LEARNER GUIDE

Water Quality

Level 3

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Title:		**Maintain Water Quality Parameters**					
Applied Title:		**Maintain Water Quality Parameters for Citrus Production**					
Field:		Agriculture and Nature Conservation					
Sub-Field:		Primary Agriculture					
SETA (SGB):		AgriSETA					
Skills Area:		Water Quality					
Context:		Citrus Production					
US No:	116212	**Level:**	3	**Credits:**	2	**Notional Hours:**	20
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Unit standard alignment and assessment tool development:
Cabeton Training and Development

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Directions

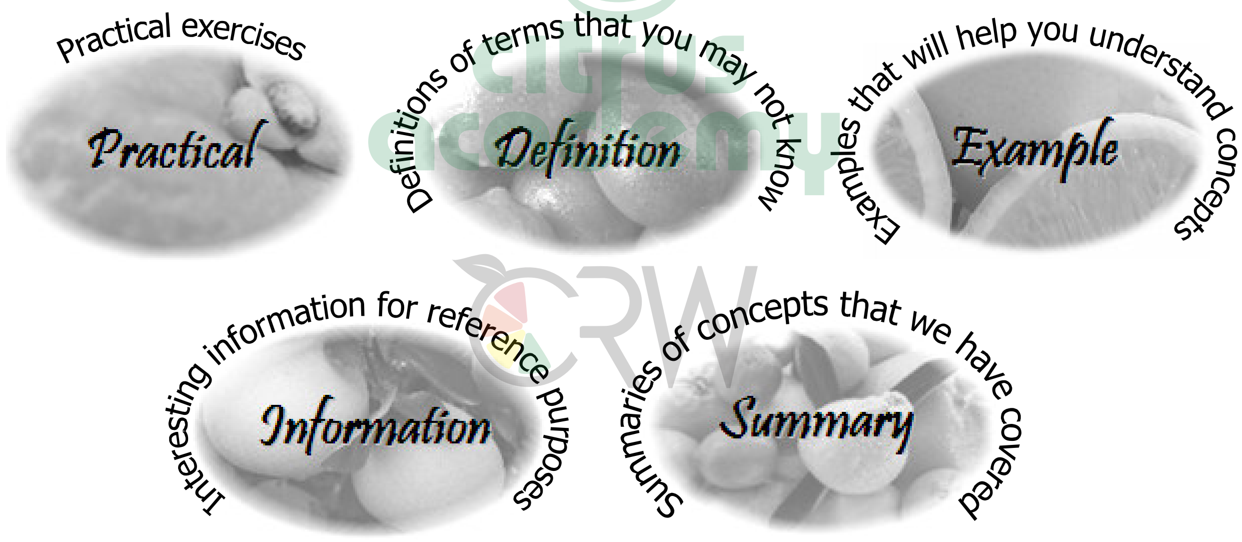
This learning material has been developed to assist the learner wishing to complete this unit standard. The guide contains all necessary learning to ensure that the learner will attain the competencies required by the unit standard.

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 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***
NQF2		Literacy and Numeracy
2	116077	Monitor water quality
2	116070	Operate and support a food safety and quality management system in the agricultural supply chain
2	116121	Apply sustainable farming practices to conserve the ecological environment

Revision of Level 2

1. Understanding Water Quality Management

- 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 are determined by the foreign material that does not dissolve in the water. These materials can clog emitters and pipes.
- Chemical water quality factors refer to the non-visible qualities of water, and affects crop production, the sustainability of the soil productivity and the effectiveness of the irrigation system.

2. The Importance of Water Quality in Agriculture

- 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.

3. Basic Water Quality Tests and Analyses

- 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.

4. Maintaining Water Quality Control Systems

- A water quality control system involves the monitoring of water received on the farm and water leaving the farm.
- Maintaining a WQCS 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.

Definition

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 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.

Chapter 1

After completing this chapter, the learner will be able to: **Ensure that quality assurance systems related to water quality are in place and maintained.**

1. Quality Management Systems

Quality management is an essential task of any producer of agricultural crops. The concept applies generally to the management of crop quality, where all the factors that impact on the quality of the crop are managed to produce a crop of the best possible quality and volume.

The concept of quality management can be applied to any other situation where quality is important. Quality management involves identifying the factors that impact on quality, deciding on the ideal value for each factor, putting in place the systems to ensure that the factors are as close as possible to the ideal, monitoring the factors, and making improvements where necessary. A quality management system encompasses all these steps.

The worst experience with any quality management system is if a failure, being crop failure in the case of citrus production, is due to a foreseeable and correctable quality factor. A loss of crop quality, volume or a reduction in fruit size has a direct effect on the profitability of the farm. Input costs have been incurred, but part of the crop that should have generated income, is lost.

The level of quality management that is required in any given situation depends mostly on how critical quality is in this specific case, and on the given quality of what is being managed, which determines how much the quality can be and has to be improved by the system.

In the case of water quality management in citrus production, the level of management is determined in the end by the quality of the water received on the farm. Where the quality of the water is good and the seasonal fluctuations in quality are small, water quality management will have a low profile.

2. Water Quality Management Systems

A water quality management system is a comprehensive approach to water quality management. It includes all the steps mentioned above, and puts in place all the necessary systems and processes to ensure that water quality is such that it contributes to optimum crop production.

For certain crops, the water quality requirements are very specific and even slight deviations can lead to huge losses in crop volume and quality. Water quality is therefore critical in these crops. These are also mostly crops that are farmed on a relatively small scale, and that does not use very large volumes of irrigation water.

In citrus, however, large volumes of water are used and the water quality requirements are neither extremely specific nor extremely critical to successful production. Some water quality factors, and specifically chemical water quality factors, can also not usually be improved economically because of the volumes involved.

This does however not mean that water quality can be ignored, as water that falls far outside quality parameters can impact significantly on crop production and on the profitability of the farming enterprise. There are also water quality factors that can be improved and managed at a relatively low cost and with a minimum of effort, such as using filtration to improve physical water quality. There are also a few factors that have to be managed continuously because they will impact on crop production and the effectiveness of the irrigation system.

