LEARNER GUIDE

Water Quality

Level 2

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Title:		**Monitor Water Quality**					
Applied Title:		**Monitor Water Quality in Citrus Production**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Water Quality					
Context:		Citrus Production					
US No:	116077	**Level:**	2	**Credits:**	3	**Notional Hours:**	30
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Based on the Production Guidelines of:

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

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Directions

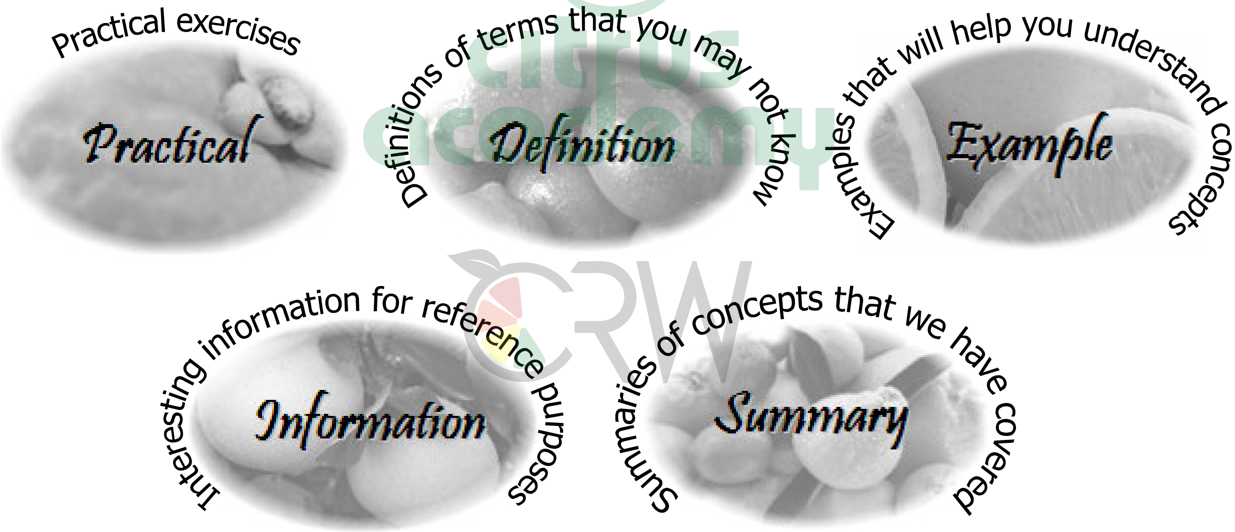
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

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 demonstrate an understanding of the importance of water quality to agriculture and to monitor and maintain water quality using established procedures. In addition, they will be well positioned to extend their learning and practice into other areas of agriculture and water management.

Learners will gain an understanding of sustainable agricultural practices as applied in the animal-, plant and mixed farming sub fields. The application of maintaining water quality practices in primary agriculture is focussed on in this unit standard.

They will be able to participate in, undertake and plan farming practices with knowledge of their environment. A culture of maintenance and care will be instilled for both the environment as well as towards farming infrastructure and operations by this unit standard.

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***
1 (ABET 4)	Literacy and Numeracy	
1	116168	Maintain basic water quality

Introduction to Citrus Production

1. Introduction

This learning material has been developed in the context of citrus production, which means that the skills area is dealt with in terms of and as applied to citrus production. To help the learner place the material in the right context, it is necessary for the learner to understand the background to citrus production, and the manner in which a citrus plant produces fruit.

2. Background

Citrus originates from the subtropical regions of south-east Asia. In the wild, citrus trees in these regions produce fruit all year round, and the fruit are small, poorly coloured and blemished. In the absence of effective production practices, citrus trees do not produce fruit suitable for the market.

Citrus production is largely concerned with management of the practices and processes that manipulate the tree to produce high yields of marketable fruit. Production management, together with the selection of superior varieties and plant improvement, can be seen as an on-going effort to influence the natural tendencies of the tree.

Consumers want the fruit of their choice to be available at all times. Fruit should look good, be unblemished, well-coloured (superior exterior quality), taste good (high interior quality) and be of the right size. At the same time, the citrus producer wants orchards that will provide high yields over an orchard lifespan of 18 to 30 years. On top of all this, the citrus orchard must be managed in such a way that production practices have the least possible impact on the natural environment. Commercial citrus production management is about achieving these objectives efficiently and cost effectively.

3. Citrus Planting

Citrus trees are planted in rows in orchards. The planting distance, also called tree spacing or espacement, between rows and between trees within rows, is determined by numerous factors including climate, variety, and soil type. A typical tree spacing is 6m between rows by 3m between trees, meaning that 555 trees per hectare (ha) are planted (1ha = 10,000 m^2).

Once planted, trees take three or more years before bearing fruit that can be marketed. Thereafter, per tree and per hectare yields steadily increase to 40 to 70 t/ha – depending on cultivar and variety – after a further 4 to 7 years. If the trees are well looked after, this level of production will remain fairly constant until trees start to decline naturally.

Yield

Yield refers to the amount of fruit produced, and can be expressed in terms of:

Tree yield	kg per tree	kg/tree
Orchard yield	tons per hectare	t/ha
Export yield	15kg carton equivalents per hectare (10kg carton equivalents for soft citrus)	cartons/ha

4. Lifespan

The average economic lifespan of a commercial citrus orchard varies between 18 and 30 years, and can be as high as 30 to 60 years in hot, dry areas. Citrus is therefore viewed as a long-term crop. For citrus production to be profitable, the orchard must produce high yields of quality fruit every year, and do this consistently over a long period of time.

In citrus production the challenge is therefore to make production decisions and take actions to ensure high annual production of marketable fruit, while ensuring that these decisions and actions contribute to the long-term sustainability of the orchard.

