and cheap method, but the acid and chemicals may damage the pump.

#### 3.1.1.2. Venturi System

The venturi is fitted in the pipeline. When water flows through the venturi, a localised drop in pressure is caused. The container with the chemicals is connected to the area of decreased pressure and the chemicals are forced into the pipeline by atmospheric pressure, and carried by the water. The rate of intake can be regulated.

#### 3.1.1.3. Pressurised Tank

A tank is connected at two points to the irrigation pipe. Between the two connecting points, a valve or tap is fitted to create higher pressure at the first point. The water flows through the tank and, due to the lower pressure at the second point, re-enters the pipeline on its way to the trees.

### 3.1.2. Active Dosing Apparatus

This group represents all the types of pumps used to force the solutions of the chemicals into the pipeline. These include pumps utilising centrifugal forces, screws, diaphragms, pistons, peristalsis, and gears to force chemical solutions into the irrigation system.

## 3.2. Filtration Equipment

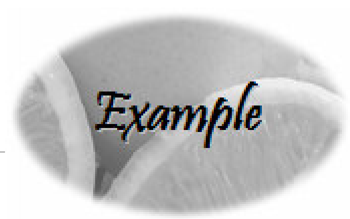
The filtration system forms an integral part of the irrigation system, but the type and capacity depend on the quality of the irrigation water. Three types of filters are commonly used, being:

- Mesh or screen filters
- Ring or disc filters
- Sand filters

### 3.2.1. Mesh or Screen Filters

Mesh filters are made of stainless steel or nylon compounds. The size of the openings and the total mesh area determine the capacity of the filter. Mesh filters are used to filter water of good quality that contains sand and silt. It is not suitable to remove algae form water.

In the table below, the standard filtration grades are shown. The mesh number refers to the number of cross wires per square inch that create the openings.




**Standard Filtration Grades**

| | | | | | | |
|---|---|---|---|---|---|---|
| Size of Openings (microns) | 300 | 250 | 200 | 130 | 100 | 80 |
| Size of Openings (mm) | 0.30 | 0.25 | 0.20 | 0.13 | 0.10 | 0.08 |
| Mesh Number | 50 | 60 | 75 | 120 | 155 | 200 |

### 3.2.2. Ring or Disc Filters

Ring filters have a three-dimensional filtering action and a higher capacity than mesh filters of the same measurements.

The filter unit consists of a number of flat plastic discs with grooves on the flat side. When packed together in a cylinder, they form a surface with small channels from the outside to the inside of the cylinder.

Water is filtered when it flows from the outside to the inside of a cylinder through this maze of tiny grooves. Ring filters are cleaned by backwashing, when water flows in the opposite direction, being from the inside to the outside of the cylinder.

### 3.2.3. Sand Filters

Sand filters remove organic and inorganic material, but not suspended clay particles, from the water. It is also a three dimensional system with a high capacity.

The particle sizes of the sand used in the filters are specified to remove suspended solids with a diameter of as small as 80 microns (0.08 mm). The lower the flow rate through the sand filter, the better the filtration. Sand filters are always used in conjunction with a disc or mesh filter.

## Summary

**Chapter 1**

- The majority of data used for the assessment of water quality is collected on the farm, with laboratory analysis of samples adding more information to the records
- Physical, chemical and biological water quality impact on the irrigation system, crop production and sustainable crop production.
- Physical water quality impact mainly on the irrigation system, and is improved through filtration.
- The assessment of chemical water quality factors is more complicated, and expert assistance is needed in many cases to determine the best course of action.
- In citrus production, the impact of microbiological and biological water quality factors is limited to those that promote the growth of bacteria and slimes in the piping after filtration.
- Operational technical systems refer to acid and disinfectant applicators, or dosing apparatus, and filtration equipment.
- Acidification and disinfection are done by using the same equipment as for applying fertilisers through fertigation.
- The two groups of dosing apparatus are passive dosing apparatus and active dosing apparatus.
- Passive dosing apparatus include using the irrigation pump, a venturi system, or a pressurised tank for sucking or forcing the acid or chlorine solution into the irrigation system.
- Active dosing apparatus refer to a range of pumps that are used to actively introduce the acid or chlorine solution into the irrigation system.
- Three types of filtration systems are commonly used, being screen or mesh filters, ring or disc filters, and sand filters.

## Practical

Complete activity 1 in the **Learner Workbook**.

# Chapter 2

After completing this chapter, the learner will be able to:

**Demonstrate a thorough understanding of the reasons, impacts and (implications) side effects of specific corrective actions related to water quality**

## 1. Introduction

The reason for any water treatment should be to improve the quality, minimise the negative effect of the water quality factor on the soil, tree, and environment, and improve economic returns. For every water treatment, or corrective action, there is a side-effect, or implications, which is not always desirable. Before taking corrective actions, consider the consequences, which in many cases develop over time.

## 2. Side-Effects of Corrective Actions

In table 2.1 various treatments used to improve physical, chemical and biological water quality is listed, together with the desired effect and possible side effects. Apart from the direct effects and side-effects of a treatment, the cost effectiveness must however also be considered. For instance, desalting irrigation water will have a positive effect on production, the soil and environment, but it is simply too expensive.

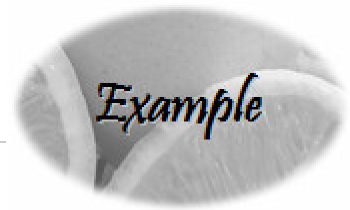
| ***Treatment*** | ***Desired Effect*** | ***Comments*** | ***Side Effect*** |
|---|---|---|---|
| Sedimentation | Sedimentation removes some insoluble material at low cost | Load of suspended solids is reduced, benefiting the next filtration action. Requires sedimentation dams and extra pumping facilities. | Sedimentation dams silt-up and require removal of the silt. Frequency depends on concentration of insoluble material and size of dam. |
| Filtration | Filtration reduces emitter blockages | A major must for micro-irrigation. | None, provided that effluent from backwashing filters are disposed of properly and not allowed to re-enter water supply system. |
| Decreasing pH | Lowering the pH make pesticides more effective | Improve effectiveness of treatment, hence fewer treatments or lower concentrations needed, and production improves. | Acidifiers or buffers must be compatible with pesticide. Some pesticides MUST NEVER be acidified and can damage fruit and leaves when acidified. |
| | Lowering the pH to improve solubility and utilisation of nutrients | Acids add another ion to the water while it removes the bicarbonates. Nitric acid adds nitrate, phosphoric acid adds phosphate and sulphuric acid adds sulphates. | Citrus requires majority of nitrogen during July to October and little during February to June. Presence of nitric acid may cause problems with fruit colour.<br>With micro-jets, phosphoric acid is not an effective source of P.<br>Water with a high pH usually contains high concentrations of sulphates. |

| ***Treatment*** | ***Desired Effect*** | ***Comments*** | ***Side Effect*** |
|---|---|---|---|
| Lowering EC | Lowering the EC will improve production | Currently too expensive for irrigation and foliar sprays. Electromagnetic treatments decrease surface tension of water, and could assist in leaching salts from root-zone. | Need to meet the leaching requirement for this combination of soil, water and crop. Extra water will be required. |
| Disinfection | Disinfection reduce blockages by limiting microbiological growth | A major must for micro-irrigation, especially where drippers are used. | Additional chemicals are introduced into the water supply system. |

**Table 2.1: Water Quality Treatments with Effects and Side Effects**

## 3. Data Analysis

The process of assessing, analysing an evaluating data starts with a comparison of the laboratory results with the standard set of norms, which can be obtained from the Department of Water Affairs. Thereafter, a series of questions and answers will add value until satisfactory decisions can be made.