Water quality management in citrus focuses on measuring and monitoring water quality, and ensuring that actions that can be taken to improve quality, are effective. Regular testing is done, and corrective action is taken when required. Setting up a water quality management system for citrus production requires less effort than maintaining it. A water quality management system is maintained over months and years, and tends to receive less attention once other activities require attention. Maintaining a quality control system is to ensure that:

- Measurements are done in time
- Measurements are recorded in the correct format
- Results are reviewed according to the set intervals
- Appropriate actions are taken to maintain quality
- Outcomes of actions are monitored

The water quality manager should have a fixed schedule for measuring, recording, reporting and reviewing results. This schedule must include the critical physical and chemical water quality factors, and should not be cluttered by unnecessary measurements and information.

To develop an effective water quality management system, the water quality manager requires knowledge of all water quality factors, the impact of these factors on the irrigation system, the soil and the crop production, and the impact of water quality factors on fertigation and chemigation. Water quality management also requires updated information on cleaning chemicals, fertilisers and other aids that are used to improve water quality factors.

3. <u>Purpose of Water Quality Management Systems</u>

An effective water quality management system is a simple system that focuses only on those factors that have a negative impact on the production of the particular crop. In the case of citrus production these include factors that:

- Clog emitters
- Reduce water penetration into the soil
- Has a negative impact on the productivity of the soil
- Reduce the efficiency of foliar sprays
- Reduce the production of quality fruit
- Pollute the water leaving the farm

The water quality control system that is employed on a citrus farm has to address the following aspects:

- **Evaluation of the quality of the water received on the farm:**
  Where and when do I take water samples for analysis?
  Which water quality factors are suboptimal?
  Which water quality factors can be improved?
  What precautions are required?

- **Evaluation of the seasonal variation in water quality:**
  To what extent do seasonal fluctuations influence the requirements for the water quality management system?

- **Development of systems to improve the quality where possible:**
  Filtration is required for almost all water. Is a pre-filtration process, such as a settling dam, required to remove excessive suspended solids?

- **Setting up systems to minimise the impact of those water quality factors that cannot be improved economically:**
  How do I deal with a high sodium concentration in the water?
  What is the leaching requirement?
  Do I need to acidify the water used for foliar sprays?

- **Monitoring of water quality:**
  Is the filtration adequate?
  Are the systems that have been set up to minimise the impact of water quality factors that cannot be improved having the desired effect?
  Is there a recordkeeping system in place to record the analytical data required to monitor the water quality factors over time, including such data as the level of sodium and salts in the soil?

- **Evaluate and monitor the quality of the water leaving the farm:**
  Where do I sample the out-going water?
  How are the results of the analyses recorded?

4. Water Quality Management Equipment

In more sophisticated water management systems that is employed where water quality is critical to crop production, sophisticated equipment is used to constantly measure and adjust water quality. In citrus production the most important equipment that requires attention is the irrigation system, which includes the filters.

Water quality management is interlinked with the irrigation system and managing the irrigation system includes water quality management. The even distribution of water throughout the citrus orchard is in the first place dependent on the quality of the irrigation system, but, once the system has been installed and is functioning properly, the continuous even distribution of water also depends on effectiveness of the water quality management.

Apart from the quality of the water received for irrigation, the introduction of other chemicals like fertilisers, called **fertigation**, cleaning aids and pesticides, called **chemigation**, also dictate the scope and magnitude of the water quality management.

Chemigation

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

The level of water quality management is determined by the quality of the water received for irrigation, with consideration given to whether fertigation and chemigation are practised. When chemicals are added to the water, the electrical conductivity increases, chemical reactions can result in the formation of precipitates, and the pH and microbial activity might be affected. These reactions require a re-evaluation of the water quality management system, specifically at the critical control points.

5. Recordkeeping

Effective recording of water quality measurements is very important. Without effective recording and reporting, changes in the quality of the water that is received on the farm cannot be monitored, and the effectiveness of actions that are taken to improve water quality cannot be evaluated.

Recordkeeping systems vary and can for instance be computerised or handwritten, but the basic information that the system must be able to keep track of includes the following elements:

- The current quality of the water
- Comparisons with previous measurements, providing an answer to the question: "Is the water quality deteriorating?"
- Actions to improve or maintain the quality or limit the impact

- A schedule for actions to be taken
- The outcome of the actions

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

6. Improvements to Quality Management Systems

Improvements to water quality management systems in terms of citrus production are on two fronts, being the administration of the system and the incorporation of new technology to improve quality and measurements.

No two water quality management systems are ever exactly the same and the administration of the system depends on the facilities available and the people involved. This leaves room for continual improvement with the focus on simplicity and efficiency. However, any WQMS must be able to report and manage all those water quality factors that will impact on production of quality fruit.

Chapter 1

- ➢ 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.

Complete activities 1, 2, 3 and 4 in the **Learner Workbook**.

Chapter 2

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

Demonstrate an understanding of critical control points in water quality management.

1. Introduction

In the previous chapter, the principles of quality management and how this links to water quality management systems were discussed. In this chapter we will look at the role that identifying and managing critical control points play in water management systems.

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.

There are three major critical control points in a water supply system, being:

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

The quality of water at each of these points is usually determined by assessing the physical and chemical water quality factors. Physical water quality factors are determined by the foreign material not dissolved in water, while chemical water quality factors refer to the non-visible qualities of water.

2. Water Received On Farm

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

The water quality manager has very little control over the quality of the water received on the farm. The quality is determined by a number of upstream factors, such as the activities of other agricultural users and industries.

If the quality of the water that is received is very poor, or if the water quality deteriorates rapidly, the water quality manager can attempt to determine the cause of the poor quality. If it can be established that the poor quality is caused by the activities of others, the manager may be able to address the issue through the local water user association.

In most cases this is however not possible, and the water quality manager has to make use of the available water.

The main activity at this point is to determine the physical and chemical quality of the water, and to measure and monitor these factors over a period of time.

