# Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Plants

Chris Swartz Water Utilisation Engineers
CSIR Durban
Umgeni Water
Cape Peninsula University of Technology
Tshwane University of Technology
North-West University
Development Bank of Southern Africa

TT 408/09

Water Research Commission

# Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Plants

Report to the
**Water Research Commission**

by

**Chris Swartz Water Utilisation Engineers**
**CSIR Durban**
**Umgeni Water**
**Cape Peninsula University of Technology**
**Tshwane University of Technology**
**North-West University**
**Development Bank of Southern Africa**

**WRC Report No. TT 408/09**

**AUGUST 2009**

Obtainable from

Water Research Commission
Private Bag X03
Gezina 0031
South Africa

orders@wrc.org.za

The publication of these guidelines emanates from a project entitled *A manual and training aids for the sustainable operation and maintenance of small water treatment plants*
(WRC Project No. K5/1599).

**DISCLAIMER**

This report has been reviewed by the Water Research Commission (WRC) and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the WRC, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

**ISBN: 978-1-77005-870-5**
**Set no: 978-1-77005-871-2**
**Printed in the Republic of South Africa**

## ABOUT THE GUIDELINES

Various local and international studies have shown that the selection and implementation of the correct water treatment system is only a first step in ensuring sustainable supply of potable water to small communities. Of even greater importance for sustainability of supply is the following of the correct operational and maintenance procedures. A study of 20 small water treatment plants (Swartz, 2000 (WRC Report no. 738/1/00 *Guidelines for the upgrading of small water treatment plants*)) found that most local small water treatment plants experienced problems in operating on a sustainable basis. This was due to a number of both technical and human factors. However, due to the wide and encompassing nature of this investigation, it was not possible to identify and characterise these operation and maintenance (O & M) related problems fully. Although most suppliers of small water treatment systems provide their clients with some operational and maintenance guidelines, these may not be exhaustive, or certain important generic aspects may not be covered. Therefore, there existed a need to determine the nature and full extent of the problems experienced, and provide practical and user-friendly guidelines for the required preventative and remedial actions to be taken to rectify the situation.

**Identify technical issues related to operation and maintenance of small water treatment plants**

Current management practices for small water treatment systems in South Africa were surveyed to determine what the best-practice methods are to ensure long-term sustainability of the plants. All the issues that have, or may have, an impact on the quantity or quality of the treated water were identified and evaluated.

**Draw up technical guidelines and compilation of Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Systems in South Africa**

From the technical and socio-economic issues that were identified above, a set of specific guidelines were developed for treatment plant managers, process controllers and plant O & M personnel on best practices for O & M of small water treatment plants to ensure long-term sustainability of these plants. The guidelines cover all the different types of systems and technologies used for drinking water treatment for small and rural communities, focusing on rudimentary and basic systems, and conventional treatment systems.

Based on the results of this survey of acceptable and unacceptable practices, a number of preliminary guideline themes or topics were drawn up. The guidelines were grouped under ***Technical Guidelines*** and ***Management Guidelines***, the latter including the important soft issues at small water treatment plants which often present major challenges with the sustainability of these plants. These preliminary guidelines were further researched and investigated by project team members, and specific guidelines then developed that were used in the guidelines and training aids for small water treatment plant O & M.

A framework and lay-out for the Guidelines was developed with the inputs of all project teams. In drawing up the framework, the following aspects and aims were considered:

- Focusing on the ultimate objective of this project to improve the sustainability of small water treatment systems.
- Clearly stating what the needs and shortcomings in the sustainable O & M of small water treatment systems in South Africa are.
- A review of existing manuals, and prioritising of issues that need to be addressed and included in these Guidelines.
- The Guidelines should be user-friendly.
- The Guidelines will be aimed at the senior process controller, supervisor, engineering department and middle management level.
- The guidelines for effective O & M of small water treatment systems that are presented in the document must be comprehensive and must address all the possible problems that are, or may be, found in the sustainable operation of small water treatment plants.
- Links must be provided to all related guideline documents, policy papers, operational manuals, information documents and databases that could be used to facilitate and improve sustainability of small water treatment plants.
- As much background information as possible should be provided for cross-reference in using the Guidelines, bearing in mind that the Guidelines should be a practical guide that can be used on a daily basis.
- The Guidelines must contain a trouble-shooting section.

**Project Team:**

**Mr Chris Swartz**, Chris Swartz Water Utilisation Engineers (Project Leader)
**Mr Godfrey Mwiinga**, Cape Peninsula University of Technology
**Mr Mike Marler**, Development Bank of Southern Africa
**Ms Verena Meyer**, Tshwane University of Technology
**Dr Mbhuti Hlophe**, North-West University
**Mr Rachi Rajagopaul**, Umgeni Water
**Mr Kenny Charles**, CSIR Durban

# GUIDELINES FOR THE SUSTAINABLE OPERATION AND MAINTENANCE OF SMALL WATER TREATMENT PLANTS



## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

# Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Plants

## SECTION 1 SCOPE OF THE GUIDELINES DOCUMENT

## CONTENTS OF SECTION 1

## 1.1 DEFINITION OF SMALL WATER TREATMENT PLANTS

Small water treatment plants are defined as water treatment systems that have to be installed in areas which are not well-serviced and which do not normally fall within the confines of urban areas. They are therefore mostly plants in rural and peri-urban areas and include water supplies from boreholes and springs that are chlorinated, small treatment systems for rural communities, treatment plants of small municipalities and treatment plants for establishments such as rural hospitals, schools, clinics, forestry stations, etc. Most of these applications require small plants of less than 2.5 ML/d (although plants of up to 25 ML/d may sometimes also fall into this category). Package plants are normally at the small end of the scale for ‘small plants’ and are plants which can be installed easily and be moved easily if required.

## 1.2 NEED FOR SUSTAINABLE OPERATION AND MAINTENANCE OF SMALL WATER TREATMENT PLANTS

A number of local and international studies have shown that the selection and implementation of the correct water treatment system is only a first step in ensuring sustainable supply of potable water to small communities. Of even greater importance for sustainability of supply is the following of the correct operational and maintenance procedures. In a study of 20 small water treatment plants (WRC Report 738/1/00 *Guidelines for the upgrading of small water treatment plants*) it was found that most local small water treatment plants experienced problems in operating on a sustainable basis. This was due to a number of both technical and human factors. However, due to the wide and encompassing nature of this investigation, it was not possible to identify and characterise these operation and maintenance (O & M) related problems fully. Although most suppliers of small water treatment systems provide their clients with some operational and maintenance guidelines, these may not be exhaustive, or certain important generic aspects may not be covered. Further, post-commissioning training cannot be provided on a sustainable basis. Therefore, there existed a need to determine the nature and full extent of the problems experienced and to provide practical and user-friendly guidelines in the form of a manual for the required preventative and remedial actions to be taken to rectify the situation.

## 1.3 AIMS OF THE GUIDELINES FOR SUSTAINABLE OPERATION AND MAINTENANCE OF SMALL TREATMENT PLANTS

The aims of the guidelines are:

a. To identify the various technical issues related to O & M of small water treatment plants impacting upon the quantity and quality of potable water before distribution.
b. To provide technical guidelines to small water treatment plant operations and maintenance personnel for the sustainable O & M of such plants, and to compile these guidelines into a user-friendly manual suitable to be used as a general reference for everyday, practical O & M on all categories of small treatment plants found in South Africa.

## 1.4 APPROACH TO DEVELOPMENT OF THE GUIDELINE

The following steps were performed during development of this guideline:

a. Perform literature review and audit of international operation and maintenance practice in small water treatment plants

A comprehensive literature review was conducted on all aspects related to O & M of small water treatment systems. The literature review covered all types of treatment systems and technologies used for small water treatment applications. Specific attention was also given to non-technical issues affecting the sustainability of small water treatment systems, such as a lack of funds for O & M, and lack of financial management.

b. Identify technical issues related to operation and maintenance of small water treatment plants

Current management practices for small water treatment systems in South Africa were surveyed to determine the best-practice methods and ensure long-term sustainability of the plants. All the issues that have, or may have, an impact on the quantity or quality of the treated water were identified and evaluated.

The O & M issues were identified and further investigated by visits. Detailed evaluation of all types and categories of small water treatment plants, spread geographically across the country, was conducted. Forty five plants were visited throughout the country in each of the provinces (excl. Gauteng).

c. Draw up technical guidelines and compilation of *Guidelines for the Operation and Maintenance of Small Water Treatment Systems in South Africa*

From the technical and socio-economic issues that were identified, a set of specific guidelines was developed for treatment plant managers, process controllers and plant O & M personnel on best practices for O & M of small water treatment plants to ensure long-term sustainability of these plants.