**Step 1: Data Analysis**

The laboratory report indicates that the water contains 55mg per litre suspended solids, which is, according to the above rating, a minor clogging hazard. This data must be assessed, analysed and evaluated to make a sound business decision. Is it necessary to filter water to remove the 55mg per litre suspended solids? If the concentration of suspended solids were 155mg per litre, it would have been clear that the water required to be filtered.

To assess, analyse and evaluate the data additional information is required, for instance:

- Was the sample taken correctly?
- Are the 55mg suspended solids clay and / or silt particles, plastic cuttings, seeds or organic debris? If this is established, it may be possible to address the specific source.
- How many emitters were blocked in the past three months, six months and year?

All the additional information is generated on the farm and, if properly recorded, add value to the results and support a proper decision. Every time you can answer one of the questions, you make the final decision easier and more accurate.

**Step 2: Evaluating Physical Water Quality Before Filtration**

| | ***Information*** | ***Decision*** | ***Questions*** |
|---|---|---|---|
| 1 | 68mg suspended solids per litre water | Minor clogging hazard | What type of solids? |
| 2 | Solids consists of silt, clay and plastic cuttings | Train staff to use sharp knives when repairing plastic tubing | How many emitters clogged the past three months? |
| 3 | 3% of emitters were clogged in the past three months | | Can this be detected before it impacts on production? |

| | | | |
|---|---|---|---|
| 4 | Easily, with current monitoring system | Prevent plastic in the system and continue with current filtration system. | |

**Step 3: Evaluating Physical Water Quality After Filtration**

| | *Information* | *Decision / Conclusion* | *Questions* |
|---|---|---|---|
| 1 | 78mg suspended solids per litre water | Minor clogging hazard | What type of solids? |
| 2 | Solids consists of silt, clay and slimy material | Ineffective filtration and build-up of microbes | What protocols are followed to clean the system? |
| 3 | Chlorination, but not done in last four months.<br>Flushing laterals once per month according to protocol | Investigate breach of protocol | Maintenance records for filtration system are required |
| 4 | Not available | | How many emitters clogged? |
| 5 | 16% the past three months | Investigate breach of protocol | How can developments like these be prevented and / or detected in time?<br>What material clogged the emitters? |
| 6 | Whitish precipitate that dissolves in acid, and slimy substances | Possibly calcium carbonate and bacterial slimes | When was the water analysed and what was the pH, calcium, bicarbonate concentration and bacterial counts? |
| 7 | March 2005<br>pH=7.5<br>Ca=30mg<br>Bicarbonate=125mg<br>Bacteria=1500 per litre | Compared to pervious analysis, not much change in the composition. | |

The procedure for assessing, analysing and evaluating data and taking decisions on corrective actions are based on actual measurements, but value is added to the analytical data by using historical records. The process does not stand alone but forms part of a management system. Any breach in recordkeeping decreases the value of any current data.

Table 2.2 serves as a guide to identify the causes of clogging together with some recommendations to correct the problem (Hansen et al. 1992).

| *Cause* | *Solution* |
|---|---|
| Whitish precipitate indicates carbonates. The pH is usually >7.5 and HCO3 content >120mg per litre. | Continuous application of acid to maintain a pH in the water of between 5.0 and 7.0<br>or<br>Shock treatment with acid at a pH of 4 for 30 to 60 minutes |
| Reddish precipitate indicates iron deposits. The water contains >0.1mg Fe per litre. | Aerate the water – suitable for water containing > 10mg Fe per litre. Chlorination at a rate of 1mg chlorine per 0.7mg Fe per litre. Apply the chlorine before the filter in order to remove the precipitated iron. Reduce the pH to 4.00 for 30 to 60 minutes every day to dissolve the Fe precipitated during the day to prevent accumulation. |

| ***Cause*** | ***Solution*** |
|---|---|
| Dark / black precipitate indicates manganese deposits. The water contains >0.1 mg Mn per litre. | Apply chlorine at a rate of one mg per 1.3mg Mn per litre water before the filter to remove the precipitated Mn. |
| Reddish slime indicates bacteria using iron in their metabolism. The Fe content >0.1 mg per litre. | Chlorinate at a rate of 1mg chlorine per 0.7mg Fe per litre continuously or 10 to 20mg chlorine for 30 to 60 minutes. Apply the chlorine before the filter in order to remove the precipitated iron. |
| Whitish fluffy slime indicates sulphur bacteria. The water contains >0,1mg S. | Chlorinate at a rate of 1mg chlorine per 4 to 8mg S per litre continuously or 10 to 20mg chlorine for 30 to 60 minutes. |
| Algae and other slimes | Chlorinate at a rate of 0.5 to 1.0mg chlorine continuously or 10 to 20mg chlorine for 20 minutes at the end of the irrigation cycle. |
| Black gritty precipitate indicates iron sulphide at a concentration of > 0.10mg per litre water. | Continuous application of acid to maintain a pH in the water of 5.0 to 7.0. |

**Table 2.2: Causes of Clogging**


**Aeration**

Aeration means the addition of oxygen to water. The simplest method is to spray water into a dam through the air, where it dissolves oxygen. Another method is to bubble air through water.


**Chapter 2**

- For every water treatment, or corrective action, there is a side-effect, or implications, which is not always desirable.
- Apart from the direct effects and side-effects of a treatment, the cost effectiveness must also be considered.
- The process of assessing, analysing an evaluating data starts with a comparison of the laboratory results with the standard set of norms, after which a series of questions and answers will add value until satisfactory decisions can be made.
- The procedure for assessing, analysing and evaluating data and taking decisions on corrective actions are based on actual measurements, but value is added to the analytical data by using historical records.


Complete activity 2 in the **Learner Workbook**.

# Chapter 3

| |
|---|
| After completing this chapter, the learner will be able to:<br><br>**Implement corrective actions related to the quality of water and water quality systems** |

## 1. Water Quality Treatment Systems

Most micro-irrigation systems include one or more treatment systems to improve the quality of irrigation water. For the irrigation of citrus by means of micro-jets and dripper, filtration, acidification, and disinfection are standard procedures, with chlorination used where necessary. The frequency of acidification and disinfection depends on the quality of the irrigation water.

### 1.1. Filtration

Designing an irrigation system usually includes the filtration system. The type and number of filters depend on the quality of the irrigation water and the type of irrigation system. Little or no filtration is required for flood irrigation, while a dripper system will almost always use some sort of filtration. The filtrations system may include one or more of the following:

- Sedimentation dams
- Cyclones
- Sand filters
- Mesh filters
- Disc filters

The operation and maintenance procedures are prescribed by the supplier or manufacturer of the system, and will not be discussed in this section. However, these procedures should form part of the system's management protocols.

### 1.2. Acidification

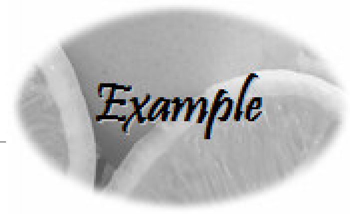
Acidification is done by using techniques that vary in their degree of sophistication. The techniques include pre-dilution of the acid before addition to the irrigation water or adding the concentrated acid to the water during irrigation by means of pumps or a suction action. Pumps and suction units used for this purpose are controlled manually or by computer.

Whatever the technique used, the operation and maintenance instructions will be supplied by the supplier or manufacturer. These procedures should form part of the system's management protocols.

Acidification is also done to dissolve carbonates of calcium and magnesium, which pose a clogging hazard by continuous application of acids, such as in hydroponics, or by using a so-called shock treatment. The shock treatment allows the acid at a concentration of 0.6% (Netafim, 1998) to remain in the system for one hour, after which it is flushed out with irrigation water. The 0.6% concentration is applicable only when the concentration of the various acids is:

- Hydrochloric acid 33-35%;
- Sulphuric acid 70%;
- Nitric acid 60%; and
- Phosphoric acid 85%

If the concentration of the available acids differs from these values, adapt the percentage with a factor of 0.6 x % stated / % available.