The water quality manager does not only measure the quality factors of the water alone, but also identifies the points of impact on the crop, soil and equipment. Based on the quality of the received water, the water quality manager identifies the actions that are required to improve the water quality where possible, and to minimise the impact of sub-standard water. The actions must be reassessed and adjusted if the water quality should change over time.

Irrigation water is required in large volumes. It is usually only possible to improve the physical water quality economically, while most chemical water quality factors cannot be improved economically. Although the biological water quality factors are of lesser importance, they should form part of the water quality management.

3. Water Used

The golden rule for the actions taken at this control point is **first, do no harm**. The quality of the water should first of all be maintained at the levels of when it was received on the farm, and secondly improved where possible. At this point, there are three minor critical control points, being:

- Storage (if used)
- Filtration
- Irrigation

3.1. Storage

Water is in many cases pumped directly from the water source, whether it is a river, canal or borehole, but in some cases the water may be stored in a dam.

Storage dams act as a form of pre-filtration where impurities are allowed to settle to the bottom while the water is not moving. While the water is being pumped into the storage dam, it can also be aerated, meaning sprayed into the dam through the air, allowing it to dissolve oxygen, which assists with the oxygenation of certain metals in the water.

The main requirement for maintaining the quality of the received water while in storage is protecting it from contamination, mostly by ensuring that no chemicals or fertilisers enter the storage facility.

This can happen when empty chemical containers are rinsed in the vicinity of the storage dam or near any waterway feeding the dam. Run-off water from adjacent orchards or animal houses should not enter the storage dam under any circumstances, because this water is contaminated with fertilisers and other nutrients from animal waste. If nutrients, especially nitrogen and phosphorus, are added to the water in the storage, the microbial activity is increased in the dam, creating numerous quality problems when the water is introduced into the irrigation system. Water from back flushing the filtration systems should also be channelled away from the storage dam.

3.2. Filtration

Filtration is when the water is pumped through a filter, such as a sand or disc filter, before entering the irrigation system. The filter system catches the physical impurities in the water and therefore improves the physical water quality.

The type and number of filters that are required 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.

Sampling and analysis is done at the filter system to measure and monitor the physical water quality. We will discuss this in more detail in Chapter 4.

3.3. Irrigation

Water quality can be measured and monitored at this point through measuring and monitoring the delivery of emitters, and by assessing the debris that is flushed from lateral lines. Clogged emitters can be cut open and inspected to determine the cause of the clogging, which can then be addressed upstream from where the water enters the irrigation system.

Debris in the water flushed out of pipes indicates the kind of material that is passing through the filtration system as well as the materials that is entering the system or developing in the system after filtration.

Most filters cannot remove all suspended clay particles successfully. This fine suspended material will settle when the flow rate decreases, which usually happens at the end of the lateral pipes. Inspecting the kind of material accumulated in the laterals helps to detect and address the sources.

4. Water Leaving the Farm

The third critical control point in a water quality control system is measuring the quality of the water leaving the farm. Note that water does not only leave the farm through natural rivers and streams that remove excess or drainage water from the farm or orchards, but also through drainage furrows and water-lanes, and even subsoil-water to where nitrates and chlorides are leached.

In chemical and related industries legislation prohibits water users to dispose of water that exceeds certain levels of contamination compared to the incoming water. The quality of the water leaving the plant is determined by the quality of the water received, but also by the activities at the plant and the waste disposal principles employed.

In agriculture such legislation does not exist and will be difficult to enforce. Water leaving the farm usually does so through other means than the system that is supplying the water. Leaching water for instance enters the natural water system via the soil and it could take years before it affects the water supply.

Every water user therefore has the responsibility to ensure that the water quality of the waterway is maintained. The main actions at this point are concerned with ensuring that water sources are not contaminated in any way.

Chapter 2

- 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.

Practical

Complete activity 5 in the **Learner Workbook**.

Chapter 3

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

Enable corrective action to occur on certain operational or technical issues that control specific physical and chemical factors in water and relate it to a specific organism's water quality requirement.

1. Introduction

At previous levels we discussed the physical and chemical water quality factors that play a role in water quality management. In this chapter we will look at these factors in greater depth, and at the impact of these factors on farming activities. We will also discuss the water quality requirements for crop production, and specifically for citrus production.

2. Physical Water Quality

Physical water quality is affected by the foreign material that is suspended in water, which are referred to as **suspended solids** or **insoluble suspended material**.

2.1. Factors Influencing Physical Water Quality

It is important to know the sources of insoluble suspended material, and to be able to recognise them. The main sources of suspended solids are:

- Clay, silt, sand and organic debris
- Aquatic plants and animals
- Rust and scales
- Waste and debris
- Lubricant residues

2.1.1. Clay, Silt, Sand and Organic Debris

Clay, silt, sand and organic debris are part of the natural soil-plant system. Running water collects soil and organic particles on its way and the movement (velocity) of the water carries these materials to storage dams or into the irrigation system.

These particles settle at the bottom of the dam when the velocity of the water decreases. The settling rate depends on the size of the particles and the chemistry of the water. Clay particles are very small, with an average size of <2 micron, and will take much longer to settle than sand, with an average size of 50 to 200 micron. If sodium is abundant in the water, the settling rate of clay is reduced.

Soil Composition

Clay, silt and sand are the basic components of soil. Clay particles are very small at less than 0.002mm or 2 micron. Silt is in fact very fine sand at 0.002mm to 0.050mm or 2 to 50 micron and is inert material. Sand has a diameter of 0.050mm to 2.00mm or 50 to 200 micron.

Organic debris refers to leaves, seeds and other plant and animal material. Water from boreholes contains less organic debris but can have suspended clay particles.

2.1.2. Aquatic Plants and Animals

In storage dams, aquatic plants and animals produce living and dead material of variable sizes and in various states of decomposition. Borehole water has little aquatic activity but once the water is pumped into a dam, the same situation develops.

2.1.3. Rust and Scales

Rust and scales is found in metal mainline pipes and are caused by chemical water quality factors. The scales and rust particles accumulate in the irrigation pipes and can eventual cause blockages of the pipes or emitters.