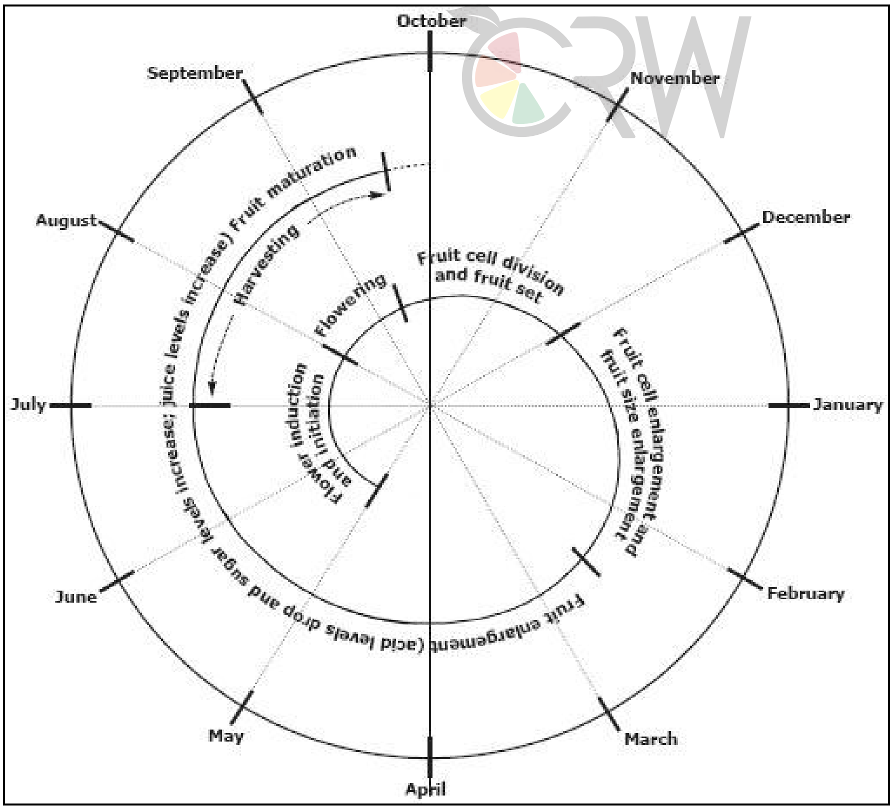
5. Citrus Plant Phenology

Phenology

Phenology refers to regularly recurring biological phenomena and the environmental and climatic factors that influence them. In citrus, phenology specifically refers to the annual cycle of the citrus tree.

Understanding the phenology of the citrus tree is essential to understanding the reasoning behind many of the practices and actions employed in citrus production. For example, the timing of fertiliser applications is linked to the phenology of the tree, with most fertilisers being applied at appropriate times to optimise flowering, fruiting, fruit development and fruit maturation.

The figure and table below set out the annual cycle of the citrus tree with regard to fruit production. Please note that this figure and table reflect the approximate flower and fruit development cycle of a valencia orange tree, and that the phenology of various cultivars differ.



Stage	*Description*	*Time Period*
Flower Induction and Initiation	Flower initiation is the induction and differentiation of vegetative buds into flower buds at a cellular level, and cannot be seen with the naked eye.	May to July
Flowering	Flowering or "bloom" is when blossoms appear on the tree.	August to Mid-September
Cell Division and Fruit Set	Cell division is the period when cells making up the fruit increase in number. Fruit set is the period from flowering or "bloom" until the end of fruitlet drop, after which the final fruit load is determined.	Mid-September to November
Cell Enlargement and Fruit Growth	Cell enlargement is the period during which cells making up the fruit increase in size. Fruit growth is the period during which the fruit grows and develops.	December to Mid-February
Fruit Maturation and further Fruit Growth	During this period fruit enlarges further and matures internally, meaning that the flavour, sugars and acids reach their optimum levels.	Mid-February to September
Harvest		July to September

It is important to note the term **citrus season** refers to the period from when flower initiation begins to the harvest. The season is generally from the beginning of August of one year to the end of July of the next year, although harvesting may extend to September and October for late cultivars.

6. Citrus Learning Material

The following citrus specific learning material is available from the Citrus Academy:

Skills Area	*Description*
Enterprise Selection, Planning and Establishment	Concerns itself with identifying the various components of an agricultural enterprise, and with the selection and planning processes for a new enterprise, and looks at the physical layout of a farm, with specific reference to infrastructure, orchard layout, etc.
Propagation	Concerns the various methods and requirements for the multiplication of plant material of specific varieties that possess desired qualities.
Crop Establishment	Concerns the establishment of a new citrus orchard, in terms of the physical planting of trees and the care for young trees.
Plant Structures and Functions	Considers the structure and function of various plant parts and the manner in which nutrients, water, air and sunlight is taken up and processed.
Plant Nutrition and Soil Management	Concerns itself with plant nutrients, in terms of the requirements of the citrus plant and the supplementation of nutrient elements through fertilisation, with specific reference to the timing and manner of application.
Water Quality	**Considers the various factors that influence water quality and manners in which water quality can be measured and controlled. Considers furthermore the effect of water quality on tree and fruit growth and development, in combination with effective irrigation, fertilisation and pest control.**