**Adapting the Acid Concentration**

Nitric acid is available at a concentration of 70%.

0.6 x % stated / % available
= 0.6x60/70
= 0.51%

Nitric acid is the preferred chemical for this purpose, because all nitrates are soluble in water and nitrate is also an essential nutrient element. The following procedures are recommended (Netafim, 2000):

- Calculate the volume water in the system at operating pressure.
- Calculate the volume acid required to add 0.6% acid to the volume of water in the system.
- Connect the injector pump to the irrigation system to be cleaned after the filter.
- Start the irrigation system and let it gain operating pressure.
- Inject the acid into the system over a period of at least 10 minutes.
- Stop the irrigation pump for one hour.
- Resume irrigation for another hour to flush-out the acid and regain the pH before the acidification process in the soil and root-zone.

Always use protective clothing and gear when handling acids, and observe all health and safety procedures that are prescribed for handling dangerous chemicals.

## 1.3. Disinfection

The purpose of disinfection is for the chemicals to kill the microbes, and oxidise some of the simple organic molecules and even manganese and iron. Disinfection of the water and system is done by applying sodium or calcium hypochlorite, hydrogen peroxide, ozone or other disinfectants. Hypochlorite and hydrogen peroxide are the most commonly applied agents. These chemicals can be used in a maintenance or corrective program.

### 1.3.1. Maintenance Application

In the maintenance program, disinfectant chemicals are applied at frequencies determined by historical data and current assessments and analyses. The microbial counts in the irrigation water initiate the inclusion in the maintenance program. Data on clogged drippers or micro-jets and analyses of the deposits in the pipes determine the frequency.

### 1.3.2. Corrective Application

Corrective or shock treatments are done to bring the microbial population down to acceptable levels in short period. This is done by applying the chemical at a high concentration at the end of the irrigation cycle.

### 1.4. Chlorination

Chloride is formed when chlorine oxidises organic material or manganese. In the process, the chlorine atom is reduced to the inactive chloride form. Chloride will not oxidise organic material and, at a moderate concentration, will not kill microbes.

Chlorine is a strong oxidising agent. It oxidises organic deposits and slimes to carbon dioxide. In this process, the living organisms are killed. Iron and manganese will also be oxidised to prevent precipitation. Microbes, iron and manganese must be in contact with the chlorine for a minimum period and at a minimum concentration in order for the oxidation to be completed. In table 3.1 below is the recommended concentration for active chlorine for various management systems.

| ***Purpose of Chlorination*** | ***Method of Chlorination*** | ***Recommended Concentration (mg/litre)*** | |
|---|---|---|---|
| | | ***Injection*** | ***End Emitter*** |
| Prevention of sedimentation caused by agglomeration of particles by slimes and waste products due to biological activities. | Continuous | 3 to 5 | >1 |
| | Periodically* | 10 | >3 |
| Cleansing the system | Continuous | 5-10 | >3 |
| | Periodically* | 15 | >5 |

* Inject the chlorine during the last 30 to 60 minutes of the irrigation cycle and leave it over night in the system.

**Table 3.1: Recommended Concentration for Active Chlorine**

The following procedures are recommended:

- Apply the chorine as closely as possible to the system to be cleaned.
- The pH of the water should be between 6.5 and 7.2.
- When chlorination is done to precipitate iron and manganese, apply the chlorine before the filters.
- Before chlorination, flush the laterals properly.
- Free chlorine must be present at a concentration between 1mg and 5mg per litre at the emitter farthest from the injection (see column in table), otherwise chlorination is incomplete.
- Chlorine concentrations exceeding 100mg per litre may damage certain parts of the system.
- Never mix chlorine and acid.

Always use protective clothing and gear when handling acids, and observe all health and safety procedures that are prescribed for handling dangerous chemicals.

## 2. Water Quality Management Systems

As we have seen at previous levels, certain crops are extremely sensitive to water quality and changes in water quality, and sophisticated and highly technical water quality management systems are developed for these crops. Citrus is not that sensitive to water quality, which makes the precise management of water quality unnecessary, while the volumes of water used for irrigation is so large that precise management is also not feasible.

A water quality management system for citrus production needs to be developed according to the requirements of the irrigation system, the quality of the incoming water and the quality of water required at the trees. With a flood irrigation system, the requirements will be much less stringent than with a drip irrigation system, where water with almost no suspended solids and a pH of 6.50 is required.

To develop a management system, one has to identify the quality required, the improvements that can be made, suboptimal quality factors that must be managed, and what to measure to be in a position to manage the improvements and impact on the soil and trees.

At a previous level, we identified the critical control points in the water quality management system as follows:

- Where water is received on the farm
- Where water is used
- Where water leaves the farm

The management of these critical control points were discussed in detail at the time. It is however necessary to look in more detail at the treatments that are used to improve water quality that forms part of the second major critical control point, being where it is used. Managing these treatment processes is essential for managing water quality.

The most common water quality treatment processes that need to be managed with micro irrigation are the filtration, acidification and disinfection.

## 2.1. Filtration

The filtration process forms part of the irrigation system and is managed by the irrigation manager. However, specific points to measure the concentration of suspended solids must be identified, monitored, recorded, and assessed continuously. These critical control points include:

- Incoming water
- Water after filtration
- Debris when flushing the pipes
- Water when backwashing the filters
- Clogged emitters

Measurements and recordkeeping of this data enable the manager to take corrective steps before an incident occurs that causes damage.

| ***CCP*** | ***Frequency*** | ***Measurement*** |
|---|---|---|
| Incoming Water | Twice per annum | Insoluble suspended material in mg/l |
| After Filtration | Twice per annum or whenever repairs or maintenance have been done on the filtration system. | Insoluble suspended material in mg/l |
| Debris in Pipes | Monthly | Insoluble suspended material. Identify the type and possibly the origin and estimate the volume / mass. Distinguish between the suspended solids and identify its origins, as follows:<br>• **Silt** – poor filtration<br>• **Slimes** – inadequate disinfection<br>• **Sand** – valves that do not operate properly |
| Backwashing Water | Depending on historic data of the incoming water and debris in pipes | Insoluble suspended material in mg/l |

| *CCP* | *Frequency* | *Measurement* |
|---|---|---|
| Clogged Emitters | Whenever clogged emitters are replaced, one or at least 10% of the clogged emitters should be opened and the deposits analysed in order to identify the case and origin. | Insoluble suspended material in mg per litre. Identify the composition as follows:<br>• **Acid** – carbonates will fizz, other salts will dissolve<br>• **Colour** – red=iron, black=organic<br>• **Touch** – plastic, silt and clay and / or slimes |

**Table 3.2: Critical Control Points for Monitoring Suspended Solids**

The frequency in the table above reflects the minimum. Recorded data, the quality of the incoming water and seasonal variation will determine the actual frequency. Remember: rather a too high than a too low frequency.

## 2.2. Acidification

Acidification is not always required when micro-irrigation is practised. Usually, it is required in open hydroponic systems or other drip systems during July to September or October for citrus. Its use is determined by economic decisions and the added nitrogen, phosphorus or sulphur should form part of the total fertilisation program.