2.1.4. Waste and Debris

Water sources are easily contaminated by waste material that is not properly disposed of. The most common materials found in irrigation water are plastic cuttings and other such debris that ends up in the water when installing or repairing the plastic pipes and fittings in the irrigation system.

2.1.5. Lubricant Residues

Lubricants, such as oil, grease and even fuel, are contaminants that enter the irrigation water from the pumps. Care must be taken to ensure that spillage does not occur, and that leaks in the pump system are repaired as soon as they occur.

2.2. Impact of Physical Water Quality

Physical water quality impacts on the performance of the irrigation system, because the material that is suspended in water clogs emitters and pipes.

The degree to which water quality affects the irrigation system depends on the type of irrigation used.

2.2.1. Micro-Irrigation

Citrus are mostly irrigated with micro-irrigation systems, meaning that water is pumped through pipes to emitters that are positioned at individual trees. The emitters that are most commonly used are micro-jets and drippers.

The openings in these emitters are very small and can become clogged or blocked by debris that is suspended in the water, decreasing the efficiency of the irrigation system. Material that accumulates in pipes can also eventually block the pipes, further decreasing water delivery to the trees.

The guidelines issued by the Department of Water Affairs and Forestry (DWAF, 1996) that rates the clogging hazard of suspended solids are reflected in table 3.1.

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

Table 3.1: DWAF Clogging Hazard Ratings

2.2.2. Macro-Irrigation

Where macro-irrigation, such as basin or flood irrigation, is used, the physical water quality influences the soil and the plant. Silt and seeds are the two physical water quality factors that are of consequence in this case.

When water that contains silt is used, the silt settles and accumulates on the soil surface over time. Citrus is a permanent crop that grows on the same site for many years, and over the years the accumulated silt may form a layer on top of the soil, with completely different chemical and physical properties from the soil below. This may change patterns of root development and water penetration, and eventually have a detrimental effect on production.

Seeds in the water source are carried to the orchard where they germinate and grow. These weeds compete with the tree for water and nutrients, and must be removed and monitored constantly, adding to production costs.

2.3. Managing Physical Water Quality

Physical water quality is improved through filtration, which removes the suspended solids from the water by trapping it in the filter system.

Various types of filters are used, with the most common being sand, disc and screen filters. The filter system is normally found just after the pump system, where it is able to filter the water before it enters the mainline pipes. Filters must be checked and serviced regularly to ensure that they remain effective. The monitoring of filter performance is discussed in greater detail in chapter 4.

The filters remove suspended solids from the water that entered the system before this point, and care should be taken that the water is kept clean as it moves through the irrigation system. Leaks, breaks and rusted or perished piping must be repaired and replaced immediately. Lateral lines must also be flushed regularly to remove any material that may have settled in the pipes.

3. Chemical Water Quality

Chemical water quality refers to those invisible attributes of water that can only be measured through analysis.

3.1. Factors Influencing Chemical Water Quality

Chemical factors that impact on the quality of water for agricultural use include:

- Total dissolved salts (TDS)
- pH
- Calcium
- Magnesium
- Sodium
- Chloride
- Bicarbonates
- Boron
- Iron, manganese and sulphides

3.1.1. Total Soluble Salts or Total Dissolved Salts (TDS)

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.

The total concentration of salts dissolved in water is measured in terms of the electrical conductivity (EC) of the water or in milligrams per litre water. EC is expressed in milli-Siemens per meter (mSm^{-1}). The EC and the milligrams TDS can be expressed in many ways but most of these classifications are based on the system of US Department of Agriculture (USDA, 1954).

3.1.2. pH

pH is a measurement of the level of acidity or alkalinity of water. A pH-value of 7 is neutral (neither acidic nor alkaline), while pH of less than 7 indicates acidity and greater that 7 alkalinity. Therefore, the lower the pH-value of the water, the more acidic it is, and the higher the pH-value, the more alkaline the water. The optimal pH of irrigation water is 6 to 6.5, meaning slightly acidic.

The optimum pH of soils for optimal citrus production is 6.5 to 7 as measured in a soil-water suspension. Water with a low pH will contribute a little to acidification of the soil, but water with a high salt content is a major reason for the salinisation of the soil.

The pH of the water determines to a large extent the solubility of salts and hence the TDS of water. At a low pH, water dissolve metals in metal pipes and fittings, and salts in cement based piping. At a high pH, salts like calcium and magnesium carbonates precipitate.

3.1.3. Sodium

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.

The importance of sodium and its effect on soils are expressed as the sodium adsorption ratio (SAR) of water. This is the magnitude of the relation between sodium and calcium plus magnesium. A SAR-value of less than one indicates no hazard, between 1 and 3 a minor hazard, and higher than 3 a major sodium hazard.

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.

Please Note:

There is an important difference between the concepts of absorption and adsorption. **Absorption** means the uptake of a liquid into the fibres of a substance, such as the example of water being absorbed by a sponge.

Adsorption means the accumulation of substances on the **surface**, or the process by which a layer of a substance, normally a gas, is formed on the surface of a solid or liquid.

3.1.4. Chloride

Chloride (Cl) has several effects on citrus. Chloride is an essential nutrient element, but a high concentration increases the osmotic pressure of the water and competes with other anions.

Osmosis 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 A measure of the ability of a cell to attract water into itself through the mechanism of osmosis.
Electrolyte Any substance which, when in solution, will conduct an electric current. Acids, bases, and salts are common electrolytes.

3.1.5. Bicarbonates

Dissolved bicarbonates (HCO_3) are responsible for the high pH of water. An alkaline pH has a negative effect on the solubility of certain plant nutrients.

3.1.6. Boron

Boron (B) is also an essential nutrient element, but is required in very small amounts. If the water contains too much boron, it becomes toxic to plants. The maximum concentration of boron in irrigation water for citrus is 1mg per litre water.

3.1.7. Iron, Manganese and Sulphide

These three elements are responsible for the formation of insoluble oxides, sludge and filamentous gelatine-like slimes that block emitters.