Skills Area	*Description*
Plant Manipulation	Concerns various types of physical and chemical plant manipulation, with specific reference to pruning, girdling and the application of plant growth hormones, and tools and equipment used for this purpose.
Irrigation	Looks at the technical aspects of orchard irrigation, with reference to the types of irrigation systems, the installation of new irrigation systems, and the repair and maintenance of an irrigation system. Also concerns irrigation scheduling, and measures to ensure effective irrigation.
Pests, Diseases and Weeds	Concerns the identification of pests, diseases and weeds that threaten citrus production. Also considers various methods of effective control, and the planning required for this purpose.
Crop Protection	Looks at the practical application of crop protection agents through various methods, with specific reference to tools and equipment used, and health and safety requirements.
Food Safety	Concerns the requirements in terms of health and safety, and environmental control for ensuring food safety and hygiene.
Harvesting	Looks at the process of determining fruit maturity through maturity indexing, the harvesting of fruit, and the tools and equipment used for this purpose.
Conservation	Considers the impact of farming practices on the environment, with reference to the measures required to minimise this impact and protect the environment.
Marketing	Concerns the factors influencing citrus marketing, and the development of an effective marketing plan.
Production Management	Concerns the actions and processes involved in effective production management, with specific reference to the coordination of the various production tasks and processes and the creation of a strategic plan for the enterprise.
Industry Overview	An overview of the citrus industry and the various institutions involved.
Packhouse Practices	Concerns the specific principles and practices that are employed in the packhouse environment, and specifically: • Citrus Product Characteristics • Understanding Citrus Fruit Markets • Health and Safety in the Packhouse • Personal Hygiene Requirements for Packhouse Personnel • Understanding and Maintaining the Cold Chain • The Role of Quality Checks in the Packing Process • The Application of Fruit Treatments • The Application of Pre-Sorting Prior to Packing • Receiving Fruit into the Packhouse • Grading Fruit in the Packhouse • Packing and Packaging Materials • Palletisation of Packed Fruit • Storage of Fruit • Dispatch and Transportation of Packed Fruit • Understanding Automated Packing Solutions

Chapter 1

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

Demonstrate an understanding of water quality management

1. Introduction

Water is used in citrus production to irrigate trees, and to apply nutrients and pesticides to the leaves through foliar sprays. Profitable production of citrus is not possible in Southern Africa without irrigation, through which an adequate supply of water must be provided to ensure economic yields, the required fruit size and quality.

Trees are irrigated using one of the following methods:

- Irrigation with micro-jets
- Irrigation with drippers
- Basin irrigation
- Flood irrigation
- Under-tree-sprinklers

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.

The water quality factors of relevance in citrus production depend on the irrigation method employed on the specific farm. Micro-jets are the most popular method used in commercial citrus production, with drip irrigation the second most common method.

In its purest form, water contains only water molecules with the chemical formula of H_2O, meaning each molecule consists of two hydrogen (H) atoms and one oxygen (O) atom. Water is however an excellent medium for many other materials, such as salts, to dissolve in. Water is also host to a variety of organisms, and furthermore often carries insoluble and suspended material.

These properties of water cause its quality to be variable and are why it is polluted so easily. All the non-water components dissolved, living or suspended in water are regarded as foreign materials. These foreign materials are responsible for the chemical, physical and biological quality factors of water.

The type and concentration of foreign materials determine the quality of the water. Managing water quality therefore concerns six critical control points, namely:

- Determining the quality of the water received on the farm;
- Identifying the causes of the said quality;
- Being aware of the quality standards of water for citrus production;
- Improving the quality of received water where possible;
- Identifying water quality factors that cannot be improved and need to be managed; and
- Managing the quality of the water leaving the farm.

In most cases, the water quality manager has little say in the quality of the water received on the farm. The manager has to make the best of what water is available to produce citrus profitably. However, the manager can influence the quality of the water leaving the farm, and must take this responsibility seriously.

2. Physical Water Quality Factors

Physical water quality factors are influenced by all the foreign materials that do not dissolve in the water, and that can usually be seen with the naked eye. These materials pose problems primarily to the irrigation system.

Micro-jets and drippers have very narrow openings (0.25mm to 2.50mm diameter) and are blocked by any material that is too large to pass through, or that accumulates in this narrow pathway. When partly or totally blocked, the micro-jet or dripper cannot deliver the required volume of water to the trees.

The following materials influence the physical quality factors and are often responsible in clogging the drippers or micro-jets:

- Inorganic materials, such as clay, silt and sand;
- Organic debris, such as remnants of plants, seeds, animals, aquatic fauna and flora;
- Living aquatic plants and animals, such as algae and snails;
- Plastic cuttings from the irrigation pipes and equipment; and
- Lubricant residues

While the first three contaminants can usually not be controlled and must be managed, the last two contaminants can be controlled by taking the necessary steps to prevent contamination by plastic cuttings and lubricant residues.

3. Chemical Water Quality Factors

The chemical water quality factors refer to the non-visible components in water. Instruments are used to determine their presence and concentration. Chemical water quality factors are very important, because they determine the short- and long-term potential and sustainability of the entire plant production system. Chemical quality factors affect:

- Crop production;
- Sustainability of the productivity of the soil; and
- The effective operation of the irrigation system.

The most important chemical water quality factors and their impact on each of these areas are shown in table 1.1, with the following classifications:

- **Y** = This factor has an impact
- **Y/N** = This factor may have an impact depending on other factors
- **N** = This factor seldom has an impact

Chemical Water Quality Factors	***Crop Production***	***Soil Productivity***	***Irrigation System Efficacy***
Total soluble salts	Y	Y	Y
pH	Y	Y	Y
Calcium	Y	Y	Y/N
Magnesium	Y	Y/N	Y/N
Sodium	Y	Y	N

Chemical Water Quality Factors	***Crop Production***	***Soil Productivity***	***Irrigation System Efficacy***
Chloride	Y	Y/N	N
Bicarbonate	Y	Y/N	Y/N
Boron	Y	Y/N	N
Iron, manganese and sulphides	N	N	Y

Table 1.1: The Impact of Chemical Water Quality Factors

Definition

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**.

4. Water Quality Management

Water quality management (WQM) is the evaluation of:

- The impact of the incoming water on the soil, the tree and the efficiency of the irrigation system;
- Steps that can be taken to remove or neutralise negative factors; and
- Steps that can be taken to manage economically those factors that cannot be altered.

In short, WQM has to do with managing foreign material in the water, and not with the water itself.