Managing the pH of the irrigation water can be done manually or continuously aided by a pH-sensor and a computer. The acidification process of irrigation water can also be managed by recording the volume of water treated and the volume of acid used in the process. These volumes should add up to the estimated acid usage. The volume of acid is best determined by chemical titration. Otherwise the volume can be calculated based on the concentration of carbonates and bicarbonates. The volumes of nitric acid and phosphoric acid required to acidify irrigation water to pH 6.0-6.5 are based on the concentration of the bicarbonates.

| *Bicarbonate me (mg) per litre water* | *Acid Required (ml per 1000 litres water)* | |
|---|---|---|
| | **Nitric Acid[1]** | **Phosphoric Acid[2]** |
| 0.10 ( 6.1) | 7 | 2.86 |
| 0.20 (12.2) | 15 | 5.71 |
| 0.30 (18.3) | 22 | 8.57 |
| 0.40 (24.4) | 30 | 11.43 |
| 0.50 (30.5) | 37 | 14.29 |

[1] 60% with a normality of 13.7 and density of 1.36
[2] 85% with a normality of 36.4 and density of 1.69

**Table 3.3: Volumes of Acid Required to Acidify Irrigation Water**

When the volume of acid required is determined by titration, the volume to be added to the water can be calculated. Monitoring the acidification process can then be done as in the example below.

*Example*

**Monitoring Acidification**

| Orchard 11 | |
|---|---|
| ***Date*** | ***Acid Required ml/1000 litres*** |
| 19/05/2004 | 126 |
| 11/06/2005 | 135 |

| *Date* | *Water Applied x 1000 litres* | *Acid Added Litres* | *Acid added ml/1000 litres* | *Difference %* |
|---|---|---|---|---|
| 15/07/2005 | 112,506 | 15,750 | 140 | +3,7 |
| 16/08/2005 | 150,103 | 19,513 | 130 | -3,7 |
| 15/09/2005 | 172,252 | 22,900 | 133 | -1,5 |
| 18/10/2005 | 199,000 | 28,100 | 141 | +4,4 |

| *Date* | *Water Applied x1000* | *Acid Applied Litres* | *Acid Added ml/1000 litres* | *Difference %* | *pH* |
|---|---|---|---|---|---|
| 15/07/2005 | 112,506 | 15,750 | 140 | +3.7 | 6.34 |
| 16/08/2005 | 150,103 | 19,513 | 130 | -3.7 | 6.12 |
| 15/09/2005 | 172,252 | 22,900 | 133 | -1.5 | 6.31 |
| 18/10/2005 | 199,000 | 28,100 | 141 | +4.4 | 6.45 |

Choose the recordkeeping system that suits the requirements best, but ensure that it supplies the correct and sufficient information for management to optimise conditions and prevent hazardous incidents. Instead of commercial acids, buffer solutions can be applied. The advantages of buffer solutions are that it is safer to use and overdosing is less of a hazard.

### 2.3. Disinfection

Disinfection can be done continuously or periodically. Measuring the concentration of the free chlorine at the most distant emitter is the best method to ensure that the treatment was done on all emitters at an effective concentration. Additional information, such as mass hypochlorite applied and intervals of application can assist in managing the process.

## 3. Maintaining Quality in Water Quality Management Systems

The quality of any management system depends on the:

- Relevance of the measurements taken
- Accuracy of measurements
- Frequency of testing
- Frequency of data assessment
- Frequency of reporting

## 3.1. Relevance of Measurements

A management system can be killed by too much meaningless data. Too many measurements take up time and effort and are the first thing to be neglected when time is limited. A few measurements that can be done quickly and accurately, and that have a meaningful input on the decision-making process, should be selected. Data must be recorded immediately and transferred to the water quality database.

The most appropriate measurements that can be done on the farm are pH and EC. Although the EC measurement cannot indicate what type of salts is dissolved, it does indicate the magnitude of changes. Comparing the latest EC measurement with historical records, including that of laboratory analyses, indicates changes and whether additional actions or tests are justified. pH strips or a handheld pH and EC-meter that can be easily used in the orchards should be available. Follow the instructions of the supplier to ensure accuracy.

The concentration of suspended solids in the water is another simple measurement that can be included in the management system. Other important measurements are the concentration of sodium, chloride and boron, and SAR. These can only be done in a laboratory and should form part of the report on the complete analyses of the water.

The quality of a water quality management system depends on what is done with the data and not how much data is collected. Collect data that can be used to optimise the production of citrus in a sustainable environment.

## 3.2. Accuracy of the Measurements

Measurements on the farm and in the orchard cannot be as accurate as those done in a laboratory. However, on-farm measurements should be accurate enough to give results similar to that of the laboratory.

The procedures used on the farm should also include standard solutions for pH (pH-buffers) and EC. However, always strive to measure as accurately as possible, without increasing the cost too much. Handheld instruments that are calibrated regularly are usually very accurate. Laboratory results should be of a high standard.

## 3.3. Frequency of Testing

The general quality of the water and the variation in the water quality dictate the frequency of testing. Water from a huge storage dam, such as the Gariep or Kwena dams, have a fairly constant composition and the frequency of testing will be low. The quality of irrigation water in a river like the Olifants River in the Lowveld is subjected to more fluctuations and will necessitate frequent testing.

Historical data is used to determine the frequency required to optimise water quality managment. If no data is available, start with a complete laboratory testing followed by weekly testing of pH and EC on the farm until enough data is collected to set a schedule.

## 3.4. Frequency of Data Assessment

Data is collected to optimise the application of the water. If it is not analysed and evaluated regularly, the whole water quality management system is useless. The very reason for a water quality management system is to monitor the quality so that actions can be taken before damage is done to the crop, the trees, or the environment.

In a sound water quality management system, evaluation and assessment of data are done soon after logging the data on the recordkeeping system. If any change that can have a negative impact is detected, it should be reported immediately, even in a formally structured management system.

### 3.5. Frequency of Reporting

The reporting system depends on the farm management. On a small farming unit where the farm manager is also the water quality manager, reporting on and assessing the collected data can be the same process.

The frequency of reporting also depends on the variations in the quality of the water. With few and insignificant changes, a report on water quality should be filed at least once a year. Where the quality of the water changes more rapidly, the reporting should be scheduled to avoid disasters, to facilitate corrective or preventative actions, and to ensure that the relevant people or department get the message in time.

## 4. Maintaining Water Quality Management Systems

A water quality management system that is of relevance to optimise the irrigation system, production and environment, is maintained by the fact that is it being used continuously. When the quality of the water is poor or fluctuate, the operations are dependent on the information. The water quality management system forms such an important part of the farming operations that its priority will greatly ensure that the system is maintained.

A system that is only used on an *ad hoc* basis will let the manager down when it is needed the most. This often happens with constant supply of moderate or good quality water. Under such conditions, the measurements, recordkeeping and evaluations are neglected. For these reasons, a formal schedule should be compiled and the senior management should enforce its maintenance by requesting regular reporting according to a fixed schedule.

Fluctuations in the quality of the water depend to a large extent on the activities upstream. This information can also be used to determine the frequency of measurements and reporting. Industries letting effluent into the upstream can cause major fluctuations.

The minimum requirement is a laboratory report twice per annum, before and after the rainy season. Thereafter, the frequency will depend on the quality of the water and the type of irrigation.

In the third example in section 3 of chapter 2, the management system was neglected and not properly maintained. The problems experienced at that time were due to a poorly maintained system and not to a major change in the quality of the water. This incident could have been prevented if the quality management system, including frequent reporting, was maintained. The cost of replacing 13% of the drippers and the loss in production outweighs the cost of maintaining the water quality management system.


**Chapter 3**

- Most micro-irrigation systems include one or more treatment systems, of which filtration, acidification and disinfection are standard procedures for the irrigation of citrus by means of micro-jets and dripper. Chlorination is used when necessary.
- The filtration system forms part of the irrigation system.
- Acidification is done by pre-dilution of the acid before addition to the irrigation water or adding the concentrated acid to the water during irrigation by means of pumps or a suction action. Acids are applied continuously or in shock-treatments.
- The purpose of disinfection is for the chemicals to kill the microbes, and oxidise some of the simple organic molecules and even manganese and iron, and is applied either as maintenance applications or as a corrective application.
- Chlorine is a strong oxidising agent and oxidises organic deposits and slimes to carbon dioxide.