3.2. Impact of Chemical Water Quality

Chemical water quality affects plant production, the sustainability of soil productivity, and the efficient operation of the irrigation system.

The most important chemical water quality factors and their impact on each of these areas are shown in table 3.2, 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 Efficiency***
Total soluble salts	Y	Y	Y
PH	Y	Y	Y
Calcium	Y	Y	Y/N
Magnesium	Y	Y/N	N
Sodium	Y	Y	N
Chloride	Y	Y/N	N
Bicarbonate	Y	Y/N	N
Boron	Y	Y/N	N
Iron, manganese and sulphides	N	N	Y

Table 3.2: The Impact of Chemical Water Factors

The negative effects of water quality factors are usually cumulative and the final result is more than the sum of the individual parts.

3.2.1. Impact on Crop Production

Crop production is usually the last to respond to the impact of poor water quality and should not be regarded as an indicator of the water quality. The affect of chemical water quality on crop production can be seen in suboptimal yields, decreasing fruit size, erratic blossom, and a decrease in the number of fruit. Many other production factors can however be the cause of these problems.

The total dissolved salts (TDS) impacts specifically on crop production because the higher the salt content of the water, the more energy a plant needs to utilise the water. This energy would have been better spent on producing vegetative material, such as leaves, shoots and roots, and fruit.

Citrus trees irrigated with water containing moderately high concentrations of salts usually produce smaller fruit. When the salt content increases, the number of fruit produced by the tree decreases. The salt content of water is also of importance with irrigation systems that wet the leaves, such as rain replacement systems. High concentrations of salts can scorch the leaves and cause them to drop prematurely.

3.2.2. Impact on Sustainable Soil Productivity

Soil analyses are a cheap and effective method to monitor the effects of chemical water quality on soil. The most important soil characteristics that can be caused or affected by water quality are:

- Soil salinity
- Crusting
- Leaching

3.2.2.1. Soil Salinity

The total dissolved salts (TDS) is the factor that most significantly affects soil salinity. Water applied to the soil is either utilised by the plants or evaporates from the surface, leaving salts behind in the soil. Because of irrigation, this process is repeated several times per month.

The rate at which salts accumulate depends, amongst other factors, on the concentration of dissolved salts in the water. Apart from erosion, this is the most important cause of the loss of productive soils. This process is called salinisation of soil, or "verbrakking" in Afrikaans.

Salinity can be detected by the pH, resistance or electrical conductivity (EC), and the sodium and chloride content of the soil. An increase in pH, EC and / or sodium and chloride content is the first signs of salinisation.

To detect changes in the concentration of these parameters, all results must be recorded. Recordkeeping is the fundamental requirement for any water quality management system.

When the concentration of sodium exceeds 5% of the total cations, salinity becomes a real threat and additional analyses are required. Additional analyses include the sodium adsorption ratio (SAR) and electrical conductivity (EC) of saturated soil paste, which is a sample of the soil that has been mixed with water.

3.2.2.2. Crusting

Crusting refers to when the top few millimetres of the soil becomes much harder and more brittle than the soil immediately underneath it. This is caused by a decrease in the relative concentration of calcium as a result of irrigation with water that is too fresh, meaning water with a very low concentration of salts, or water containing too much sodium.

Crusting impedes the infiltration of water into the soil, and thereby causes more water to run off, which contributes to soil erosion.

The first sign of crusting is runoff of water halfway through the irrigation cycle. Runoff occurs when the application rate exceeds the infiltration rate of water into the soil. Initially the infiltration rate exceeds the application rate and the water will disappear quickly. After a while, the top layer closes, reducing the infiltration rate, and water accumulates on the surface. Less water than intended reaches the roots, although the correct volume was applied.

3.2.2.3. Leaching Requirement

The leaching requirement of a crop-soil-water system is important, depends on the concentration of salts in the water.

The leaching requirement is the extra volume of water required, over and above what is needed to re-wet the soil to field water capacity, to leach salts left from the previous irrigation from the root-zone.

By incorporating the leaching requirement into the water requirement, the salts will not accumulate in the soil and the salt content of the soil will not increase. The leaching requirement is a factor of the crop and the EC of the water.

3.2.3. Impact on Irrigation

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. These three critical points are all affected by chemical water quality factors.

The total dissolved salts is one of the factors contributing to the corrosive potential of water. The concentration and type of dissolved salts determine to what extent water contributes to the corrosion of irrigation equipment.

Apart from erosion, the concentration and types of salts also determine to what degree water adds to the problem of scale forming in pipes, blocking micro-jets and drippers.

Three indexes are used to quantify the potential of water to corrode and form scale in pipes, and to block emitters, namely the Langelier, Rysnar and Aggressiveness Indexes. The concentration of calcium, magnesium and carbonate are specifically important.

3.3. Managing Chemical Water Quality

Chemical water quality cannot be changed or adjusted cost effectively for the large volumes of water that is required for irrigation in citrus production. The water quality manager rather focuses on monitoring the chemical water quality over time in order to detect deterioration in the water quality. In some cases where there is more than one water source available and the quality of the water from the one source is considerably better than the water from the other source, the water from the two sources can be mixed to get water with reasonable quality.

4. Biological 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. These include factors that have an impact on aesthetics, being the floating matter in the water and the colour, odour and clarity of the water, and biological and microbial constituents, being algae, pathogens such as Bilharzia, nuisance plant such as water hyacinth and other organic material that stimulates microbial, faunal an floral activity in the water.

The standard tests to evaluate the dissolved organic carbon content of water are the biological oxygen demand (BOD) and the chemical oxygen demand (COD). However, unless the water is heavily contaminated, these constituents have a limited effect on the biological quality of irrigation water used in citrus production. The biological quality of irrigation water has an indirect effect on the efficacy of the irrigation system and hence on citrus production, related to the clogging caused by the water fauna, flora and microbes growing in the water.