Summary

Chapter 1

- Irrigation is used in citrus production to supply plants with the water they need in addition to rainfall.
- Water quality factors that are important depend on the type of irrigation system used. Micro-jet irrigation is the most commonly used in South Africa and drip irrigation the second most common.
- Water dissolves many substances, such as salts, and is a carrier for a lot of suspended material, which influences the water quality, and which is why it is polluted to easily.
- Water quality management (WQM) has to do with managing foreign material in the water, and not with the water itself.
- Water quality management concerns six critical control points, being:
  - Determining the quality of the water received on the farm;

  - Identifying the causes of the said quality;
  - Being aware of the quality standards of water for citrus production;
  - Improving the quality of received water where possible;
  - Identifying water quality factors that cannot be improved and need to be managed; and
  - Managing the quality of the water leaving the farm.
- Physical water quality is determined by the foreign material that does not dissolve in the water. These materials can clog emitters and pipes.
- Chemical water quality refers to the non-visible qualities of water and affects crop production, the sustainability of the soil productivity and the effectiveness of the irrigation system.

Complete activities 1 and 2 in the **Learner Workbook**.

Chapter 2

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

Demonstrate an understanding of the importance of water to agriculture

1. The Importance of Water Quality

The final evaluation of water quality is its effect on sustainable crop production. In citrus production, it is measured by the yield of quality fruit according to the demands of local and export markets. Water quality has a **direct** and **indirect** influence on citrus production and fruit quality.

1.1. Direct Effects

The direct effects of water quality include:

- The concentration of salts dissolved in the water has a direct effect on the water available to the tree. The higher the salt content, the more energy is required by the tree to utilise the water. Remember that dissolved fertilisers add to the salt content of the water.
- Magnesium (Mg) is a plant nutrient, but can cause imbalances at high concentrations. A high concentration of magnesium interferes with the utilisation of potassium (K).
- Citrus trees require fairly high concentrations of nitrogen from July to September, which is their active vegetative growth stage. After September, the concentrations of nitrogen must be decreased. From January to June, very small amounts of nitrogen or none at all must be applied. If the water contains too much nitrates, the reduction in applied nitrogen from October, and the very low application rate in January to June, cannot be achieved. Too much nitrogen during January to June will reduce fruit quality and yield.
- The high pH of water is caused by the bicarbonates. In water with low total dissolved solids, a little bicarbonate can cause a high pH. Too high pH reduces the availability of nutrients, especially the micro-nutrient elements.
- High concentrations of chlorides in water used for foliar sprays can cause scorching of the leaves.
- Although boron (B) is an essential nutrient element for plants, it is required in low concentration and can easily be over-supplied by water containing more than 1mg boron per litre.

1.2. Indirect Effects

The indirect effects of water quality include those factors that have a detrimental effect on soil properties, the efficacy of foliar sprays and blocking of the emitters (micro-jets and drippers).

- Sodium adsorption ratio (SAR) is a measurement of the potential hazard posed by the sodium in the water to the soil. Water with high sodium content will gradually reduce the stability of the soil structure. A stable structure of the soil is required to promote water penetration and root development.

- The efficiency of foliar sprays to supplement nutrients depends on the pH and buffer capacity of the water used to mix the chemical. The optimal pH for the uptake of nutrients from foliar sprays is 5 to 6.

- The half-life of some insecticides and pesticides depend on the pH of the water used in the spray solution.

- Blocked emitters will discharge less water than intended or none at all. The distribution of the water will also not be optimal. Therefore some trees will receive too little water and production will be reduced.

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.

2. Improving Water Quality

To improve the physical water quality factors of huge volumes of water used for irrigation is quite easy and cheap compared to the processes required to improve the chemical quality factors.

A high salt concentration or total dissolved salts (TDS) of irrigation water is the most important chemical quality factor. The TDS in water has a direct effect on most of the other water quality factors. Reducing the concentration of salts in irrigation water involves huge inputs of energy and is not an economical option for agriculture in South Africa. Processes that result in desalting (desalinisation) of the water involve reverse osmosis (RO), distillation, and deionisation or demineralisation.

Reverse Osmosis

Reverse osmosis is 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

Distillation is 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

Deionisation is the removal of ions from water by exchange with other ions associated with fixed charges on a resin.

The quality of irrigation water can however be improved by focussing on specific factors that can be improved economically.

2.1. Improving Physical Water Quality Factors

Improving the physical quality factors of irrigation water involves processes such as sedimentation and filtration.

2.1.1. Sedimentation

Sedimentation is a process whereby the flow of water is reduced and the suspended material is allowed to settle to the bottom. This is done by letting the water into a storage dam from where it is pumped to the orchards. During the time the water is in the storage dam, the flow is reduced to zero and solid particles settle.

Sedimentation is effective for removing solids such as clay, silt, sand, cuttings and some organic debris. However, when the water has a high SAR, the clay settles slowly and in severe cases, the clay remains in suspension.

2.1.2. Filtration

Filtration is a process where water is passed through a structure, called a filter, with very small openings which allow the water to pass through, but trap insoluble suspended particles. Filtration does not remove dissolved salts.

The small openings in the filter are created by filling a container with sand (a sand filter), by a series of plastic discs containing narrow spleens on their flat surfaces that are fitted together (a disc filter), or by a series of steel plates with small holes in or mesh wire (screen filter).

2.2. Improving Chemical Water Quality Factors

Chemical water quality factors can either be improved or dealt with under certain conditions by one of the following processes:

- Correcting the pH
- Oxidation
- Dealing with Sodium Adsorption Ratio (SAR)
- Dealing with chlorides

2.2.1. Correcting the pH

It is not economically viable to correct the pH of irrigation water, because such large volumes are required. However, for water that is used for applying pesticides, adjusting the pH is always justifiable due to the cost of the pesticide, the small volumes of water required, and the potential lost in exportable yield if the pesticide is less effective. The volume of acid needed for the correction of the pH of water can be determined by titration, using a pilot plant.

The pH of water can also be reduced by adding commercially available buffers. These buffers are usually mixtures of inorganic and/or organic acids. Application directions are supplied with each product.