The guidelines were then incorporated into a user-friendly document entitled *Guidelines for the Operation and Maintenance of Small Water Treatment Systems in South Africa.*

d. Develop training guidelines on small systems O & M to be used by trainers or for self-study by O & M personnel

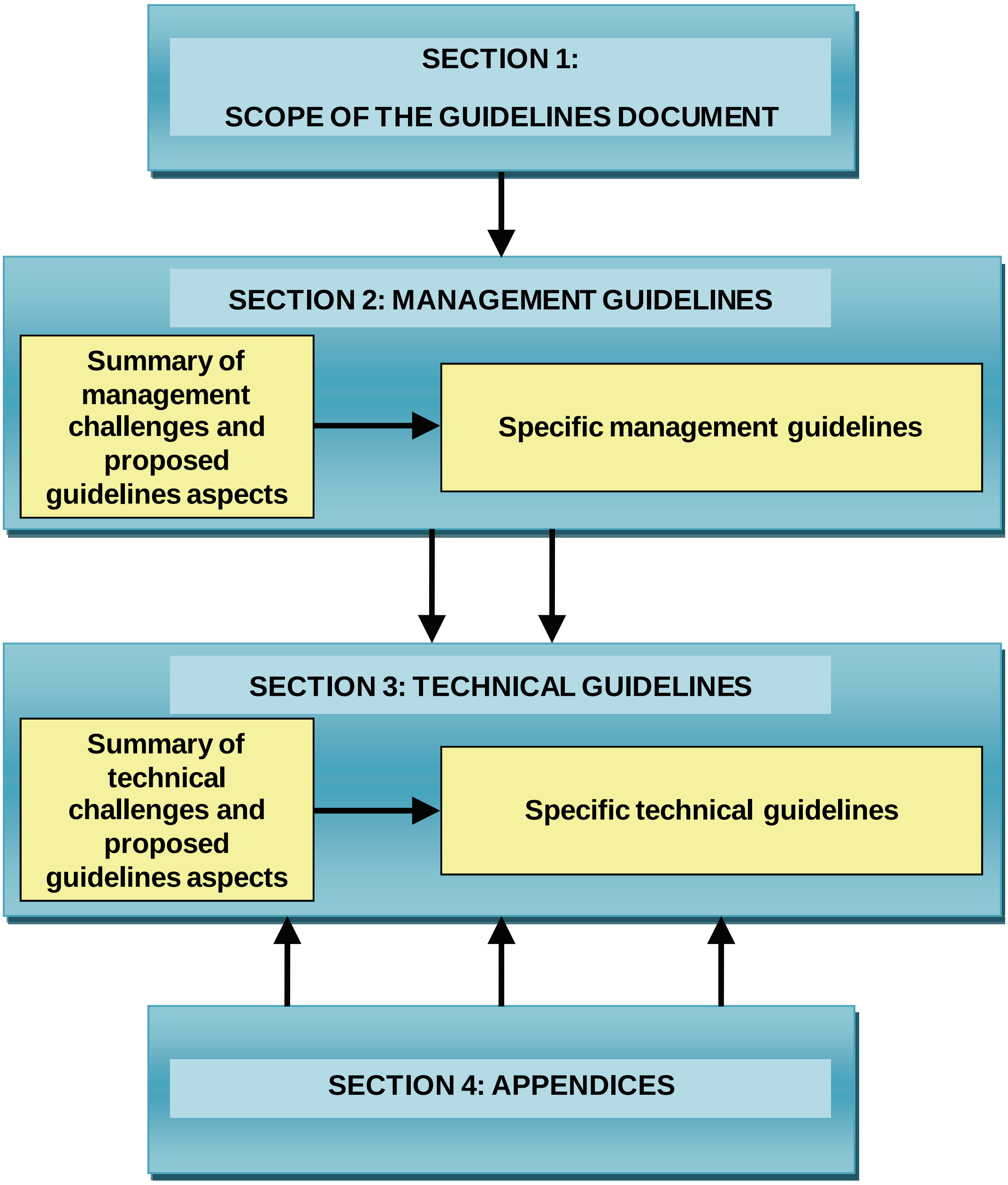
A comprehensive suite of training material was developed to be used by trainers/managers at the various water supply authorities and small municipalities to train their O & M personnel on a continuous basis on how to implement and run efficient O & M programmes for their small treatment systems.

## 1.5 STRUCTURE AND INTENDED USE OF THE GUIDELINES AND TRAINING PACKAGE

### 1.5.1 Who the guidelines are intended for

The guidelines are aimed at plant operation and management level, i.e. for process controllers, supervisors and plant managers. It is intended to be a reference document for O & M personnel, but also a training tool for municipal trainers in water supply and treatment.

### 1.5.2 Lay-out of the guideline



# Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Plants

## SECTION 2 MANAGEMENT GUIDELINES

## CONTENTS OF SECTION 2

## 2.1 SUMMARY OF MANAGEMENT PRACTICES AND ISSUES AND PROPOSED GUIDELINES

### 2.1.1 Introduction

Current management practices for small water treatment systems in South Africa were surveyed to determine what the best practice methods to ensure long-term sustainability of the plants are. All the issues that have, or may have, an impact on the quantity or quality of the treated water were identified and evaluated, which included the various raw water sources and its spatial and temporal variability. From the technical and socio-economic issues that were identified above, a set of specific guidelines was developed for treatment plant managers, process controllers and plant O & M personnel on best practices for O & M of small water treatment plants to ensure long-term sustainability of these plants. The guidelines cover all the different types of systems and technologies (including package plants) used for drinking water treatment for small and rural communities, focusing on conventional treatment processes. The problems and acceptable and unacceptable practices were then discussed, and based on these discussions several preliminary guideline themes or topics were drawn up. The guidelines were grouped under Technical Guidelines and Management Guidelines, the latter including the important soft issues at small water treatment plants which often present major problems with the sustainability of these plants. These preliminary guidelines were further researched and investigated by project team members, and specific guidelines then developed that were used in the manual and training aids for small water treatment plant O & M.

### 2.1.2 Description of table of management practices and guidelines

The tables on the following pages present practices and guidelines for management aspects involved in the O & M of small water treatment plants in the following sequence:

- Operation and maintenance issues or aspects
- Proposed practices or actions for effective O & M
- Consequences of not performing the proposed actions

The tables do not contain detailed guidelines or proposed actions for improving the O & M; they provide general best practice guidelines with references to more detailed elaboration on these aspects further in the document.

To find more detailed information on any of the best practice guidelines in the table, the user can simply click on the highlighted word in the HTML version and will then be taken to the section in the document where more information and details may be found. The numbers of the relevant sections are also provided for manual cross-referencing.

**It should be noted that the list of management issues and aspects in the tables was derived from the plant surveys and inspections. It relates to the types of plants that were targeted in the study, and was specifically intended to address the South African situation.**

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **MANAGEMENT RESPONSIBILITIES AND ACCOUNTABILITY** | | | |
| **1** | Effective management | Appropriate B.Tech or BSc (Built Environment) qualifications and related experience in potable water treatment and supply. (see Section 2.3.4 for details) | Poor leadership and management support<br>Low staff morale |
| **2** | Management responsibilities and accountability | Customer driven water supply management<br>Key performance areas (KPAs) drawn up for managers<br>Management responsibilities contained in service contracts<br>(Section 2.2) | No accountability<br>Poor water quality<br>High risk to consumer |
| **3** | Management support | Reporting, implementation and follow-up<br>Resource planning<br>Chemical contracts<br>Supply chain management<br>Budgeting<br>(Section 2.2) | Communication breakdown<br>Chemicals/materials run out<br>Delay in replacement of critical spares |
| **OPERATING PERSONNEL RESPONSIBILITIES** | | | |
| **1** | Trained operators, on site facilities, working equipment | Learnerships; on the job training<br>(Section 2.3.4) (Section 4.4) | Poor morale<br>Inefficiency<br>Non-compliance |
| **2** | Equipment in order<br>Process running well<br>Data logging done<br>Housekeeping practices | Unit checks (Section 3.3)<br>Desludge clarifiers (Table 3.3.1)<br>Backwash filters (Table 3.5.1)<br>Process control tests and completing log sheets<br>Ensure good housekeeping (Section 2.9) | Equipment failure<br>Poor process performance<br>Poor hygiene<br>Unsafe working conditions |