4.1. Biological Factors Influencing Water Quality

The biological factors and processes that influence water quality are:

- Photosynthesis
- The nitrogen cycle
- Decomposition
- Organic load

4.1.1. Organic Load

Natural uncontaminated water carries a very low organic load and will seldom stimulate growth of aquatic fauna and flora to such an extent that it will influence the quality of irrigation water or water used for foliar sprays.

Under the conditions prevailing in the irrigation system and in the presence of certain nutrient elements, some types of microbes will multiply and form slimes and filaments. When these slimes and filaments agglomerate with other particles such as clay, the resultant material can clog emitters.

4.1.2. Photosynthesis

Water containing nitrate and phosphate stimulates the activities of algae and other microbes with photosynthetic abilities. This however can only happen when the water is exposed to sunlight. The presence of nitrates and phosphates in natural water is a sign of pollution and prolific growth of photosynthetic organisms can be traced to contamination.

The changes in the chemical composition of irrigation water brought about by the activity of photosynthetic organisms are usually small in comparison to the physical problems caused by the body mass of the organisms.

4.1.3. The Nitrogen Cycle

Part of the nitrogen cycle involves the leaching of nitrates as well as the removal of nitrogen and phosphates through surface runoff and erosion. When nitrogen and phosphates accumulate in underground and surface water – phosphates are seldom found in underground water – the growth of aquatic fauna and flora as well as microbes proliferates. This impact on the filtration and disinfection procedures required to maintain an effective irrigation practise.

Pollution caused by nitrogen can be controlled or minimised by correct use of nitrogen and limitation of runoff and leaching. Another source of pollution is dumping of fertilisers, cleaning of spray equipment, and sewerage systems and animal housing near waterways.

4.1.4. Decomposition

Decomposition of any organic material leads to the release of elements such as nitrogen and phosphates and the increase in microbial numbers and diversity. If the decomposition occurs in or close to water sources, it can lead to an increase in debris and microbial activity, impacting on the filtration and disinfection procedures.

The concentration and type of digestible organic matter in water determines the number and type of microbes in the water. Water containing less than 10,000 microbes per ml presents a minor clogging hazard. Microbe counts of 10,000 to 50,000 per ml present a moderate hazard, and more than 50,000 per ml poses a major clogging hazard.

4.2. Impact of Biological Water Quality

The biological factors that impact on the quality of irrigation water and water used for foliar sprays are limited to those that aggravate the clogging of emitters. Chemical changes caused by biological activities are only of importance in fairly heavily contaminated water.

The biological processes that influence the efficiency of the irrigation system include the activities of bacteria and fungi, which form slimes and filaments, and reduce manganese, iron and sulphur. The cumulative results of these activities may cause other physical particles to accumulate in the irrigation system, causing clogging of the emitters.

Under anaerobic conditions, such as in boreholes, sulphates can be reduced by bacteria to form sulphuric acid. Sulphuric acid damages the metal in the pipes and valves of borehole. The most obvious symptom of this process is nodules containing black or dark brown powdery material. This process continues to create holes in the metal and will destroy it eventually. The presence of sulphate reducing bacteria (SRB) in boreholes therefore has a negative effect on the underwater equipment.

Water may also be a carrier of spores of diseases, such as Phytophthora, and pests, such as nematodes, to the orchard.

5. Water Quality Requirements for Citrus Production

There are not many water quality requirements for citrus production and the ranges for these parameters are very broad. Citrus is produced economically using water with total dissolved salts from very low to higher than 1,500mg per litre, and with a pH ranging from 4 to 9. However, any water quality factor that has a detrimental effect on the soil, such as increasing salinity, or on the irrigation system, such as clogging or corrosion, has an impact on citrus production.

The requirements for water for irrigation and foliar sprays of citrus are categorised as optimal, marginal and undesirable in table 3.3.

Quality Factor	***Ranges***		
	Optimal	***Marginal***	***Undesirable****
pH	5.50-7.00	7.00-8.00	>8.00
EC mSm^{-1}	<75	75-125	>125
TDS mg per litre	<500	500-2000	>2000
SAR	<1.00	1.00-3.00	>3.00
Bicarbonate (HCO_3) me per litre	<1.50	1.50-3.00	>3.00
Chloride (Cl) me per litre	<2.00	2.00-3.00	>3.00
Manganese (Mn) mg per litre	<0.10	0.10-1.50	>1.50
Iron (Fe) mg per litre	<0.20	0.20-1.50	>1.50
Sulphide (S^{--}) mg per litre	<0.20	0.20-2.00	>2.00
Bacterial numbers per ml	10,000	10,000-50,000	50,000
Suspended solids mg per litre	<50	50-100	>100

Table 3.3: Classification of Water Used in Citrus Production
* Undesirable for conventional irrigation. Special attention and advice are required on an ongoing basis

Compared to other crops, such as avocado, citrus can tolerate more salts in the water. In table 3.4, the salt tolerance of crops is expressed as the maximum salt concentration where the yield will be reduced by less than 10%.

Crop	***Maximum EC (mSm-1)***
Avocado	80
Citrus	135
Asparagus	400

Table 3.4: Salt Tolerance of Crops

Please note that the maximum EC at which a crop can still be produced optimally also depends on other factors, such as the type of salts in the water, the type of irrigation system and the type of soil. The EC of the water can therefore only be seen as an indicator of the suitability of a water source for citrus production.

Another indicator of the maximum EC of water for citrus production is the osmotic pressure. At an EC above 150mSm-1, energy is required to utilise the water and less energy is available for fruit production. At this EC, the osmotic potential of the water is at 50kPa which is also the maximum water tension permissible for optimum citrus production. Remember that dissolved fertilisers add to the salt content of the water.

Chapter 3

- 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.

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

Chapter 4

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

Read, record and interpret certain parameters and abnormalities in water quality

1. Introduction

Monitoring and recording water quality is an essential part of water quality management. It is only when physical and chemical water quality factors are measured and recorded on an ongoing basis that the water quality can be assessed accurately, deterioration over time can be detected, and corrective action can be taken effectively and in time.