Some pesticides are more active at pH values higher than 6.50. Although this is not required often, special formulations of buffer solutions are available to increase the pH to the desired level. Increasing the pH of irrigation water is seldom required, but if high water acidity causes too much damage to the irrigation system, in the form of corrosion, a specialised investigation is called for.

Correcting the pH of Water

Information Supplied:

- 7.5ml acid is required to decrease the pH of 20 litres water to 5.5
- The spray machine has a capacity of 2,000 litres

Calculation:

- Requirement per litre: 7.5 / 20 = 0.375ml per litre
- Requirement for 2,000 litres: 0.375 x 2,000 = 750ml per 2,000 litres required to reduce pH to 5.5

2.2.2. Oxidation

When water gets in contact with air, dissolved metals like iron and manganese are oxidised to their insoluble form and settles to the bottom of the water. Oxidation can be accelerated through spraying the water through the air into a storage dam.

2.2.3. Dealing with Sodium Adsorption Ratio (SAR)

The SAR of water influences the soil. An SAR value of more than one indicates a possible sodium hazard. It is dealt with as part of the soil maintenance program.

2.2.4. Dealing with Chlorides

Too high concentrations of chlorides can be dealt with, to some extent, by supplying to the tree more or all nitrogen in the form of nitrates, and supplying the tree with more calcium. This is best done with fertigation and a drip irrigation system.

Fertigation

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

2.3. Improving Quality of Water Leaving the Farm

A very important aspect of water quality management is to improve the quality of the water leaving the farm, thereby improving the downstream quality. If the upstream users prevent or reduce contamination, downstream users will have fewer problems.

Prevention involves the following processes:

- Preventing nitrogen leaching
- Preventing excessive application of chlorides
- Preventing excessive runoff
- Preventing dumping

2.3.1. Preventing Nitrogen Leaching

Nitrate nitrogen is easily leached from the soil and will end up in underground or surface waters. Optimising the application of nitrogen and water will reduce leaching of nitrates.

2.3.2. Preventing Excessive Application of Chlorides

Like nitrates, chloride also leaches easily and will end up in the subsoil, underground- or surface water. The application of chlorides should therefore also be controlled carefully.

2.3.3. Preventing Excessive Runoff

When water is applied at rates in excess of the infiltration rate of the soil, runoff occurs. Runoff water carries nutrients and soil particles, and adds to the problem of suspended solids, unwanted nitrates and phosphates, and increasing the electrical conductivity of water. Runoff water also causes soil erosion.

Electrical Conductivity (EC)

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

2.3.4. Preventing Dumping

Dumping any chemicals or materials that can causes pollution or contamination of water sources is strictly prohibited. However, even approved dumping sites can add to the deterioration of the quality of water. Even French drains and other approved methods of getting rid of refuse can cause pollution problems.

Regulations regarding the safe disposal of chemicals and other harmful materials must be strictly adhered to at all times.

3. Sampling and Monitoring Water Quality

To monitor the quality of the water, samples are taken at the water source, tested and analysed. Water quality is monitored on a regular basis, including the quality of:

- Water received on the farm, whether it be water received from a river or underground water received through boreholes;
- Water contained in storage dams; and
- Water leaving the farm

Sampling is the process where the body of water to be sampled is reduced in volume so that it can be transported to a laboratory. Although this sounds strange, it is important to understand that a proper sample is not just a piece of the body of water, but a very small but true reflection or representation of the entire body. The volume of a water sample is usually 500ml, but this 500ml can represent millions of litres water. Always keep this in mind when taking a water samples.

Ensure that the 500ml taken is **exactly the same** as the millions of litres of water in the dam or river, in all aspects that are to be measured and tested. Sampling, and water quality tests and analyses are discussed in detail in chapter 3.

Summary

Chapter 2

- Water quality has direct and indirect effects on crop production and fruit quality.
- The direct effects of water quality include high salt content causing less water being available for the tree, a high concentration of magnesium interfering with the utilisation of potassium, high concentrations of nitrogen during January to June causing reduced fruit quality and yield, high water pH reducing the availability of nutrients, high chlorine levels in water used for foliar sprays causing scorching, and an oversupply of boron.
- Indirect effects refer to factors that negatively impact on soil, the efficacy of foliar sprays, and that cause the blocking of emitters.
- Indirect effect of water quality include a high water sodium content gradually destroying the soil structure, the pH value of water used for foliar sprays negatively effecting the efficacy of the sprays and influencing the half-life of certain chemicals, and blocked emitters causing uneven and insufficient water-spread.
- It is easier and cheaper to control physical water quality factors than chemical water quality factors for large volumes of water.
- Physical water quality factors can be improved through sedimentation and filtration.
- Chemical water quality factors can be improved by correcting the pH (mostly for water used for foliar sprays) and oxidation, while certain chemical water quality factors can be compensated for by dealing with the SAR in the soil maintenance program, and dealing with chlorides by supplying trees with more calcium and supplying nitrogen as nitrates.
- The quality of water leaving the farm can be improved by preventing nitrogen leaching, controlling the application of chlorides, preventing water runoff, and preventing dumping.
- Water received on the farm, stored in dams and leaving the farm is regularly tested to determine its quality.
- A sample is not a piece of the whole, but the whole reduced to a manageable volume.

Practical

Complete activities 3 and 4 in the **Learner Workbook**.

Chapter 3

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

Demonstrate an ability to monitor and perform basic water quality tests and analyses

1. Preparing Water Samples for Analysis

Care must be taken when sampling to ensure that the sample is not contaminated while or after it is taken. The following steps are involved in preparing water samples for analysis:

- Preparing containers
- Taking water samples
- Labelling containers

1.1. Preparing Containers

The most appropriate container for water samples is a plastic bottle with a screw cap. In practise, 500ml mineral water or cold drink bottles made from polycarbonate is very suitable for this purpose. Special bottles for water sampling are also available on the market.

Wash all containers that are being reused properly with warm water, but do not use a detergent. Take care that the cap is also washed properly. Do not use caps with cardboard or absorbing seals. Before taking a sample in a properly washed reused or new container, rinse it three times with the water to be sampled. Also rinse the caps.