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **3** | Graphs of flow; turbidity; dosage rates; stocks; test results; equipment; service records etc | The records must be inspected and signed at least once a month by the supervisor | Incorrect dosages applied<br>Inadequate data communication |
| **4** | Cost/kL of water produced | | Low morale<br>De-motivation<br>Poor quality water |
| | | **RISK** | |
| **1** | No disinfection | Contract for disinfectant<br>Planned maintenance of equipment (Table 3.6.1) | Health risk<br>Water quality non-compliance |
| **2** | No water | Standby critical equipment | Health risk |
| **3** | No treatment chemicals | Supply chain management (Section 2.2) | Health risk<br>Water quality non compliance |
| **4** | Breakdown of critical equipment | Planned maintenance (Section 3.2.7)<br>Standby equipment (Section 3.2.7) | Health risk<br>Water quality non compliance |
| **5** | No skilled staff | Operator training (Section 2.3.4)<br>Improved working conditions (Section 2.9.2) | Inefficient process control |
| **6** | Unreliable raw water source | Alternative water source (Section 3.2.1) | Poor water quality |
| **7** | Variable raw water quality | Pretreatment (Section 3.2.2)<br>Buffer tank (Section 3.2.1)<br>Abstraction point selection (Section 3.2.1) | Difficulty to optimise coagulation process<br>Variable quality of treated water |
| **8** | Disposal of waterworks residuals | Select appropriate technology | Potential environmental pollution |

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **9** | Hazardous chemicals on site | Proper storage (Section 3.2.2 (b))<br>Safety training<br>Site specific safety plan | Risk of personal injuries |
| **10** | Security from theft and vandalism | Security fencing and access control (Section 2.4.3) | Interruptions in water supply<br>Water quality non-compliance |
| | **LEGAL REQUIREMENTS AND IMPLICATIONS** | | |
| **1** | Water quality compliance | Process controllers should have copies of SANS 241 specifications at each of the treatment plants and be familiar with its contents (Section 2.5.1) | Water quality non-compliance<br>Consumer complaints |
| **2** | Disposal of treatment plant residuals | Treat and dispose of treatment plant residuals (settling tank underflow or filter backwash water) in an acceptable manner according to the General Authorisation of the Water Act (Section 3.2.2 (k)) | Potential pollution of the environment |
| | **FINANCIAL** | | |
| **1** | Water Services Management Plans | These aspects are addressed by the Development Bank of Southern Africa | Improper or insufficient financial planning and control may lead to:<br>Shortage of chemicals<br>Inability to repair broken pumps and equipment<br>Overspending on budget<br>Inadequate technical backup availability |
| **2** | Water Sector Asset Management Plans | | |
| **3** | Municipal Finance Management Act | | |
| **4** | Impacts of not budgeting sufficient funds | | |
| **5** | Financial courses for municipal personnel | | |
| **6** | Levels of financial management in the water care sector | Include all components, such as human resources, chemicals, energy, planned maintenance, transport, safety, training (Section 2.6.6) | |

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **7** | Guidelines on drawing up plant budgets | | |
| **8** | Stock management | Call-off chemical delivery<br>Ensure around 6 weeks stock-piling | |
| | | **INFRASTRUCTURE** | |
| **1** | Asset management | Perform an asset management process (Section 2.7.4)<br>Prioritise rehabilitation and replacement needs<br>Review asset management plans at least yearly | Expensive 'down-time'<br>Water supply interruptions<br>Water quality non-compliance<br>Dissatisfied personnel at the treatment plant |
| **2** | Working conditions | Infrastructure must be in good working condition to ensure acceptable working conditions for water care personnel | Dissatisfied personnel at the treatment plant<br>Potential safety hazards |
| | | **COMMUNICATION (INTERNAL AND EXTERNAL WITH PUBLIC)** | |
| **1** | Communication channels | Develop and implement reporting systems and recommended communication channels between management, engineers, supervisors and operating personnel, and how these systems should be used and managed to ensure effective communication (see Section 2.9). | Distrust by consumers<br>Low morale<br>Unmotivated personnel<br>Non-compliance with regulatory requirements<br>Compromised treatment plant performance |
| **2** | Use of existing networks and forums | Existing networks and Forums to be targeted are:<br>i. Water Services Provider Network led by SALGA<br>ii. District Manager's Forum *(an appointment has to be made through the coordinator of WIN-SA, they are coordinating this meeting and have schedules)*<br>iii. Cities Network Forum *(they will assist in spreading the news)* | Not aware of new legislation or regulatory requirements<br>Operating in isolation<br>No opportunity to discuss and find solution to problems and challenges |

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **2** | Use of existing networks and forums | iv. *Provincial Water Sector Forums (most of the municipalities participate in these forums)*<br>v. WSA water sector forums.<br>vi. Various Task Teams within Provincial Water Sector Forums | Not aware of new legislation or regulatory requirements<br>Operating in isolation<br>No opportunity to discuss and find solution to problems and challenges |
| | | **GENERAL HOUSEKEEPING (Section 2.9)** | |
| **1** | General cleanliness: | Water is a food and strict hygienic conditions must be maintained | Poor quality water<br>Spread of water-borne diseases |
| **2** | Untidy plant<br>Dust, cobwebs, grease on equipment. | General cleaning of all equipment should be part of the daily duties and conducted under strict safety regulations<br>All pipes and pumps should painted and colour coded<br>Plant rooms must be cleaned regularly<br>Remove unnecessary grease and grime | Low moral<br>De-motivation<br>Short cuts taken with operation<br>Poor quality water |
| **3** | Dirty and flooded plant rooms. | Ensure leaks from pumps (gland packings) are contained | Result in accidents<br>Increase down-time<br>Waste of water<br>Not cost effective |
| **4** | Leaking taps and toilets | Repair all leaking taps | |
| **5** | Basic office; desks and chairs; cupboards; stationery | Office facilities must be provided at plants | Operators unable to work effectively<br>Low morale<br>De-motivation<br>Short cuts taken with operation<br>Poor quality water |
| **6** | Personal protective gear | Essential for staff to be provided with the personal protective equipment | Safety hazard |

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **7** | First aid equipment and training | Staff to be trained in First Aid and supplied with the required equipment | This can result in minor injuries becoming serious with first aid being applied |
| **8** | Records | All records relating to the plant must be kept | Poor plant operation |
| **9** | Meetings | Monthly meetings are recommended. This should also include on-site plant inspections | Tasks not carried out; low morale |
| **10** | Uncleaned offices, rest rooms and ablution facilities. | Cleaning of offices, restrooms etc. should be part of the daily duties | Unhygienic conditions |
| **11** | Unkempt grounds | The grounds must be well maintained | Safety hazard |
| **12** | Costs | | Waste of chemicals, time and money<br>Supervisor will not know firsthand and timeously of problems on the plant |
| **SAFETY** | | | |
| **1** | Poor safety practices | Site specific safety plan<br>Safety training and awareness programme | Risk to personnel and equipment<br>Contravening safety requirements |
| **2** | No proper personal protective equipment | Issue PPE and enforce use thereof | Contravening safety requirements / disciplinary action |
| **INSTITUTIONAL ASPECTS** | | | |
| **1** | Reform strategy in the water sector | Section 2.11.4 | |
| **2** | What does DWAF do if there is non-compliance? | Section 2.11.5 | |

| | Operation and maintenance issues / aspects | Proposed practices / actions for effective operation and maintenance | Consequences of not performing proposed actions |
|---|---|---|---|
| **SOCIO-ECONOMIC ASPECTS (COMMUNITY PARTICIPATION)** | | | |
| **1** | Active involvement by the community | Community must take responsibility for managing water projects themselves. | |
| **2** | Appropriate community organisation | Management Committee must receive adequate support from organisations in the area with the necessary experience and expertise.<br>Section 2.11.2. Section 2.11.6 | |
| **ENVIRONMENTAL ASPECTS** | | | |
| **1** | Environmental regulations | Relevant legislation and regulations; application to performed certain listed activities | Contravention of environmental requirements |