The water quality that can be expected from a specific waterway can also be assessed to some degree by looking at the physical attributes of the waterway. This is obviously not done on an ongoing basis, but is a handy exercise when planning a water quality management system.

2. Attributes of Water and Waterways

The physical attributes of a waterway can be an indicator of the water quality. The most basic physical attribute of a waterway is the path along which it flows. Some waterways are classified as meandering, meaning that they are s-shaped with many bends, while other waterways have more straight sections through which water flows more quickly.

The speed at which the water moves along the waterway determines the degree of sedimentation, meaning how much of the suspended material in the water is allowed to settle to the bottom. The speed also determines the degree of turbulence. The more turbulent the water, the more oxygen is mixed with the water.

The biological attributes of water, as opposed to the biological water quality, refer to the number and types of organisms that inhabit the water. When assessing water quality the organisms that are present in the water is an indication of the chemical and physical water quality, as some organisms are more sensitive to changes in these water quality factors than others.

3. Measuring Physical Water Quality

Physical water quality is measured by assessing the following:

- Emitter delivery rate
- Suspended solids

3.1. Emitter Delivery Rate

The delivery rate of emitters is an indicator of the influence of many factors on the effective application of water, which promotes optimal yields and fruit quality. 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 with its permissible tolerance is specified for every commercial emitter on the market.

When the irrigation system is operating at working pressure, the delivery rate of all the emitters must be within these preset limits, with an acceptable deviation of 10%. Blockages decrease the delivery rate to less than specified.

The following procedure is followed to measure the delivery rate of emitters:

Micro-Jets

- Remove the micro-jet and put the riser tube in a suitable container to collect the water.
- Let the water run into this container for a set period, for instance 60 seconds.
- Measure the volume of water emitted in 60 seconds, for instance 500ml.
- Calculate the litres emitted per hour, as follows:

  (**Please Note:** 3,600 is used because 1 hour = 60 minutes x 60 seconds)
  Volume Collected x 3,600 seconds / number of seconds measured
  = 500 x 3,600 / 60
  = 30,000ml
  = 30 litres per hour

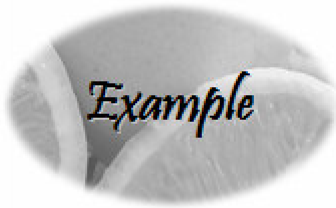
- Compare this with the specified delivery rate for the particular micro-jet.

Dripper

- Place a suitable container below the dripper to collect the water.
- Ensure that the water does not run away from the container along the pipe.
- The dripper must be the lowest point and over the container.
- Let the water drip into this container for a set period, for instance 30 minutes.
- Measure the volume of water emitted in the 30 minutes, for instance 750ml.
- Calculate the litres emitted per hour, as follows:

  Volume collected x 60 minutes / number of minutes measured
  = 750 x 60 / 30
  = 1,500ml
  = 1.5 litres per hour

- Compare this with the specified delivery rate for the particular dripper.



Specifications for Two Commercial Micro-Jets

Combination	*Pressure (m)*	*Delivery Rate (litres / h)*	*Radius (m)*
0.82mm nozzle with orange spreader	10	25	0.40
	15	30	0.40
	20	35	0.50
	25	39	0.50
1.28mm nozzle with green spreader	10	61	2.00
	15	75	2.70
	20	87	2.90
	25	98	3.30

An acceptable deviation from the specified delivery rate is <10% (ARC, 2003), meaning that the delivery rate for the 0.82mm nozzle with orange spreader should be between 22.5 and 27.5 litres per hour at an operating pressure of 10m. Please note that a pressure of 10m = 1bar = 100kPa.

The delivery rate of micro-jets can also be checked by the size of the wetted area. When blocked partially, the radius of the wetted area will be reduced. The wetted radius is not a very sensitive measurement of the delivery rate, but it is an indication when more careful measurement is required. Where it is found that emitters are blocked, they will mostly be replaced as they cannot normally be cleaned or repaired.

The delivery rate should be measured at regular intervals, and not only when symptoms of water-stress is detected in the trees. The results must be recorded as part of the irrigation recordkeeping system. The cause of the blockage must be investigated and addressed, especially if records over time show an abnormal occurrence of blockages in specific areas, or a sudden and unexpected increase in blockages.

3.2. Suspended Solids

Measuring the suspended solids in irrigation water is done by taking a water sample in the same way as a sample would be taken for chemical analysis. Samples are taken before and after the filter system, which assist in measuring the effectiveness of filtering.

Note that another method to determine whether filters require cleaning, which is normally done by back-flushing them, is to measure the water pressure before and after the filter system. If there is a large variance in the two readings, the filters have probably been clogged by dirt.

To determine the suspended solids in the water samples, the following method is used:

- Put filter paper in a drying oven, set it at 100°C and dry the paper for 24 hours.
- Record the mass of the dried filter paper (Mass A).
- Filter a known volume, for example 500ml, of the water sample through the dried filter paper. Ensure that no insoluble material is left in the sampling container.
- Put the filter paper with the insoluble material in a drying oven, set at 100°C and dry the paper and residue for 24 hours.
- Record the mass of the dried filter paper plus residue (Mass B).
- Mass B minus Mass A gives the mass of insoluble material for the volume of water that was used.
- Compare the result with the hazard indication in table 3.1 (DWAF Clogging Hazard Ratings) in chapter 3.

Note that although 100mg suspended in 1,000ml water is a low concentration, it is rated as "Severely Hazardous".

To improve the accuracy of this method, one or even two litres of water can be passed through the filter paper, which will reduce the margin of error by providing a greater mass of insoluble material to measure. The residue is inspected to identify the various components. Inorganic materials such as clay, silt and sand can be detected by rubbing the residue between the fingers. Sand has a gritty texture, while silt and clay has a slippery texture.

Living aquatic plants and animals, such as algae and snails, or organic debris, such as remnants of plants, seeds, animals, aquatic fauna and flora, are usually only of consequence with open water sources, such as dams and rivers. Borehole water seldom contains any of these. It is important to determine how much of the suspended solids are made up by these components, without having to know what the individual organisms are.