1.2. Taking Water Samples

The standard procedure for sampling water is as follows:

- Rinse the container and cap three times with the water to be sampled;
- Fill the bottle to capacity and screw the cap on, leaving **no** air space at the top;
- Label the bottle; and
- Put aside in the shade and dispatch as soon as possible to the laboratory.

Although this standard procedure remains the same on principle, special procedures are followed when sampling water from various water sources.

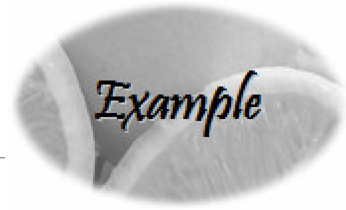
- ***Canals*** – Sample the water in the middle of a running canal.
- ***Boreholes*** – Let the pump run for at least one hour or for as long as it takes to fill all piping with fresh water. Never sample the water standing in the pipes.
- ***Storage Dams*** – Take the sample away from the sides or wall of the dam and 50cm below the surface.
- ***Rivers*** – Take the sample in the flow of the river. Standing water accumulates suspended material and has a higher concentration of salts.

- ***Water from Irrigation Pipes*** – If the purpose of the sampling is to measure the quality of the irrigation water, remove a micro-jet or open the end of a lateral line. Let the water run to flush the pipes, and then fill the bottle. If the purpose is to measure the type and mass of the deposits, open the end of two or three laterals into a suitable container with a capacity of about 50 litres. Then take the sample from this container while stirring the water.

1.3. Labelling Containers

Never write directly on the bottle, because the lettering could be rubbed off during transportation. Stick a label onto the container or tie it to the neck of the bottle. Write all relevant information on the label with a waterproof pen. The minimum information on the label includes:

- The name of the farm or farmer;
- The identification number or name of the water source;
- If only one water sample is submitted, also write the contact information of the farm or farmer on the label. Where more than one sample is submitted from the same farm or farmer, at least one label should contain all the relevant information and the rest only the farm or farmer name and the name or number of the water source.



Leaf Sample Labels

AA Farming **LARGE DAM** P.O. Box 21 Nkwalini 3816 **Tel:** (035) 460-0066 **Fax:** (035) 460-5467 **Order Number:** SF20212 **Contact:** J. Ralepele (082-987-6543)	**AA Farming** **SMALL DAM**

2. Performing Simple Chemical Water Quality Tests

Water quality tests that need to be done on a continuous basis are pH tests and electrical conductivity (EC) tests. These two tests are relatively simple, and do not require a lot of expensive equipment.

2.1. pH Testing

The following equipment and instrumentation is required:

- A pH meter, which can be a handheld or desktop instrument
- Alternatively, special pH sensitive paper strips, but **not** Litmus paper
- Glass or plastic beakers
- Washing bottle containing demineralised water
- Reagents
- pH buffer solutions for pH7 and 4 (or another two with pH ranges that include the pH of the water to be tested)

Definition

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.

The following procedure is followed when a pH meter is used:

- Switch the pH meter on and let it warm-up according to the instructions of the manufacturer;
- Rinse the electrode with demineralised water;
- Mark two beakers pH 4 and pH 7, and pour the appropriate pH buffer into each beaker;
- Insert the electrode into buffer solution pH 4. Set the pH meter to read pH 4;
- Remove the electrode from the buffer and rinse with demineralised water in a separate beaker;
- Insert the electrode into buffer solution pH 7. Set the pH meter to read pH 7;
- Remove the electrode from the buffer and rinse with demineralised water in a separate beaker;
- Repeat the process with buffer solutions until the instrument reads 4 and 7 when inserted into the buffer solutions;
- Rinse the electrode well with demineralised water;
- Insert the electrode into the water sample. Let the reading stabilise before it is noted on the report (reading A);
- Rinse the electrode and take a reading of one of the pH buffer solutions. Note the reading (reading B).

PH sensitive paper strips change colour when coming into contact with a substance that is not pH neutral. The following procedure is followed when pH sensitive paper strips are used:

- Pour either the pH buffer solution of pH 4 or pH 7 into a marked beaker;
- Insert a strip into the beaker and keep it there for the required period, according to the product instructions;
- Verify the colour of the paper strip with the colour chart. This compares to reading B in the previous procedure;
- Insert a strip into the water sample and keep it there for the required period;
- Compare the colour of the paper strip with the pH colour chart. Note the pH according to colour. This compares to reading A in the previous procedure.

2.2. Electrical Conductivity (EC) Testing

The following equipment and instrumentation is required:

- An appropriate EC meter, which can be a handheld or desktop version;
- Washing bottle with demineralised water;
- Glass or plastic beakers;
- Reagents;
- Standard solution of for instance 1,000g potassium chloride per litre water

The following procedure is followed:

- Standardise the instrument according to the instructions of the manufacturer using the standard potassium chloride solution;
- Rinse the electrode of the EC meter in demineralised water;
- Insert it into the water sample;
- Note the reading (reading C);
- Rinse the electrode of the EC meter in demineralised water;
- Insert it into the standard solution;
- Note the reading (reading D).

3. Reporting on Water Quality Tests

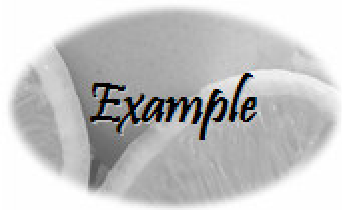
Reporting on water quality involves three steps, namely:

- Ensuring that the value of the reference standard is acceptable
- Ensuring that the units are correct
- Comparing the results with reported results from previous tests at the same source

If this sequence is followed, the accuracy and quality of the test is guaranteed.