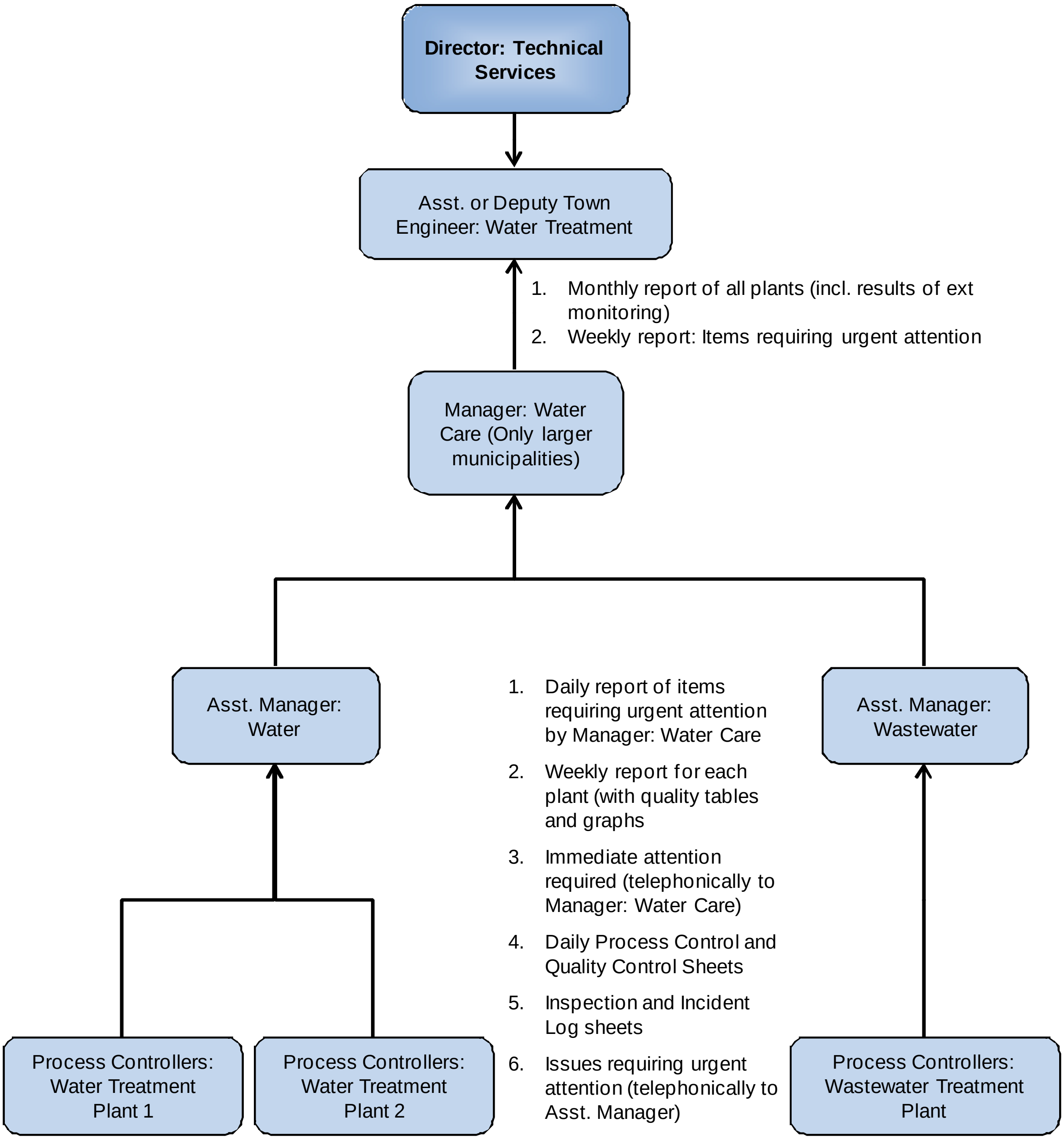
## 2.2 MANAGEMENT RESPONSIBILITIES AND ACCOUNTABILITY

The owner of a public water system is responsible for meeting all of the legal requirements that apply to the water supply. A process controller (operator) is a person who conducts day-to-day operational and technical activities related to the operation of a water supply. Although the owner may designate a process controller, the owner is ultimately responsible for providing safe drinking water and meeting regulatory requirements. It is important that both the owner and process controller work together to ensure that the water system provides safe drinking water and meets all applicable requirements. The ultimate goal for both the owner and operator is to provide safe drinking water to the public.

In municipalities, the ultimate responsibility and accountability for service delivery rests with the Municipal Manager. In the larger Municipalities, e.g. eThekwini Municipality, responsibility for water and wastewater is delegated to the Head of Water and Wastewater who is at the Executive Director level of seniority. There are various tiers of management and professional technical personnel that are responsible for a number of sections of water and wastewater activities.

In the case of district municipalities, responsibilities for all infrastructure and technical services fall under the Executive Technical Director. Reporting to the Executive Technical Director is the infrastructure director who has a fairly wide responsibility that includes water and wastewater delivery. Generally plant superintendents and maintenance foremen report directly to the director.

### 2.2.1 Suggested organogram for municipal water care function




Many of the positions on the organograms are often not filled. There are a lot of vacant positions especially where a Water Services Authority is performing dual functions, that of an authority and that of a provider. In most WSAs water services provision is not ring-fenced and therefore it becomes difficult for them know exactly how much a kilolitre costs in order to link the water business with the appropriate number of people who are supposed to work at a particular size of water treatment plant. People are working for long periods without their efforts being recognised through incentives or some sort of motivation, often resulting in the loss of good employees.

Another critical point is that there are no continuous training or induction courses which keep the water plant operators up to date with developments. There are also no succession plans or programs to ensure that should the key person leave the company/department immediately, there is an equal replacement who can run the plant smoothly.

### 2.2.2 Required minimum qualifications and experience of the Head of Water Care (*also called Manager: Water Care or Manager: Water Services*)

The minimum qualification for this management position is B.Tech (Water Care) or BSc with 5 to 7 years experience in potable water treatment and supply and wastewater treatment. The following functional competencies are recommended:

- Comprehensive knowledge of Water Quality legislation / guidelines / parameters for both raw and potable water.
- Comprehensive knowledge of Water Quantity management principles and guidelines encompassing water demand management, unaccounted for water losses, metering and water balances.
- Working knowledge of related legislation (LRA, National Water Act, Water Services Act, BcoEA, EE Act, OHASA, NEMA, PFMA, NOSA Systems Guidelines, ISO 9001 Management System, Dam Safety Act, SABS Guidelines for potable water).
- Comprehensive knowledge of Integrated Water Resource Management (IWRM) principles and practices.
- Comprehensive knowledge of municipal water distribution, storage and reticulation principles and practices.
- Comprehensive knowledge of the O & M of water treatment processes, methods, unit processes, sludge handling processes and treatment technologies.
- Ability to read and interpret engineering drawings and plans.
- Superior report writing skills.
- Comprehensive diagnostic and analytical skills.
- Sound financial acumen to compile and manage operational budgets.
- Strategic thinker.
- Project Management – the ability to facilitate multi-disciplinary projects at any given time.
- People Management – the ability to work with and through people to achieve results.
- Safety Management – ensure SHEQ compliance to statutory and company requirements.

### 2.2.3 Minimum key performance areas of the Head of Water Care

<u>Operational management</u>
Efficient management of client expectations and identification of client needs.

<u>Financial and budgetary control</u>
Management of the budget according to divisional strategies and targets in line with organisational financial policies and procedures.

Technical and environmental
Optimised usage of resources.

Management of production and distribution
Effective management of the operations.

Maintenance of the infrastructure
Optimised planned and reactive maintenance to the dam, waterworks and distribution system.

Internal processes

- Continuous improvement in processes to optimise time, specification and cost targets.
- Responsible for compliance with procurement procedures, vehicle logs, etc
- Develop and implement framework for the control of water losses, meter accuracy, billing processes and collections. Compliance with legislation and good practice controls.

Safety, Security, Health, Environmental and Quality (SSHEQ)
Ensure that safety, security, environment and quality of the raw water sources, waterworks and distribution system comply according to agreed standards.

Learning and Growth
Ensure productive individual and team performance. This may be achieved by:

- Determine HR developmental needs, skills plan and identify suitable programmes to address them.
- Continuous motivation and support of staff.
- Instil corporate governance, organisational culture and high ethical standards amongst staff.
- Proactively address HR challenges in own department.
- Act as a mentor and coach to individuals within department.
- Set performance contracts and review on a quarterly basis.
- Address non compliance and transgressions by following disciplinary procedures in line with the necessary labour laws.

## 2.3 OPERATING PERSONNEL RESPONSIBILITIES

### 2.3.1 The DWAF system as basis

In order to operate a water treatment plant effectively, water plant operators must be oriented before they commence with the work. It is critical to know the types and sizes of the water treatment plant, so that relevant candidates can be selected. This should be followed by the induction courses aimed at the succession plans in order to maintain the functioning of the water treatment plant, irrespective of any changes that may occur. Roles and responsibilities must be clearly defined. The primary functions of the water plant operators should, amongst other things, include the following:

- Conducting of jar test for determining the appropriate dosage of the coagulant.
- Taking of samples in the agreed sampling points at agreed intervals.
- Backwashing of the filters and desludging of the sedimentation tanks regularly.
- Preparing working solutions for test in the laboratory.
- Recording of incidents in the water treatment plant.
- Safe keeping of all machinery records in the plant.
- Ensure that all operation units are working properly.
- Maintenance of pumps and motors (e.g. lubrication).
- Changing of chlorine gas cylinders.
- Installation of packing glands.

Critical to the above information is the communication equipment/network needed to shorten the response time in case things go wrong while maintaining one of the process units. Spare materials must be readily available, meaning that they must be ordered in time.

### 2.3.2 Operator input requirements (typical duties)

Functions to be performed by Process Controller (example)

- Clear debris built-up from raw water intake.
- Check sediment level. Divert water away from intake chamber and remove debris/sand with spade.
- Check that the raw water pumps are running.
- Check that the high-lift pumps are started automatically when the holding tank is full. Check that the dosing pump has switched on and that chemicals are being fed through the dosing pump.
- Check whether chemicals need to be made up in the dosing tanks and make up if required.
- Check that the chlorine dosing pump is working.
- Backwash the filter as required.
- Clean the dosing pump tanks, dosing pump strainer and dosing pump valves.
- Check the chlorine residual and note daily in a logbook. Check the water pH and note daily in a log book.