- At the critical control point in the water quality management system where water is used, special attention must be paid to water treatment processes.
- In the filtration system the suspended solids are monitored in the incoming water, after filtration, in the debris when flushing the pipes, when backwashing the filters, and in the clogged emitters.
- Measuring the concentration of the free chlorine at the most distant emitter is the best method to ensure that the treatment was done on all emitters at an effective concentration.
- The quality of any management system depends on the relevance of the measurements taken, accuracy of measurements, frequency of testing, frequency of data assessment and frequency of reporting.
- To ensure the relevance of measurements, a few measurements that can be done quickly and accurately and that have a meaningful input on the decision-making process is selected.
- The general quality of the water and the variation in the water quality dictate the frequency of testing, data assessment and reporting.
- Water quality management systems are maintained if they are used continuously and if protocols and testing and reporting schedules are followed.


Complete activity 3 in the **Learner Workbook**.

# Chapter 4

After completing this chapter, the learner will be able to:

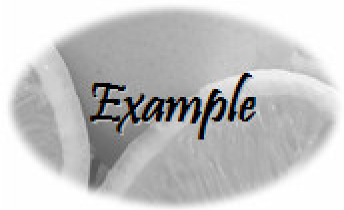
**Evaluate the effects of corrective actions or adjustments on the water quality requirements**

## 1. Corrective Actions on Water Quality

We have previously discussed the commonly used treatments to improve the quality of irrigation water for citrus production, being filtration, disinfection and acidification. Other water quality factors are not as easily addressed.

A good example of this is total dissolved solids, which is measured by the electrical conductivity (EC) of the water. At this time, this most important chemical water quality factor cannot be improved economically. We can add substances to the water, but, apart from carbonates and bicarbonates, we cannot remove soluble salts from water economically.

Other methods are employed to make unsuitable water more suitable to increase the water supply for irrigation. In this case, the simplest method is to mix waters of a low and high salt content in order to get water with a medium but acceptable salt content. If the waters are mixed in equal portions (50:50) the EC of the mix will be half the sum of the two separate ECs.




**Calculating the EC of Mixed Water Source**

The EC of source A is 25 and that of Source B 125mSm$^{-1}$. If these two sources are mixed at equal volumes (one volume of A plus one volume of B), the estimated EC of the mix will be:

1 x 25 + 1 x 125 /2
= 75 mSm$^{-1}$, i.e. good quality water

If the sources are mixed at different ratios, the estimated EC can be calculated as follows:

| ***Volumes of A EC=25 mSm$^{-1}$*** | ***Volumes of B EC=125 mSm$^{-1}$*** | ***Formula*** | ***Estimated EC mSm$^{-1}$*** |
|---|---|---|---|
| 1 | 1 | 1 x 25 + 1 x 125 / 1 + 1 | 75.00 |
| 2 | 1 | 2 x 25 + 1 x 125 / 2 + 1 | 58.33 |
| 3 | 1 | 3 x 25 + 1 x 125 / 3 + 1 | 50.00 |
| 1 | 3 | 1 x 25 + 3 x 125 / 1 + 3 | 100.0 |

Another fairly simple method is the electron magnetic treatment of water with high TDS, which will not change the chemical composition of the water. In this process, the surface tension of water is decreased by passing the water through a tube-like instrument constructed of dissimilar metals. The process adds electrons to the water, which reduce the surface tension and increase the carrying capacity of the water. Equipment is available in South Africa and installation and maintenance is done according to the specifications of the suppliers.

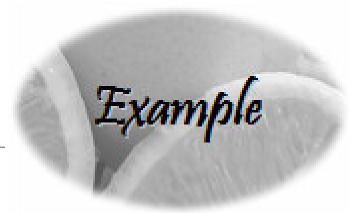
At this stage it is more important to deal with the salts than to desalt the water. Desalting of irrigation water is currently not cost-effective.

## 2. Evaluating the Effectiveness of Corrective Actions

The effects of some recommendations for corrective actions can easily be evaluated, especially those with a direct influence on water quality. Adjusting the pH of water to be applied as a pesticide spray is for instance very easy, and is done by merely measuring the pH and drawing a conclusion.

The effects of other recommendations can be quite difficult to evaluate. Evaluating recommendations to counteract the high concentration of chlorides in the water requires other information, such as yield and fruit quality data.

The simplest way to do this, is to list the factor to be improved (what to improve), the "before" measurement (why), the recommendation (how) and the "after" measurement (result).




**Evaluating the Effect of Corrective Actions**

| ***What*** | ***Why*** | ***How*** | ***Result*** |
|---|---|---|---|
| pH 8.23 | Reduce the pH from 8.23 to increase efficacy of pesticide sprays | Apply 200ml buffer per 100 litres water buffer Z to reach pH 5.5 | pH of the spray mix = 5.5 |
| Suspended solids = 85mg per litre | Moderate clogging hazard | Filtration | 10mg solids per litre water |
| Bacterial count = 15,000 per ml | Slimes forming a definite hazard | Chlorinate continuously with 3 mg free chlorine per litre water | Measured free chlorine at most distant emitter = 2 mg per litre |

A very important component of this evaluation relies on the information that necessitates the action. For instance, research results proved that pesticide A is twice as effective at pH 5.5 as at 7.00 or higher. The water quality manager must have access to this data supplied by a competent institution.

Recommendations to reduce the impact of the indirect effects of water quality need to be done in conjunction with the person responsible for the fertilisation and soil maintenance programs. Usually these recommendations involve multi-disciplinary inputs and can seldom be evaluated by simplistic measurements.

## 3. Reporting on Water Quality Management Systems

Recordkeeping and reporting is essential for evaluating the need for and effectiveness of corrective actions that are taken.

A reporting system should include the following basic elements:

- The current quality of the water
- Comparisons with previous qualities, asking the question: Is the quality deteriorating?
- Actions to improve or maintain the quality or limit the impact
- Schedules for actions to be taken
- Outcomes of the actions

The frequency and scope of reporting depend on the quality of the water received on the farm or at the orchard. With good quality water, where hardly any corrective actions are required, a laboratory analyses twice per annum suffice. If the water quality gets worse, more attention, actions and measurements are required. Reporting then needs to be more involved and should include assessments, actions and outcomes.

Data for reporting purposes is collected on an ongoing basis according to a planned schedule. The frequency and type of measurements depend on the water quality, the irrigation system and soil type.

Example

**Reporting on Water Quality**

| ***Requirements*** | ***Frequency*** | ***Measurements*** |
|---|---|---|
| Laboratory report | Twice per annum | Complete analyses |
| Comparison with historical data | At least once per annum | All data on laboratory report and that collected on farm |
| List of quality factors that require attention | Depending on water quality but at least once per annum | The "before" and "after" measurements |
| Report from the advisors on specific inputs | Whenever an advisor was consulted | According to the advisors recommendations/report |

The report must be concise and short, and should report in detail on quality factors that are important in terms of impact on soil, trees, environment, profitability and sustainability. A prediction of the quality of the water over the next year (short term) and five years (medium term) should be included. If any major actions are required, this should be properly investigated and addressed in the budget.

Summary

**Chapter 4**

- Certain water quality factors, such as total dissolved salts, cannot be addressed through cost-effective corrective actions.
- Water from different sources and of different qualities can be mixed to improve the overall quality.
- To evaluate the effectiveness of corrective actions, records must be kept of the quality factor that required corrective action, the reason why corrective action was taken, the corrective action that was taken and the result of the action.
- Recordkeeping and reporting is essential for evaluating the effectiveness of corrective actions.

Practical

Complete activities 4, 5, 6, 7 and 8 in the **Learner Workbook**.

# Chapter 5

After completing this chapter, the learner will be able to:

**Develop, design and optimise water quality systems**

Information

This specific outcome forms part of the level 5 unit standard **116369 – Optimise Water Quality**. It serves as an introduction to the next level. Because it is uneconomical to treat the large volumes of water required to irrigate citrus, a separate learner guide for citrus production has not been developed for this unit standard on level 5. We did however find it necessary to address this specific outcome.