3.1. Reference Standard

In the methods described above, reference standards are used for pH and EC to calibrate the instruments. The same solutions are used to verify the results by using it as an unknown sample together with the water sample. A water sample cannot be used as a reference, since the composition will change over time. Use one of the calibration standards, which are chemically stable, as a reference.



pH Testing

Let us assume that buffer pH 7 was used as an unknown and was read at the end of the procedure. The reading is recorded as "Reading B", with the value of 7.03. Compared to what it should read, namely 7.00, one can conclude that the deviation is acceptable and that the reading on the water can also be accepted as correct. Therefore "Reading A" is accepted and reported. Deviations of less than 5% are acceptable. A deviation of 0.03 from the expected 7.00 represents a deviation of 0.03 / 7.00 x 100 = 0.43% which is acceptable.

EC Testing

The same procedure is followed for verifying the EC reading. At 25°C, 1,000mg potassium chloride per litre water has an EC of 185mSm^{-1}. Let us assume that the reading of the potassium chloride solution at the end of the procedure was 150mSm^{-1} (Reading D). This deviation is not acceptable and the value noted for the water cannot be accepted. Therefore, the procedure needs to be repeated, ensuring that the EC meter is correctly calibrated. A deviation of 35 from the expected 185mSm^{-1} represents a deviation of 35 / 185 x 100 = 18.92%, which is not acceptable.

3.2. Units

The pH value has no unit. It is only a value referring to the pH scale which runs from 0 (acid) to 14 (alkaline). The international standard for EC is milli-Siemens per metre (mSm^{-1}). There is however other units that are used, which may create confusion. In the table below, the relationship between the internationally accepted mSm^{-1} and other measurements are shown for reference purposes.

Relationship between EC Units

One Siemen = One mho
mScm^{-1} = mmhocm^{-1}
1 mScm^{-1} x 100 = 1 mSm^{-1}
1 mSm^{-1} = 1 mmho m^{-1} = 0.01 mmho cm^{-1} = 10 micro mho cm^{-1}

'mho' is a unit of electrical conductance, with the symbol Ω^{-1} and has been renamed the Siemens. Conductance in mho is the reciprocal of resistance in ohms, mho is ohm spelled backwards.

3.3. Comparisons

Once the reference standards and units are verified, the results can be compared with previous result from the same source.

These comparisons must be done on a seasonal basis: Do not compare values of samples taken in spring with those of samples taken during summer or autumn. Compare results from water samples taken in spring with those of samples previously taken in spring.

Chapter 3

- For water samples, use new or used plastic bottles that have been washed properly with the water to be sampled. Tie labels to the neck or stick them on the outside.
- Take a water sample by filling the bottle and closing it without leaving an air bubble.
- pH tests and electrical conductivity (EC) tests are performed on a regular basis.
- pH test are done with the help of either a pH meter or pH sensitive paper strips.
- EC testing is done with an EC meter.
- In both pH testing and EC testing a reference standard is used against which the sample is tested.

- Reporting on water tests involves ensuring the correctness of the standards, ensuring that the units are correct, and comparing the results from previous results of tests taken from the same source.

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

Chapter 4

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

Demonstrate an ability to perform and understand maintenance tasks on certain operational technical systems related to water quality

1. Introduction

Technical water quality control systems are not used as such in citrus production, as water quality is not monitored and corrected constantly.

Regular testing is done, and corrective action is taken when required. The water quality control system that is discussed in this chapter refers to the system that is put in place to ensure that such testing and corrective testing is done correctly and timeously.

2. Maintaining Water Quality Control Systems

The basic water quality control system involves the monitoring of received water and water leaving the farm. Monitoring must be done at regular intervals, with the frequency depending on the magnitude of fluctuations in the quality over time.

The water quality of the input water should however be measured at least twice per annum, once at the beginning of the rain season and once after the rain season. Without these measurements, no improvement or maintenance program is possible.

Another important component of a water quality control system is measuring the quality of the water leaving the farm. This is not only done where natural rivers and streams are used to remove excess or drainage water from the farm or orchards, but also includes drainage furrows and water-lanes. Monitoring and measuring of this nature includes analyses of subsoil-water to monitor leaching of nitrates and chlorides.

Maintaining a water quality control system involves monitoring the following:

- Main water source or sources
- Effluents from rinsing the irrigation pipes
- Effluents from backwashing the filters
- Other signs of water contamination
- Composition of the water leaving the farm

2.1. Main Water Source or Sources

Sample all water sources utilised on the farm for irrigation of the trees or for applying foliar sprays at least twice per annum. Record all analytical data on a chart or graph.

2.2. Effluents from Rinsing the Irrigation Pipes

This information is important to identify the causes of blockages, and for evaluating the possibility of them occurring. Blockages are caused by:

- Salts that dissolve in diluted acid;

- Material that will not dissolve in diluted acid, including sand from the filters, silt and clay, organic debris, and plastic from cutting the pipes during repairs;
- Slime and filamentous material of biological origin.

It is not easy to measure these factors accurately and the quality manager has to rely on subjective observations. Nevertheless, these observations supply useful information.

The most appropriate method is to collect the material, let it dry out to form a paste and then proceed as follows:

- Drop diluted hydrochloric acid on some of the paste. If it dissolves, the paste consists of salts. If it fizzes, the paste contains carbonates. **Do not handle the paste after hydrochloric acid has been added to it**.
- Examine the deposit for pieces of plastic, seeds, and other debris.
- Feel the paste between the fingers. A silky feeling indicates clay and silt, while a slippery, slimy feeling indicates microbial deposits.

2.3. Effluents from Backwashing the Filters

Inspection of these materials will help to identify a change in the quality of the water. An increase in the concentration of clay and silt will indicate that the water source carries more solids. This can be related to the season or current climate, but indicates the need for more frequent backwashing.

To inspect the backwash from filters, collect the backwash water in a 50-litre drum. Let all the insoluble material settle, decant the water carefully and inspect the deposits visually and by touch.

2.4. Other Signs of Water Contamination

Contamination is not easily detected except through specific testing as described above. Monitoring fauna and flora, and activities upstream will assist in detecting possible contamination.