### 2.3.3 Schedule of operating action (example)

Daily

Start raw water pumps
Check pH and chlorine levels and keep a record
Check pH/flow readings and record
Check water flocculation and record pH
Check stirring chemicals in make up tanks
Make up chemicals in tanks if required

Backwash filter as required
Check that dosing pumps are pumping and that dosing rate is correct
Check the chlorine dosing rate and record
Start high lift pumps

Weekly

Conduct all daily checks
Backwash filters
Flush the dosing line with acid

Monthly

Carry out daily and weekly checks
Check pumps, glands, etc.
Clean items as required further in plant
Allow the HTH chemical make up tank to empty and clean out sludge from HTH / alum make up tank

Six-Monthly

Check sand in filters and replace or replenish if necessary

Yearly

Perform daily, weekly and monthly checks
Check all electrical connections
Check functioning of all pumps

Three-Yearly

Service motors and pumps – see suppliers' manuals
Have dosing pumps serviced by supplier, or authorised dealer

### 2.3.4 Learnerships (ESETA) to formal training (different levels)

Senior management must ensure that water treatment personnel have the requisite expertise appropriate to their job function. The training can be provided by contract trainers who will use guidelines set out in this Guidelines Manual. More information can be found in Section 4.4 in the Appendices.

## 2.4 RISK

### 2.4.1 Importance of risk management at water treatment plants

It is essential that water treated at a treatment plant should comply with the required standards as set out in the SANS 241 document. This can only be achieved by ensuring that the plant is capable of producing good quality water and that the operating staff is sufficiently trained. It is also essential for test equipment to be available to perform basic tests to ensure good quality water.

Poor quality water can lead to various diseases being spread, as was recently the case at a small town in the Mpumalanga Province (Delmas), where numerous people contracted cholera.

Two of the main reasons for poor quality water are high turbiditys and poor disinfection.

High turbidity in drinking water has an adverse effect on the disinfection process of the water as it tends to screen the bacteria. It is also aesthetically unacceptable.

Poor disinfection of water will result in the spread of water borne diseases such as cholera, diarrhoea, dysentery, gastroenteritis and typhoid. This can rapidly spread in a community resulting in an epidemic, as was the case in the Eastern Cape in 2002/3. Treatment of patients suffering from the effects of poor quality water negatively impacts on clinics, hospitals, doctors, nurses and the country as a whole.

Apart from the health issues, poor quality water (unstable water) also impacts on plant structures and reticulation systems. Aggressive water attacks concrete structures such as plant structures, reservoirs and reticulation systems resulting in damage in the long term.

Water which is scale-forming adversely affects reticulation systems, especially hot water systems and hot water equipment.

#### 2.4.2 Impact of poor operation

- Unsafe drinking water.
- High treatment costs.
- Need for specialist and time-consuming intervention to fix problems.
- Breakthrough of viruses and pathogens in the drinking water – water borne diseases.
- Compromises well being of consumers – especially babies, the aged, and those with poor immune systems.
- Legal action against service provider.

#### 2.4.3 Risk evaluation

A risk evaluation guideline is used to provide a clear and nationally consistent method of evaluating the risk of a water or wastewater system (in first nation / indigenous communities). Risk levels are then used as part of the priority ranking framework for capital and operation maintenance projects and in the development of action plans and long term capital plans for the purpose of correcting the systems at risk.

A Water Research Commission project on risk evaluation and risk management in small water treatment plants is currently in progress, and the user of the Guidelines is referred to the guidelines document that will emanate from this project (Water Safety Plans).

## 2.5 LEGAL IMPLICATIONS

This document is aimed at assisting municipalities with small water treatment plants in operating and maintaining them in a sustainable manner. The survey performed on the small water treatment plants in the country identifies various gaps that need to be addressed with regard to the water services institutions responsible for water services provision (especially small water treatment plants), ranging from managerial and financial to technical departments. As a starting point, the document has been presented to various water sector forums and networks, in order to cover the bigger audience. The objective is that as it reaches all relevant sectors, it will hopefully create demands from the WSAs that are affected by the gaps in managerial, technical and financial departments in their areas. The Technical Assistance Centre was launched at the WISA conference 2008 to ensure that all the challenges encountered by the water services institutions operating small water systems have a facility to request assistance.

### 2.5.1 Summary of important aspects from SANS 241 of 2005 (updated 2006)

The SANS 241 is a South African National Standard for drinking water published as Edition 6 in 2005 by Standards South Africa. It is thus generally referred to as **SANS 241: 2005**. Unlike guidelines, standards are legally binding.

As result, the ***South African Compulsory National Standards Regulations*** under section 9 of the ***Water Services Act, 1997 (Act No. 108 of 1997)***, for the quality of potable water directs Water Services Authorities to use the SANS 241:2005 (referred to as SABS 241) for guidance.

Therefore, it is important to realise that, **as a standard, SANS 241 is a legally binding publication**. It specifies the quality of acceptable drinking water, with respect to microbiological, physical, organoleptic and chemical parameters **at the point of delivery**.

For the microbiological requirements, there is no classification as far as water quality is concerned. All drinking water shall meet the stipulated microbiological requirements. However, for the physical, organoleptic and chemical parameters, the SANS 241:2006 describes the following two classes of drinking water:

**CLASS I**: This class is considered to be acceptable for lifetime consumption, and is the recommended compliance limit.

**CLASS II**: This class is considered to represent drinking water for consumption for a limited period. This class specifies a water quality range that poses an increasing risk to consumers, depending on the concentration of the parameter within the specified range.

Note that in its text, the SANS 241 makes reference to several standards, which through reference, are deemed to constitute provisions of the SANS 241. It is therefore imperative that the Water Services Authorities are knowledgeable about the provisions of these referenced standards.

**Requirements:**

The assessment of the suitability and acceptability of the water for drinking purposes shall be based on considering the micro-biological content, and the physical, organoleptic and chemical properties as indicated in Tables 1 and 2 of the SANS 241 document. Table 1 is hereby reproduced and an extract of basic parameters that are commonly measured at water treatment plants is presented in Table 2.

**Table 1:** Micro-biological safety requirements (SANS 241:2006)

| **Determinant** | **Unit** | **Allowable compliance contribution**[a] | | |
|---|---|---|---|---|
| | | **95% of samples, min.** | **4% of samples, max.** | **1% of samples, max.** |
| | | **Upper limits** | | |
| *E. coli*[b] or | Count/100 mL | Not detected | Not detected | 1 |
| Thermo tolerant (faecal) coliform bacteria[c] | Count/100 mL | Not detected | 1 | 10 |

a. The allowable compliance contribution shall be at least 95% to the limits indicated in column 3, with a maximum of 4% and1%, respectively, to the limits indicated in column 4 and column 5. The objective of disinfection should, nevertheless, be to attain 100% compliance to the limits indicated in column 3.

b. Definitive, preferred indicator of faecal pollution.

c. Indicator of unacceptable microbial water quality; could be tested instead of *E. coli* but is not the preferred indicator of faecal pollution. Also provides information on treatment efficiency and aftergrowth in distribution networks.

### 2.5.2 Water quality targets

*Microbiological requirements*

The percentage allowable compliance given in Table 2 applies to the microbiological statistics for a period of one year. Where a microbiological test result exceeds the value given in column 4 or column 5 of Table 2, immediate re-sampling, together with associated remedial action, shall be implemented until the water quality complies with the requirements given in column 3 of Table 1. **If a microbiological test result exceeds the value given in column 5 of Table 1, and the result is confirmed by a further test, unacceptable risk to health is implied.**

*Physical, organoleptic and chemical parameters*

The water shall comply with the requirements for Class I for lifetime consumption in relation to the physical, organoleptic and chemical but not the aesthetic parameters. Nevertheless, compliance with aesthetic requirements has cost implications. **A 95% compliance target on an annual basis for Class I is recommended, while for Class II, a 97% compliance target on an annual basis is recommended.** The organoleptic quality of the water is of an operational nature, and does not make the water unsafe to drink. Therefore, the organoleptic quality of the water should be acceptable to the majority of consumers.