If you wish to complete the unit standard 116369, please select an alternate agricultural crop where it would be economical to treat the irrigation water.

## 1. Introduction

As we have said before, although the concentration and type of salts dissolved in water influence citrus production, it is not economical to treat the large volume of water required for irrigation by micro-jets or to desalt water used in drip irrigation systems. The water quality factors that cannot be changed must therefore be managed. These include the concentration of total dissolved salts (as measured by EC), pH, SAR and magnesium. In addition, physical water quality factors that impact on the efficiency of the irrigation system also have to be managed.

With some crops where water quality plays an important role, the volume of water that is required is also usually relatively low. With micro-irrigation, the water requirement is around 8,000m3 per hectare per year, which makes it very expensive and impractical to treat the water to improve the EC, SAR or pH. With drip irrigation, the pH can be changed economically, but desalting the water to reduce the EC is still not economically justifiable. The management of the impact that water quality has on the soil and on the irrigation system is discussed in detail in the learning material on Irrigation, and on Soil Management and Plant Nutrition.

Previously, we looked at the various corrective actions that can be taken to improve water quality in detail. To summarise:

- The pH of water can be improved, but only where drip irrigation is used. The acidification of the water forms part of the fertigation system and therefore the fertilisation program.
- The pH of the water that is used for certain foliar sprays for plant nutrition or plant protection product applications can be improved. Whether it should be done depends on the product. Certain plant protection products become harmful to the trees if the water that it is mixed with is acidified.
- Suspended solids can be removed from irrigation water by filter systems, of which disc filters, sand filters, and screen filters are the most common.
- Water can be disinfected to kill microbes that cause slimes and other suspended solids.

Apart from these corrective actions that can improve water quality, the water quality factors are monitored on an ongoing basis.

Citrus farms mostly do not employ fulltime water quality managers, except on very large estates where a large variety of water sources are used. On most farms, the irrigation manager monitors the water quality and the systems, such as the filters and storage dams, as part of his duties, the pest and disease control manager will see to the acidification of water used for plant protection product applications where it can be done, and the fertilisation manager oversees the acidification of water that is used for foliar sprays and will also monitor the possible increase in the salt content of the water that can result from fertigation.

## 2. Designing a Water Quality Management Systems

When designing a water quality management system for a new citrus farm, the focus-areas for water quality management that must be kept in mind are:

- Monitoring water quality
- Identifying corrective actions that can be taken
- Implementing corrective actions

Designing a water quality management system depends on the quality of the water, but must also incorporate the soil properties and the requirements of the specific crop. Water with a high SAR will not have the same effect on soil containing 95% sand and has virtually no structure than on a clayey soil. Likewise, cotton will tolerate a much higher concentration of salts in the water than lettuce, which is very sensitive. The development of a water quality management system therefore starts with an analysis of the water and additional information on the soil and crop. Designing a water quality management system involves the following steps:

- Analysing water quality in available sources
- Determining crop water requirements and soil type
- Identifying corrective actions and areas to be monitored
- Developing task lists for monitoring and corrective actions
- Developing recordkeeping systems

## 3. Analysing Water Quality in Available Sources

The manner in which water from available sources is sampled and analysed has been discussed in detail before. Below is an example of test results where two water sources on a citrus farm were analysed for evaluation and development of a water quality management system.

*Example*

**Water Analysis**

| | | |
|---|---|---|
| Laboratory Number | 3313 | 3314 |
| Your reference number | Borehole | Dam |
| Suspended material (mg per litre) | 5 | 139 |
| pH | 8.23 | 6.55 |
| Electrical conductivity ($mSm^{-1}$) | 251 | 55 |
| Total dissolved solids (mg per litre) | 1597 | 355 |
| Potassium (me per litre) | 0.01 | 0.01 |

| | | |
|---|---|---|
| Calcium (me per litre) | 4.22 | 3.14 |
| Magnesium (me per litre) | 7.24 | 1.02 |
| Sodium (me per litre) | 14.18 | 1.37 |
| Chloride (me per litre) | 11.32 | 2.08 |
| Sulphate (me per litre) | 4.33 | 1.87 |
| Bicarbonate (me per litre) | 6.16 | 1.48 |
| Carbonate (me per litre) | 1.21 | 0.00 |
| Boron (mg per litre) | 1.21 | 0.03 |
| Nitrate-N (mg per litre) | 1.50 | 3.50 |
| Ammonium-N (mg per litre) | 2.05 | 0.00 |
| Sodium adsorption ratio (SAR) | 5.92 | 0.95 |
| Class (USDA) | $C_4S_2$ | $C_2S_1$ |
| Total bacterial count (colonies per ml) | 10 | 25 000 |

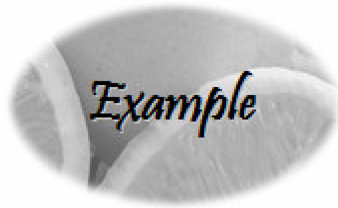
Although all the components of the water do not require attention they have to be noted and logged into the database.

## 4. <u>Determining Crop Water Requirements and Soil Type</u>

Apply the skills and knowledge that you gained on this and previous levels to initiate the water quality management system for the two water sources with reference to the requirements of citrus trees and the soils.

## 5. <u>Identifying Corrective Actions and Areas to Be Monitored</u>

Some qualities of irrigation water can be changed to optimise production or managed to reduce the negative impact on production. Using the information previously supplied, select those factors that will have an impact on production, both directly and indirectly, and list them.

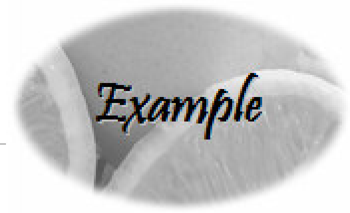



**<u>Identifying Areas that Require Attention</u>**

| | ***Borehole*** | ***Impact*** | ***Dam*** | ***Impact*** |
|---|---|---|---|---|
| Suspended material (mg per litre) | 5 | No | 139 | Yes |
| pH | 8.23 | Yes | 6.55 | No |
| Electrical conductivity ($mSm^{-1}$) | 171 | Yes | 55 | No |
| Total dissolved solids (mg per litre) | 1109 | Yes | 355 | No |
| Potassium (me per litre) | 0.01 | No | 0.01 | No |
| Calcium (me per litre) | 1.22 | No | 3.14 | No |
| Magnesium (me per litre) | 4.24 | Yes | 1.02 | No |
| Sodium (me per litre) | 5.68 | Yes | 1.37 | No |
| Chloride (me per litre) | 5.45 | Yes | 2.08 | No |

| | | | | |
|---|---|---|---|---|
| Sulphate (me per litre) | 1.33 | No | 1.87 | No |
| Bicarbonate (me per litre) | 4.16 | Yes | 1.48 | No |
| Carbonate (me per litre) | 0.22 | Yes | 0.00 | No |
| Boron (mg per litre) | 1.21 | Yes | 0.03 | No |
| Nitrate-N (mg per litre) | 1.50 | No | 3.50 | No |
| Ammonium-N (mg per litre) | 2.05 | No | 0.00 | No |
| Sodium adsorption ratio (SAR) | 3.44 | Yes | 0.95 | No |
| Class (USDA) | $C_3S_1$ | | $C_2S_1$ | |
| Total bacterial count (colonies per ml) | 10 | No | 25 000 | Yes |

The physical and biological water quality factors must be dealt with in order to use a micro-jet or drip irrigation system. The chemical water quality factors that need attention are also listed, with an indication of whether it can be solved or must be managed.