Plastic cuttings from the irrigation pipes and equipment, and lubricant residues are seldom related to the water source, but to activities around the irrigation system.

To be of any practical value, results and observations must be recorded in a matrix of previous readings. Without historical data, the water quality manager can only conclude that the source poses a minor, moderate or severe hazard, without being able to tell whether the water quality is deteriorating, or whether the filtering system is operating effectively.

4. Measuring Chemical Water Quality

Chemical water quality can only be measured accurately by sampling and laboratory testing and analysis. Water sampling and analysis should be done at least twice per annum, before the rainy season, for example in March, and after the rainy season, for example in July.

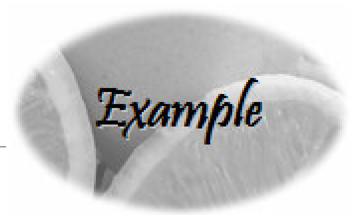
Water sampling is done by the water quality manager or a designated person capable of taking the sample correctly. The correct procedure for taking and handling water samples were discussed in the level 2 learner guide. It is very important that sampling is done correctly, because many decisions and actions are based on the analytical results of the sample. If the sample does not represent the water source correctly, the wrong answers will lead to wrong decisions. Always remember the first principle of sampling: A sample is not a piece of the whole that is being sampled – in this case the body of water – but a reduced but true reflection of the whole.

The analysis of samples allows one to determine the chemical water quality factors accurately, through for example the measurement of the pH and electrical conductivity of the water with the help of special equipment. Procedures for determining the pH and EC of water were discussed in the level 2 learner guide. The water is further analysed in a laboratory to determine its chemical composition.

5. Interpreting Water Quality Data

Any recordkeeping system is only as good as the data that is entered into it. It is therefore essential that water quality data is collected and entered by knowledgeable people that can assess the general validity of the data at the same time.

Interpreting information from the recordkeeping system is done against the background of other production information on the farm. If it is for instance found that soil salinity is increasing, it may be due to higher water TDS, but it may also be because of other factors such as over-fertilisation. The water quality records must therefore form part of the overall recordkeeping system of the farm, and the information must be interpreted in conjunction with all other information that is available. Below is an example of how historical records can be interpreted.



Water Quality Record

Below is a sample record of the concentration of insoluble material (mg per litre) in water source "BIG DAM" and filter bank "BLOCK A"

	Date	***Before Filtration***	***After Filtration***
1	26/07/03	211	16
2	05/03/04	386	21
3	12/07/04	384	10
4	03/03/05	588	18

In this example, water samples were taken before the rainy season in March and after the rainy season in July. The comparisons between readings 1 and 3 or readings 2 and 4 give an indication of the year-on-year variation in water quality, while comparisons between readings 1 and 2 or readings 3 and 4 gives an indication of the seasonal variation in water quality.

The ***Before Filtration*** readings indicate the stability of the catchment area and upstream environment of the water supply. In this example, the readings show increases from 1 to 3 as well as from 2 to 4, which indicate that the concentration of insoluble material is increasing.

The ***After Filtration*** readings indicate the efficiency of this filter bank, which will be related to the number of drippers or micro-jets blocked, as well as to the insoluble material find when the lateral piping is flushed. A seemingly low concentration of insoluble material can accumulate in the piping and cause problems.

6. Abnormalities in Water Quality Data

Water quality records can be an indication of serious problems in the water supply system, chief amongst which is contamination. If the water quality deteriorates suddenly, or if abnormal readings are recorded, the reason must immediately be established. If it is found that water contamination is occurring, the source of the contamination must be identified without delay and steps must be taken to stop the contamination. The main sources of contamination include:

- Excessive leaching
- Poor waste management
- Poor sewage disposal

6.1. Leaching

Some elements such as nitrates, chlorides and even sodium moves quite easily through the soil profile and can be leached out of the soil. If these elements are transported to the waterways, they will end up in the water leaving the farm and will have a negative impact on the quality of the water available downstream. Chlorides and sodium should be leached to the soil layers below the root-zone. This is however not always manageable due to rainfall, which adds to the leaching caused by irrigation. Chlorides must be used in a sound fertilisation program and in conjunction with proper irrigation scheduling.

Over-irrigation is the main culprit in terms of the excessive leaching of nitrates. When too much water is applied after or during nitrate applications, the nitrate is leached beyond the roots. In such cases more nitrogen will be required to satisfy the demand of the trees, which results in even more leaching. Evaluating the magnitude of leaching of nitrates should therefore form part of the fertilisation program. High concentrations of nitrates in the water stimulate microbial and aquatic growth and render the water less suitable or more expensive to use.

6.2. Waste Management

All soluble waste must be disposed of in a manner that will prevent these materials from ever entering the waterways. A proper designed waste disposal system is essential on any farm. No chemical container should be rinsed and no expired or unused chemical should be exposed of in a manner that can lead to the chemicals entering the water system. Most suppliers of chemicals supply a disposal service.

6.3. Sewerage Disposal

Untreated sewerage, including animal and human waste, must never be allowed to enter the water ways. Ensuring that the disposal areas for sewerage are far from open or underground water source is no guarantee that it will not contaminate the water. It is essential to ensure that the sewerage is properly decomposed in the allocated site.

The use of microbial decomposition processes contributes less towards pollution that chemical processes. However, the monitoring of these disposal sites need to be formalised and managed. Ongoing analyses of the water sources to determine the total organisms, as well as the presence of coli-form bacteria, aid in keeping the water sources free of sewerage contamination. Coli-form bacteria are associated with contamination by raw sewerage.

Summary

<u>Chapter 4</u>

- 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.

Practical

Complete activity 8, 9 and 10 in the **Learner Workbook**.

Bibliography

<u>Publications</u>:

Irrigation Operation Manual, ARC, 2003, Chapter 8: Micro Irrigation Systems, ARC – Institute for Agricultural Engineering
South African Water Quality Guidelines, Vol. 4, DWAF, 1996
Saline and Alkaline Soils, Booklet 60, USDA, 1954