**Table 2:** Basic physical and organoleptic requirements and chemical parameters that are commonly measured at water treatment plants (extracted from Table 2 in SANS 241:2006)

| **Determinant** | | **Unit** | **Class I (operational limit)** | **Class II (max. allowable for limited duration)** | **Class II water consumption period, max** |
|---|---|---|---|---|---|
| **Physical and organoleptic parameters** | **Significance** | | | | |
| Colour | Aesthetics, operational | mg/L Pt | < 20 | 2- 50 | No Limit |
| Conductivity at 25°C | Aesthetics | mS/m | < 150 | 150-370 | 7 years |
| Dissolved solids | Aesthetics | mg/L | < 1000 | 1000-2400 | 7 years |
| Odour | Aesthetics | TON (Threshold odour number) | < 5 | 5-10 | No Limit |
| pH value at 25°C | Aesthetics, operational | pH Units | 5,0-9,5 | 4,0-10,0 | No Limit |
| Taste | Aesthetics | FTN (Flavour threshold number) | < 5 | 5-10 | No Limit |
| Turbidity | Aesthetics, operational, indirect health | NTU (Nephelometric turbidity units) | < 1 | 1-5 | No Limit |
| **Chemical parameters** | **Significance** | | | | |
| Iron as Fe | Aesthetics, operational | µg/L | < 200 | < 200-2000 | 7 years |
| Manganese as Mn | Aesthetics | µg/L | < 100 | 100-1000 | 7 years |

### 2.5.3 World Health Organisation (WHO) Guidelines for Drinking Water Quality

An established goal of WHO and its member states is that: *'all people, whatever their stage of development and their social and economic conditions have the right to have access to an adequate supply of safe drinking-water'.*

In this context, 'safe' refers to a water supply which is of a quality that does not represent a significant health risk, is of sufficient quantity to meet all domestic needs, is available continuously, is available to all the population and is affordable. These conditions can be summarised as five key words: quality; quantity; continuity; coverage; and, cost.

To assist governments in dealing with these and related issues regarding water quality, WHO has over the years, been involved in the review and evaluation of information on health aspects of drinking-water supply and quality and in issuing guidance material on the subject. The first WHO publication dealing specifically with drinking-water quality was published in 1958 as *International Standards for Drinking-Water*. It was subsequently revised in 1963 and in 1971 under the same title. Because of the ever-continuing research on water quality, the 1971 standards were again reviewed, and in 1984 the *WHO Guidelines for Drinking-Water Quality* were published. Further reviews have taken place; the latest edition was published in 2005. Information on the WHO guidelines can be accessed on the website – http://www.who.int/.

### 2.5.4 Permits / Compliance with the Act

General Authorisation is required for discharge of plant residuals to natural water sources or source of water for the treatment plant (see also Section 3.2.2 (k)).

| |
|---|
| Legislation related to water supply and sanitation may be found at<br>http://www.dwaf.gov.za/dir_ws/tkc/default.asp?nStn=technologies&reslist=complete&TechTypeID=3 |

### 2.5.5 What does DWAF do if there is non-compliance?

The Department has developed the Drinking Water Quality Regulation strategy for water services provision, in which a brief compliance protocol has been included. Below, briefly, are the steps followed by the Department. For more information see the draft generic intervention protocol report:

**a. Notification of the problem**

Through various sources: toll-free line; media; other government departments; the DWAF offices; private sector. Notification is either to the DWAF regional office or to the DWAF head office. Initiation of the process must include communication to the relevant regional and national offices of DWAF to prevent duplication and promote co-ordination of resources.

**b. Initial assessment**

This initial assessment must be undertaken as speedily as possible, with timeframes relevant to the situation. Potential or actual emergency situations should be assessed/classified within 24 hours if possible and the relevant procedure – disaster management; Section 20 or 53 of the National Water Act (1997) – followed.

**c. Notice of Non-compliance**

The classification in Step 2 determines whether the situation is resolved or whether further action is needed. A formal Notice of Non-compliance to the offending party should follow a classification of "non-compliant". This notice MUST contain either an action plan and/or recommendations (with a time frame), or a request for such.

**d. Report back**

If an offending party receives a Notice of Non-compliance from the DWAF, it is required to respond in writing within the prescribed time frame – as stipulated in the Notice of Non-compliance – to inform the DWAF of the remedial action taken to restore compliance. The DWAF must monitor the offending party during this phase and provide support if required.

**e. Corrective Action Plan**

If the WSI has not taken any steps to rectify the situation, a meeting must be organised with the relevant officials. Relevant government departments should also be invited to this meeting. If the WSI is seen to be uncooperative, both the DPLG and DWAF National Office must be informed immediately so that higher intervention can be sought to ensure that such a meeting does take place.

**f. Detailed Investigation and Decisive Action**

The detailed investigation should include an assessment of all major contributing factors to the non-compliance and be a multi-disciplinary approach. Economic, technical, institutional, HR, legal and environmental aspects should be assessed.

**g. Final Notice of Non-compliance**

If compliance has not been achieved, and the offending party has shown no significant effort to institute the required remedial action, the DWAF needs to issue a Final Notice of Non-compliance and warning of possible legal action.

**h. Legal Action**

Legal Action is seen as a last resort, requiring documented evidence to prove that National Government has exhausted all means of co-operative governance before taking this step. The DWAF should endeavour to avoid this step by negotiating and convincing the WSI of its responsibilities. However, as a contingency measure, DWAF (Water Services & Legal Services) must investigate strategies to deal with issues that cannot be solved by means of negotiations.

During all these steps, the complainant must continuously be informed of the procedures and communications taking place. It is also essential that the offending party be given warning of any administrative action as required by the Promotion of Administrative Justice Act (PAJA). The requirements of this Act must be adhered to throughout this protocol.

## 2.6 FINANCIAL

Proper financial planning and financial management and control are integral to ensuring effective and sustainable O & M of small water treatment plants. The following plans and legislation contain important information on financial management of municipal water treatment plants including, in this case, the small water treatment plants.

- Water Services Management Plans
- Water Sector Asset Management Plan
- Municipal Finance Management Act

### 2.6.1 Levels of financial management in the water care sector

There are two levels of financial management in the municipal water care sector.

**a. Manager (Head of Water Care)**

- Guidelines for planning

- Procurement processes
- Guidelines for budgeting for water treatment

Cost control (budgeting)(budget control)

- On-plant exposure for these managers
- Water treatment terminology as related to financial management
- Importance of balancing income and expenditure (do not try to save costs on essential aspects such as chlorine, but do not overdose either)
- Income (cost recovery, etc. – refer to 1.6)(free basic water)
- Cost spreadsheets

**b. Plant personnel (operating personnel [supervisors and process controllers])**

The essential expenditure on small treatment systems includes:

Human resources

- Superintendent
- Permanent operator
- Security
- Temporary staff

Planned equipment maintenance and breakdown maintenance

- Annual maintenance contract
- Critical spares
- Emergency/ breakdown

Maintenance of Infrastructure

- Grass cutting
- General cleaning
- Sand filter cleaning

Chemicals

- Coagulants/flocculants
- pH correction (lime)
- Disinfectant

Transport

Safety

- Personnel protective equipment
- Overalls
- Safety boots
- Goggles, protective gloves
- Ear muffs
- Rain coats

Energy

Training

- Safety
- Adult Basic Education and Training (ABET)
- Operator

### 2.6.2 Stock management

Generally, a district municipality (DM) is in charge of a number of small water treatment systems located in a wide area. One of the problems associated with treatment chemicals with respect to small water systems is that the different water treatment plants may require different water treatment chemicals, depending on the raw water source.

Only a jar test can estimate the most cost-effective coagulant for a particular application. Therefore bulk supply of water treatment chemicals to a central chemical storage facility may not be appropriate.

It is also not recommended that chemicals be stock-piled on site due to poor safety and security in small water treatment plants. It is therefore recommended that the DM procurement department get into contract arrangements with suitable chemical suppliers, where required volumes of chemicals are requisitioned on a call-off basis. Depending on the availability of suitable storage space on site, about 6 weeks' supply can be stored at the waterworks.

A log of chemical usage will be kept by the plant operator whenever a new batch is prepared. He will then alert his senior as soon as the agreed minimum chemical stock is reached. A call-off for chemical delivery will be made and the stock replenished.

### 2.6.3 Systems (proposed/ideal) for ordering equipment/chemicals timeously

It is important that certain essential items on a water treatment plant always be available and in stock. This includes equipment such as dosing pumps, as well as treatment chemicals.

In a new Water Research Commission project (see Section 2.6.10), operational information tools will be developed that will facilitate plant operating personnel to order essential equipment and chemicals timeously, thereby ensuring availability at the plant at all times.

### 2.6.4 Log sheets

Operational information sheets (also referred to as log sheets) are very important to ensure not only optimal functioning and performance of the water treatment plant, but also financial management; they should be completed and managed meticulously by the process controllers and plant supervisory and management personnel. Log sheets for this purpose have been developed specifically for South African conditions in a Water Research Commission Project on "*Operational Information Tool for the Effective Operation and Maintenance of Small Water Treatment Plants*" (WRC Project K5/1718).

The operational spreadsheets (log sheets) are provided in Section 3.3 of this document.