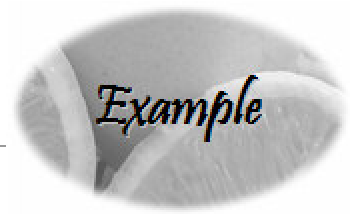



**Identifying Corrective Actions and Areas to Be Monitored**

| ***Component*** | ***Assessment*** | ***Action*** |
|---|---|---|
| **Borehole Water** | | |
| pH, bicarbonate and carbonate | Too high for pesticide sprays | Acidify whenever a spray tank is filled |
| EC and TDS | Too high | Related to soil maintenance and need to be monitored |
| Magnesium | Could induce potassium deficiencies | Related to fertilisation and need to be monitored |
| Sodium and SAR | Accumulation will cause crusting and collapse of soil structure | Related to soil maintenance and need to be monitored |
| Chloride | Accumulation will cause increase in osmotic potential | Related to soil maintenance and need to be monitored |
| Boron | Too high and will cause phytotoxicity | Related to fertilisation and need to be monitored |
| **Dam Water** | | |
| Suspended solids | Cause clogging of emitters | Ensure optimal functioning of filtration system |
| Total bacterial count | Single cells and spores will pass the filters and increase clogging hazard | Program for monitoring bacterial counts and sterilisation |

## 6. Developing Task Lists for Monitoring and Corrective Actions

Developing task lists for monitoring and corrective actions must take into account equipment and procedures to monitor, evaluate, and report on the results of tests or evaluation and actions taken. This step involves listing the water quality factors that need to be monitored (what), the intervals (when), prescribe the procedures (how) and assign the staff (who) responsible to do or oversee the tasks.




**Task Lists – Borehole Water**

| *What* | *When* | | *How* | *Who* |
|---|---|---|---|---|
| | **Borehole** | **Dam** | | |
| Suspended material | - | Twice pa | Lab+FP | WQM+OM |
| Incidence and nature of clogging | Twice pa | Twice pa When emitter is replaced | FP | OM |
| pH | Monthly | Twice pa | FP1 | OM |
| Acidification | Twice pa | Twice pa | FP2 | OM |
| Electrical conductivity | Weekly | Twice pa | Lab+FP3 | OM |
| Leaching requirement | Twice pa | - | FP4 | OM |
| Magnesium | Twice pa | Twice pa | Lab | WQM |
| Sodium | Twice pa | Twice pa | Lab | WQM |
| Salinity | Twice pa | - | FP5 | OM |
| Chloride | Twice pa | Twice pa | Lab | WQM |
| Bicarbonate | Twice pa | Twice pa | Lab | WQM |
| Carbonate | Twice pa | Twice pa | Lab | WQM |
| Boron | Twice pa | Twice pa | Lab | WQM |
| Sodium adsorption ratio | Twice pa | Twice pa | Lab | WQM |
| Crusting | Twice pa | - | FP6 | OM |
| Total bacterial count | Twice pa | Twice pa | Lab | WQM |
| Slimes forming | - | Twice pa | FP7 | OM |

**Lab:** Tests done in a suitable laboratory
**FP:** Farm procedure 1 to 7 applicable to the specific test
**OM:** Orchard manager

Even though some water quality factors, such as suspended solids or bacterial counts, were within the optimal range when the analysis was done, they must be retested at least twice per annum.

## 7. Developing Recordkeeping Systems

Records refer to not only the findings and results of the tests that are done in accordance with the task list above, but also to the procedures that are developed as part of the water quality management system.

### 7.1. Farm Procedures

Farm standard operating procedures are developed to prescribe the manner in which certain tasks must be undertaken on the farm. These procedures also form the basis for staff training programs. Farm procedures are developed to ensure that all the objectives of the water quality management system is achieved, being effective monitoring, identification of corrective actions and the implementation of corrective actions. If all procedures are implemented and applied as prescribed, there should in fact be certainty that the water quality is being managed optimally.

The following are examples of procedures that are generally used on farms and that are referred to in the example in section 2.4:

- FP1: Evaluating laboratory report on suspended solids
- FP2: Evaluating suspended material in the backwash from filters
- FP3: Evaluating suspended material when laterals are flushed
- FP4: Evaluating suspended material in clogged emitter
- FP5: Measuring water EC
- FP6: Evaluating leaching requirement, salinity and SAR
- FP7: Evaluating crusting and infiltration
- FP8: Measuring water pH
- FP9: Determining volume acid to be added
- FP10: Evaluating boron concentrations
- FP11: Evaluating magnesium concentrations
- FP12: Evaluating slime-forming microbes
- FP13: Standard procedures for logging collected results
- FP14: Standard procedures for reporting
- FP15: Standard procedure for issuing action plans

### 7.1.1. FP1: Evaluating Laboratory Report on Suspended Solids

Compare the results to the set of standards supplied by DWAF in table 1.2. This is a straightforward comparison.

### 7.1.2. FP2: Evaluating Suspended Material in the Backwash from Filters

Collect a sample of the water during backwashing when the water is the dirtiest. Allow the suspended material to settle. Note the cloudiness of the supernatant water (water above the settled solids). If the supernatant remains cloudy for more than 60 minutes, the sediment contains clay particles.

Inspect the sediment for the following indicators:

- Grittiness indicates sand or solid precipitates of iron, manganese or sulphites
- Pieces of plastic or metal from pipes and other component are easily recognisable
- Whitish salts indicate calcium and / or magnesium carbonate or calcium sulphate
- Apply diluted acid and a fizzing reaction will confirm the presence of carbonates
- If the white material does not fizz but dissolves it can be any other salt
- A slimy feeling is an indication of silt
- A slimy feeling and filament-like appearance indicate slimes due to microbial activity

### 7.1.3. FP3: Evaluating Suspended Material When Laterals Are Flushed

Open one lateral line and note at what stage the water is the most loaded with suspended material. Collect the dirtiest volume of water at three to five laterals in a bucket. Note the cloudiness and inspect the sediment at the bottom of the bucket as described in FP2.

### 7.1.4. FP4: Evaluating Suspended Material in Clogged Emitter

Cut the emitter to expose the flow path. Remove the solid material and put it to the test as described in FP2.

### 7.1.5. FP5: Measuring Water EC

You should by now be familiar with the test that is done to measure the EC of water, as described in Chapter 3.2 of the level 2 learner guide.

### 7.1.6. FP6: Evaluating Leaching Requirement, Salinity and SAR

To evaluate the salinity and SAR, soil and leaf samples have to submit to a competent laboratory. For the evaluation of the SAR see table 1.3 in chapter 1. To evaluate chlorides and sodium leaf or soil analyses can be used, with the following guidelines:

- The relative concentration of sodium in the soil must be less than 5%
- The maximum concentration of sodium in the leaves should be 2,000mg/kg
- The maximum concentration of chloride in soil must be less than 50mg/kg
- The maximum concentration of chloride in the leaves should be 0,65%

### 7.1.7. FP7: Evaluating Crusting and Infiltration

Crusting results in a decrease in the infiltration rate of water into the soil. The first step is to see if any free water accumulates when the irrigation cycle is almost completed. If there is no accumulation of water, crusting is not causing a problem.

If free water is accumulating, note the number of hours from when irrigation starts until the first free water appears. If free water accumulates before less than 80% of the irrigation is completed, crusting could be a problem.

Compare the observation with previous readings. A decrease in time from start to first free water indicates a decrease in infiltration rate and possible crusting.

### 7.1.8. FP8: Measuring Water pH

You should be familiar with the tests that can be done to measure the pH of water, as described in Chapter 3.2 of the level 2 learner guide.

### 7.1.9. FP9: Determining Volume Acid to Be Added

You should by now be familiar with the procedure of using a pilot plant to determine the volume of acid that is required for the adjustment of the pH of water. The procedure was described in detail in a activity that was part of the level 2 learner workbook.