2.5. Composition of the Water Leaving the Farm

The Department of Water Affairs (DWAF) requires that the quality of water leaving the farm is similar to the quality of water received on the farm. This means that farm management is responsible to maintain the quality of the water passed onto the next user.

3. Requirements for Maintaining Optimal Water Quality

3.1. Requirements for Maintaining Optimal Physical Water Quality

Materials required for maintaining optimal physical water quality factors depend on the method of irrigation employed on the farm. It will however always include replacement parts for the filter system and spare emitters.

Although this forms part of the maintenance program for filters and the irrigation system, which will be dealt with in the guide for Irrigation, the reasons for blockages of emitters and filters must be logged to assist in water quality management.

Example

Logging Water Quality

Orchard Number 15			
Irrigation Type:	Drippers	Netafim Uniram 2.3 litre per hour	
Total Number:	2064		
Replacements			
Date	***No. Replaced***	***Reasons***	***Actions/Remarks***
25/08/04	13	Salt deposits, soluble in acid	Note for acid wash, check pH of incoming water
16/10/04	21	Salt deposits, soluble in acid	Organise acid rinse scheduled for 25/10/04
30/10/04	0	-	Acid rinse successful

3.2. Requirements for Maintaining Optimal Chemical Water Quality

The requirements for maintaining optimal chemical water quality factors depend on the quality of the water and the extent to which the composition of the water needs to be adjusted. Before this can be attempted, the quality of the water and the volumes required per month must be known.

Chemicals that will be required include the following:

- Acids such as nitric acid, phosphoric acid or sulphuric acid to acidify the water;
- Sterilising agents like sodium hypo chloride or hydrogen peroxide;
- Additives to lower and/or buffer the pH of the water when applying pest control chemicals

A list should be available of the volumes of each of these chemicals required per month and the stocks must be ordered in time.

4. Reporting on Water Quality Control System Maintenance

Water quality varies throughout the year. When reporting on the water quality control system, it is important to first of all decide when a deviation in water quality is large enough to be alarming, and then to determine whether deviations are due to natural variation, or to contamination.

To do this, one needs a set of standards for irrigation water used on citrus and historical data to set standards for the particular water source. This means that a water quality control system is required for every water source utilised, especially for those sources that are only being used when the usual or main source is depleted.

Detecting deviations should prompt actions to contain or address the deviations in order to minimise their effect on citrus production.

4.1. Water Quality Standards for Citrus Production

Water quality standards are only of value to indicate limitations, because one seldom has a choice between water sources. Where more than one source is available, mixtures of good and moderate quality water must be used to increase the volume of acceptable quality water.

The optimal water quality for citrus is water that:

- Contains little or no chloride and sodium;
- Has an EC of less than 50mSm-1; and
- A neutral pH of 7

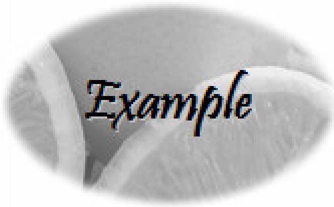
Water like this is however scarce, and therefore the maximum level for each factor is stated as follows:

Factor	***Maximum Value***
pH	8.5 if the EC is below $75mSm^{-1}$ 7.5 if the EC is between 75 and $125mSm^{-1}$
EC	$125\ mSm^{-1}$
SAR	1 if total sodium is 1me (23mg) per litre 3 if total sodium is 2me (46mg) per litre
Cl	2me (70mg) per litre
HCO_3	1.5me (92mg) per litre

Table 4.1: Water Quality Standards for Citrus Production

4.2. Historical Data for Received Water

Historical data of the composition of received water is the most important. This information determines the actions required to optimise water quality. Information on the effluent when rinsing the pipes, backwashing, contamination, and output water is also informative for managing the complete water system. Using this information, seasonal and long-term variations are studied.



Historical Water Quality Data

Date	***pH***	***EC***	***SAR***	***Cl***	***HCO_3***
Optimal	**<8.50**	**<125**	**<1.00**	**<2.00**	**<1.50**
26/07/00	7.24	74	0.52	1.62	1.67
24/03/01	6.35	45	0.49	0.51	0.62
27/07/01	7.18	82	0.72	1.83	1.58
25/03/02	6.55	51	0.41	0.45	0.55
24/07/02*	7.55	99	0.92	1.93	1.85
26/03/03	7.05	71	0.55	0.62	0.78
24/07/03	7.67	110	0.99	1.95	2.01
25/03/04	7.07	82	1.10	0.82	0.93

* Below long term average rainfall

Rainfall has a marked influence on the quality of most water sources, and therefore the record should include some sort of reference to the rainfall for the ensuing period or season.

Also note the two dates chosen for sampling. This farm is in the summer rainfall area. Sampling in July is done before the summer rain starts and will reflect the worse condition of water quality. The sampling in March is after the summer rains and should reflect the best quality available.

The major conclusions that can be drawn from the example data are the following:

- The quality of the water fluctuates significantly between summer and winter
- The quality of the water source is deteriorating

Summary

Chapter 4

- A water quality control system involves the monitoring of water received on the farm and water leaving the farm.
- Maintaining a water quality control system involves main water source or sources, effluents from rinsing the irrigation pipes, effluents from backwashing the filters, other signs of water contamination, and the composition of water leaving the farm.
- To maintain optimal physical water quality factors, records must be kept of irrigation maintenance actions, such as the replacement of emitters, to assist with water quality management.
- To maintain optimal chemical water quality factors, acids to acidify the water, sterilising agents, and buffers to adjust the pH of water used for foliar sprays are required.
- Records are kept to set standards for particular water sources, and to monitor changes in the water source over time.
- Water that conforms to the water quality standards for citrus production, and sources of good and moderate quality water is often mixed to achieve more acceptable quality.
- Historical water quality records are kept for the beginning and end of each rain season, and are used to detect historical trends.

Practical

Complete activities 8 and 9 in the **Learner Workbook**.

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