## 2.7 INFRASTRUCTURE

### 2.7.1 Asset Management

Applying the practices recommended in these Guidelines will assist with improving the management of small water treatment systems by:

- Increasing knowledge about small water systems, which will allow better financial decision making. This is useful information when considering options to address various system challenges such as meeting regulatory requirements or upgrading system security.
- Reducing system 'down-time' and the number of emergency repairs, since plans will be in place for the replacement and rehabilitation of your assets.
- Prioritising rehabilitation and replacement needs and providing time to research cost-effective alternatives.
- Showing investors and the public that their money is used effectively and efficiently, which may make them more likely to increase investment or tolerate rate increases.
- Providing greater access to financial assistance. Some funding sources give applicants extra credit (higher priority ratings) for having an asset management plan or a capital improvement plan.


#### 2.7.2 What is asset management?

Asset management is a planning process that ensures that the greatest value is obtained from assets and that the financial resources are available to rehabilitate and replace them when necessary. Asset management also includes developing a plan to reduce costs while increasing the efficiency and the reliability of assets. Successful asset management depends on knowing about the plant owner's assets and regularly communicating with management and customers about the system's future needs.

Asset management plans should be reviewed at least once a year, noting any relevant changes. Throughout the year, a running list should be kept of times to consider or include in the annual update.

### 2.7.3 How does asset management relate to strategic planning?

Strategic planning is a management concept that helps plant management to address and prepare for both anticipated and unexpected problems. Strategic planning utilises asset management to evaluate the water supply system's current physical situation, and it also evaluates the system's financial and managerial situation. It requires fundamental decisions to be made about the water system's purpose, structure, and functions.

### 2.7.4 Asset management process

Asset management consists of the following five steps:

1. <u>Taking an inventory</u>. Before managing assets, it is necessary to know what assets there are and what condition they are in. This information will assist with scheduling rehabilitations and replacements of assets.

2. <u>Prioritising the assets</u>. The water system probably has a limited budget. Prioritising the assets will ensure that allocation of funds for the rehabilitation or replacement of the most important assets can be attained.

3. <u>Developing an asset management plan</u>. Planning for the rehabilitation and replacement of assets includes estimating how much money will be needed each year to maintain the operation of the system. This includes developing a budget and calculating required reserves.

4. <u>Implementing the asset management plan</u>. Once it has been determined how much money needs to be set aside each year and how much additional funding (if any) will be needed to match that amount, cohesiveness between management, customers and regulators is needed to carry out the plan and ensure that the technical means to deliver safe water is available.

5. <u>Reviewing and revising the asset management plan</u>. Once an asset management plan has been developed, it should not be stuck in a drawer and forgotten about! The asset management plan should be used to help shape operations. It is a flexible document that should evolve as more information is gained and priorities shift.

### 2.7.5 Required infrastructure for operating personnel

Guidelines for minimum requirements for small treatment plants' infrastructure (similar to DWAF minimum requirements for solid waste disposal sites) are currently being developed, and include aspects such as electricity, lighting, roads, ablution, housing, canteen facilities, offices and security.

## 2.8 COMMUNICATION (INTERNAL AND EXTERNAL WITH PUBLIC)

### 2.8.1 Record keeping

- Stocks
- Process control measurements/observations
- Quality control measurements/observations
- Complaints/requests
- Need to be checked/signed by supervisors

Examples of forms (sheets) that could be used on small water treatment plants for operational information management (WRC projects K5/1718) are shown in Section 3.3 of this Guidelines document.

### 2.8.2 Meetings

It is essential for the operators, supervisors and management to meet at least once a month – preferably on site. Such meetings motivate the operator to perform better and ensure that the plant is kept in a reasonably good condition. Generally the only time the operators hear from management is when water quality is poor.

The following can be discussed at these meetings:

- Quality of water produced as well as the costs involved in the production (i.e. the cost to produce one kilolitre of water of an acceptable standard).
- Maintenance.
- Chemical supply and stocks.
- Infrastructure – conditions.
- Discuss monthly reports.
- Actions taken regarding problems on the plant.
- Safety.

Other issues relating to the plant and operators may also be discussed at these meetings. In this way, all concerned with the production of good clean and safe water, will be kept consistently informed.

### 2.8.3 Monthly summaries by supervisors of plant records

The operational information sheets (log sheets) referred to above (see also Section 2.6.10) include a spreadsheet in which the daily sheets are summarised on a monthly basis (see Section 3.3) and from which graphs and reports can be generated automatically. The information contained in the monthly summary sheets includes summaries of water quality data, chemicals and energy use, and treatment costs that are calculated from the summary sheets.

It is recommended that formal monthly plant meetings be held to discuss the results of the previous month's performance of the plant and importantly, any action points that may arise and that should be carried out in order to improve or optimise the performance and compliance of the treatment plant.

## 2.9 GENERAL HOUSEKEEPING

### 2.9.1 General housekeeping aspects

Water is regarded as a food and therefore strict hygienic conditions should be applied in the production of potable water.

An untidy plant where dust, cobwebs and grease abound results in a low morale and de-motivation amongst the staff. This in turn results in staff indulging in short cuts with the operational procedures and consequently producing poor water quality. The general cleaning of all equipment should be part of the daily duties and should be conducted under strict safety regulations. Ideally all pipes and pumps should be colour coded.

Leaks from pumps in the plant room and from taps can result in accidents, a waste of water and down-time. Ensure that the plant rooms are kept clean and all leaks are repaired.

All records relating to the plant must be kept, e.g. flow; analyses; chemical dosage rates; stocks; service records etc.

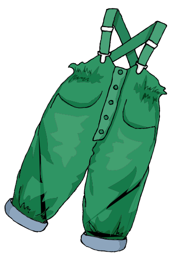
Regular on-site meetings are essential at a plant. This will enable the supervisor to know first-hand of the conditions at the plant. Site investigations and records can also be inspected during these meetings.

Operators are unable to work effectively without proper office facilities. This also results in low morale and de-motivation. Personal protective gear is essential for all staff on the plant. Injuries are likely to occur without the necessary safety gear.

- Overalls
- Gum boots
- Boots
- Gloves

First Aid equipment is essential on all plants. Staff will also have to receive the necessary training to use such equipment.

- Plasters & bandages
- Mouth to mouth inhalation mask
- Emergency blanket
- First Aid scissors
- PVC disposable gloves



### 2.9.2 Working conditions

Working conditions are generally guided by two broad laws. These are the labour laws, which clarify general working conditions. These include hours of work, leave, employee rights, and employer obligations. The second important legislation is the 'Occupational, Health and Safety Act' of 1993, which covers the important aspects of safe working conditions, obligations of the employer in ensuring a safe working environment, provision of safety equipment, training and awareness. The Act has evolved further to include security, environment and quality, SSHEQ.

Basic working conditions will include:

- A safe working environment with facilities and infrastructure that would reduce risk to acceptable levels.
- Free issue personal protective equipment (PPE).
- Job based training.
- Safety training.
- Personal injury sustained during the execution of the job is covered by Workman's Compensation.

### 2.9.3 Plant tours for managers on a regular basis to check general housekeeping condition

It is also important for management to inspect the plant on a regular basis together with the operating staff. The inspection can be conducted after a meeting where the manager can verify what has been discussed at the meeting. This will encourage the operating staff to ensure correct reporting performance of duties.

The inspection should begin at the inlet and continue through each process of the plant. Inspections of the staff rooms and offices should also be conducted. Cleanliness of the grounds, equipment, offices, safety equipment and personnel protection gear should be discussed.

## 2.10 SAFETY, OCCUPATIONAL HEALTH AND SECURITY

### 2.10.1 Introduction

The formulation of, and adherence to, safe-working procedures is in the best interest of all concerned with the O & M of treatment plants.

On large plants, it is the responsibility of management to formulate and implement safety procedures. These must be actively supported by the operating and maintenance staff. On smaller plants, the process controller himself may have to take the initiative in this regard.

### 2.10.2 Safety committees

In terms of regulations framed under the Machinery and Occupational Safety Act 1983 (replaced by Occupational Health & Safety Act 85 of 1993), one safety representative must be appointed in writing at any workplace for every 50 persons employed, except where there are less than 20 employees (farm labourers are excluded). It is mandatory for this safety officer to carry out an inspection of the workplace to which he has been designated at least once a month. Any threat or potential threat to the safety of any employee must be reported to his employer and a safety committee established in terms of the Act.

Small works should at least be served by the engineer or responsible person, the superintendent or process controller and representatives from the labour force and maintenance staff.

Meetings should be held regularly or the purpose of the committee is lost. The committee's functions are to promote awareness of safety, to investigate accidents, to recommend safe practices and procedures and to ensure compliance with statutory requirements.