### 7.1.10. FP10: Evaluating Boron Concentrations

Boron concentrations can only be evaluated with the help of soil and / or leaf analysis, with leaf analysis being more reliable. The laboratory results are evaluated as follows:

- When the soil concentration of boron exceeds 2mg/kg when using the hot-water extraction method, boron toxicity can be expected.

- When the concentration of boron in the leaves exceeds 200mg/kg, the trees are suffering from an excess of boron.

The current analytical data must be compared with previous results to indicate the trend of magnesium concentration in the soil and leaves. The trend is indicated as indifferent, increasing or decreasing.

### 7.1.11. FP11: Evaluating Magnesium Concentrations

Magnesium concentrations can only be evaluated with the help of soil and / or leaf analysis. The laboratory results are evaluated as follows:

- When the relative concentration of magnesium in the soil exceeds 25% and that of potassium is less than 5%, a problem with absorption of potassium can be expected.

- When the concentration of magnesium in the leaves exceeds 0.5%, the absorption of potassium could be inhibited.

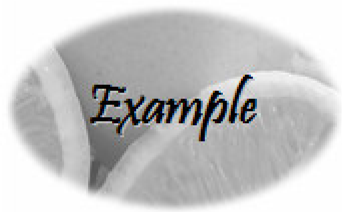
Compare the current analytical data with previous results to identify the trend of magnesium concentration in the soil and leaves. The trend is indicated as indifferent, increasing or decreasing.

### 7.1.12. FP12: Evaluating Slime-Forming Microbes

The effects of slime-forming microbes are visible in the water when the laterals are rinsed or in clogged emitters. See FP2 above.

### 7.1.13. FP13: Standard Procedures for Logging Collected Results

The most important aspect of data collection is that the results must be traceable to the orchard, irrigation block, lateral and emitter observed, inspected or analysed. Below is an example of an observation log.




**Observation Log**

| *Date* | *Orchard* | *Lateral* | *Objects in Rinsing Water* |
|---|---|---|---|
| 22/01/05 | 17A | 12 | Silty material with filaments, pieces of plastic cuttings |
| | | 24 | Silty material with filaments, pieces of plastic cuttings |
| | 17B | 12 | Silty material with filaments |
| | | 24 | Silty material with filaments |
| | 18A | 10 | Very little suspended material |

### 7.1.14. FP14: Standard Procedures for Reporting

The collected results are evaluated by means of comparisons with standards and comparison with previous records of the same orchards. The most important aspect of reporting is that the data must be presented in a concise manner to highlight the problem and / or action required. Report on the conclusions only. From the results in the example above, the following needs to be reported:

- **Orchards 17A and 17B** – Slime-forming microbes increased, plastic cuttings present

- **Orchard 18** - Nothing to report (This can be omitted, provided that the standard procedure states that if nothing is reported, all is within the operational protocols.)

The procedure for reporting on results and trends depends on the size of the farm and production practices that are employed – if dripper irrigation is used, for instance, it will be necessary to report on microbial slimes more frequently.

Reporting procedures also depends on the general water quality. If the water quality from a particular source is generally good, it does not need to be monitored as closely.

### 7.1.15. FP15: Standard Procedure for Issuing Action Plans

The most important aspect of issuing action plans is that it must be clear with no space for misunderstandings. Clearly indicate what must be done, how must it be done, when must it be done and who must do it (WHWW).

Example

**Action Plan**

| ***Orchard*** | ***What*** | ***How*** | ***When*** | ***Who*** |
|---|---|---|---|---|
| 17 | Chlorinate | Shock treatment | Before 25/01/05 | Peter |
| | | | | |

## 7.2. Monitoring Records

Action plans that are developed according to the farm procedure are used to allocate specific tasks to specific time slots, allowing farm management to plan.

Monitoring records are used to monitor that specific tasks have been executed, in this case to ensure that the required tests, analysis and observations were done in accordance with the action plan. Data is not recorded on monitoring plans. Note that all the CCP are measured but only those that are not within the limits are recorded for future references.

Example

**Monitoring Records**

On-farm measurements and observations for borehole 5 and orchards 4, 5, 8, 9 and 12.

| ***Critical Control Point*** | ***Frequency*** | ***J*** | ***F*** | ***M*** | ***A*** | ***M*** | ***J*** | ***J*** | ***A*** | ***S*** | ***O*** | ***N*** | ***D*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pH | Monthly | √ | √ | √ | √ | √ | √ | √ | x | x | x | x | x |
| Acidification | Monthly | √ | √ | √ | √ | √ | √ | √ | x | x | x | x | x |
| Electrical conductivity | Bi-monthly | | √ | | √ | | √ | | x | x | x | | x |
| Leaching requirement | Twice pa | | | | √ | | | | | x | | | |
| Magnesium | Twice pa | | | | √ | | | | | x | | | |
| Sodium | Twice pa | | | | √ | | | | | x | | | |
| Salinity | Twice pa | | | | √ | | | | | x | | | |
| Chloride | Twice pa | | | | √ | | | | | x | | | |
| Bicarbonate | Twice pa | | | | √ | | | | | x | | | |
| Carbonate | Twice pa | | | | √ | | | | | x | | | |
| Boron | Twice pa | | | | √ | | | | | x | | | |
| Sodium adsorption ratio | Twice pa | | | | √ | | | | | x | | | |

√ – Done and report filed
x – Scheduled for this month unless a monthly action.

### 7.3. Recording Results

The results from tests and analyses are recorded in a format that suits the needs of the farm. Most importantly, the format must be easy to use and to understand, and the data that it contains must be easily converted to information that forms the basis for reporting.

*Example*

**Test Results**

Records for borehole 5 and orchards 4, 5, 8, 9 and 12.

| ***Critical Control Point*** | ***April*** | | | | ***September*** | | | |
|---|---|---|---|---|---|---|---|---|
| | **2004** | **2005** | **2006** | **2007** | **2004** | **2005** | **2006** | **2007** |
| pH | 6.81 | 6.53 | | | 7.22 | 7.31 | | |
| Electrical conductivity ($mSm^{-1}$) | 86 | 98 | | | 113 | 121 | | |
| Magnesium (me/litre) | 3.12 | 3.57 | | | 4.11 | 4.15 | | |
| Sodium (me/litre) | 1.22 | 1.31 | | | 1.26 | 1.52 | | |
| Bicarbonate (me/litre) | 1.78 | 1.53 | | | 1.86 | 1.93 | | |

## 8. Using the Water Quality Management System to Improve Production

The role of the water quality manager is to inform the irrigation, fertilisation and pest control staff of any change in the expected quality of the water.

The involvement of the water quality manager in evaluating the critical control points depends on the staff responsible for irrigation, fertilisation and pest control. For the purpose of this study the water quality manager will be involved in all the aspects namely, monitoring the:

1. Quality of the incoming water
2. Filtrated water
3. Acidified water
4. Clogging

Other factors that influence the efficiency of the irrigation like crusting, infiltration, salinization, and the concentrations of magnesium and boron can be better assessed by the fertilisation manager

*Summary*

**Chapter 5**

- In citrus production, a water quality management system focuses on monitoring water quality, identifying corrective actions that can be taken, and implementing corrective actions.
- Designing a water quality management system depends on the quality of the water, but must also incorporate the soil properties and the requirements of the specific crop.
- Designing a water quality management system involves analysing water quality in available sources, determining crop water requirements and soil type, identifying corrective actions and

areas to be monitored, developing task lists for monitoring and for corrective actions, and developing recordkeeping systems.

- Farm standard operating procedures are developed to prescribe the manner in which certain tasks must be undertaken on the farm.
- Monitoring records are used to monitor that specific tasks have been executed.
- The results from tests and analyses are recorded in a format that suits the needs of the farm, and reports are developed based on this information.


Complete activity 9 in the **Learner Workbook**.

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