### 2.10.3 Basic rules

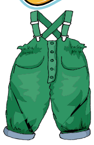
All persons visiting or employed on a water treatment works should observe the following basic rules at all times:

- Do not touch electrical equipment or switches and treat all equipment which has not been isolated and locked as live.
- Do not touch moving machinery.
- Take care when standing near or working over tanks and channels, which may be deep or contain swiftly moving water.
- Do not enter the chlorination building without testing for a gas leak with a rag that has been soaked in ammonium hydroxide solution.

### 2.10.4 Protective clothing

The items listed below make up necessary basic clothing for all those employed on a treatment works.

Hard hat - made of high density polyethylene (wear only when necessary)



Overall - elastic in the waist and cuffs; zip down the front

Gum boots - lightweight with built-in tow protection and nonslip soles

Boots - leather, nonslip, ankle-protection type with toe protection

Gloves - made of strong flexible PVC with roughened palm

### 2.10.5 Supervision

There is no purpose in equipping a works with all the recommended safety equipment and the personnel with protective clothing, if the equipment is not maintained. A fire extinguisher which does not work has no value.

Similarly, there is no purpose in drawing up a safety manual and recommended procedures if they are not followed.

The works manager, superintendent or responsible person must therefore ensure that procedures are adhered to; that ladders, fire extinguishers and respirators are inspected and tested on a routine basis; and that certain protective equipment such as the less popular earmuffs and eye protection, are in fact worn when necessary.

### 2.10.6 Machinery

When working with equipment and machinery (maintenance personnel), observe the following rules:

- Ensure that it cannot be started or operated by either disconnecting the means of starting or by isolation at the panel and/or the local stop.
- Always use the correct tools for the job.
- Keep chisels in good condition.
- Wear visors or goggles when grinding.
- Use the correct grade of protective visors or goggles when welding or brazing.
- Do not manhandle heavy objects. Use lifting gear.
- Always replace belt guards and other safety shields.
- Always read the instructions carefully before carrying out any maintenance operation on specialised equipment.

### 2.10.7 Electrical equipment

Electrical equipment requires further attention:

- No unauthorised person should work on electrical equipment, open a panel or enter a substation.

- All equipment to be handled should be properly isolated and locked so that it cannot be switched on. Suitable notices should be placed at the switch panel and adjacent to the equipment.
- All installations should be properly tested by a competent person before being put back into service.

### 2.10.8 Materials handling

When handling materials, care should be taken especially when handling heavy or bulky objects. In order to reduce the number of injuries caused by the use of incorrect material handling methods the following points should be considered:

- Use suitable lifting gear wherever possible.
- No person should attempt to lift more than can be handled comfortably.
- Wear gloves when possible. Otherwise ensure that the hands on the object are clean and not slippery, and that it is free from jagged edges, metal silvers, nails, burrs and splinters.
- Ensure firm footing and good visibility whilst manoeuvring.

### 2.10.9 Guidelines for incident/accident reporting

The ultimate responsibility and accountability for SSHEQ compliance as per the Act, rests with the Municipal Manager, who then delegates responsibilities down the line. For SSHEQ to be taken seriously, a senior manager should be the SSHEQ driver. Depending on the number and distribution of the waterworks, a number of SSHEQ co-ordinators oversee the implementation, monitoring and constant improvement to the SSHEQ system. The SSHEQ co-ordinator sets up an incident/accident reporting system as part of an integrated SSHEQ system. There are standard incident/accident reporting books that are filled as soon as an incident or accident has occurred. A preliminary incident/accident report is completed and distributed to the Line Manager and SSHEQ Co-ordinator within 24 hours. The system is such that reporting is encouraged and is followed by an investigation.

The incident/accident investigator is trained in the process of investigation. An investigation report in the form of a comprehensive questionnaire is completed by the investigator with the help of the person that reported the incident or accident. The main purpose of the investigation is to identify the cause of the incident/accident and then make recommendations to remove or reduce the risk to acceptable levels. The final report is sent to senior management for implementation of the recommendations.

In the case of an accident resulting in a disabling injury or death, the Department of Manpower and the Workman's Compensation Department have to be informed, who then conduct the accident investigation at a higher level. The employer may be prosecuted if the investigation shows that the employer was negligent by not mitigating an unsafe situation.

### 2.10.10 Regular safety meetings

For larger waterworks, a safety committee comprising a Chairman (rotational basis), safety representatives, Plant Superintendent and the Safety co-ordinator, meet on a monthly basis.

The agenda usually includes action items from previous minutes; inspection reports from safety representatives; incidents and accidents; on the job safety (safety tips, etc). The purpose of the meeting is to:

- Create an interest and awareness on safety issues amongst staff
- Monitor safety in the workplace on a regular basis.
- Facilitate learning and growth by sharing practical safety related experiences
- Facilitate continuous improvement in safety
- Encourage employee participation, responsibility and buy-in with respect to safety in the workplace.

However, for smaller plants, safety meetings may be held less frequent (once a quarter may be more appropriate).

### 2.10.11 Water Safety Plans

A methodology for implementing *Water Safety Plans* at small water treatment plants has been developed by Umgeni Water as part of a Water Research Commission project, and the reader is referred to this research report for more specific information regarding risk assessment at small water systems (see also Section 2.4).

water AT YOUR SERVICE

## 2.11 INSTITUTIONAL ASPECTS

In determining the upgrading needs of a small water system and planning upgrading measures, it is of great importance that due consideration be given to institutional aspects, as this will to a large extent determine the success of a water supply project (Swartz, 2000). This holds equally true when planning and implementing O & M, as well as management, plans for the water treatment plants and raw water abstraction and pumping facilities.

### 2.11.1 Needs assessment

Although the basic needs of rural communities are generally known, the needs and particularly the priorities of a specific community need to be established before venturing on a project. Even if an agency receives a request for assistance by some members of a community, this does not necessarily represent the feelings of the community as a whole. A needs assessment and data collection study should therefore be carried out if possible.

### 2.11.2 Community participation

Rural people are often in the grip of a poverty trap, to which factors such as isolation, powerlessness and physical weakness contribute. Often it is the women and children of low-income families who are most affected by poverty. Real change is only possible if they are organised to participate in projects of their own design, by which they learn to look differently at their situation, and start taking control of their lives.

As far as possible all sectors of a community should be involved in a development project. A project which requires the use of communal resources, such as land and water and the systematic collection of funds, will depend largely on well-organised community support.

Community participation can be defined as the organised and active involvement of the people in a community, or the potential users of services, in defining their problems and making decisions concerning the implementation of development projects. There is no one model of community participation which is applicable to all communities; the form, and degree of community participation, will differ in accordance with different socio-economic and other conditions. However, if an agency remains in total control of a project and merely calls on villagers to provide voluntary labour, the project does not have true community participation, but merely an element of self-help. More desirable is to have the community take responsibility for managing the project itself. Successful community management depends on the existence of an appropriate community organisation that is able to manage a project effectively and facilitate community participation in the project. Without such an organisation, even a project which registered successful community participation during the implementation phase will not be sustainable.

In practice, the establishment of a community management system is difficult and time consuming. It is essential that a management committee receives adequate support from organisations in the area with the necessary experience and expertise. Members of support organisations could also serve on the management committee, or on sub-committees responsible for specific matters such as agriculture and health. The involvement of the community in the election of a committee, and their ongoing involvement in projects to ensure proper accountability, has to be cultivated over several years.

### 2.11.3 Financing and financial control

There is a great deal of grant finance flowing into rural development in South Africa. While this is a good thing for getting basic levels of service into areas which have long been neglected, it is important to remember that there is theoretically an infinite demand for free goods. Only if beneficiaries of projects are prepared to contribute from their own pockets, and time, towards projects can one be sure that the projects are meeting real needs. Simple checks must be built into financial systems to ensure transparency and accountability.

A minimum level of reporting must be maintained, but not so much that it becomes a burden. Simple book keeping systems that can be understood by the whole committee, and not just by the educated elite, will best serve the purpose.

### 2.11.4 Reform strategy in water sector (centralisation vs. decentralisation)

The strategic framework for water services was approved by Cabinet in 2003. It highlights the need for the development amongst other things institutional reform for water services provision. The objectives of the institutional reform strategy for water services provision are as follows:

- Ensure the *provision* of an appropriate level of water and sanitation services.
- Improve the *performance* of water services providers.
- Improve the *financial viability* and *sustainability* of the water services sector.
- Improve the *accountability* of water services providers.
- Use existing *capacity, skills* and *resources* in the water services sector in an integrated and optimal way.
- Improve the *efficiency* of water use.
- Improve the *regulation* of water services providers.

The strategy encourages the municipalities to come together and look at the efficient and inexpensive way of providing water services to the community, approach water services provision regionally in order to unlock amongst other things economies of scales and scope, cross-subsidisation, pool of resources and so on. The strategy also looks at how the financial viable regional water services providers such as Rand Water can expand the area of supply in order to meet the Millennium Development Goals target with regard to water services backlogs.

### 2.11.5 Socio-economic aspects (community participation)

Operation, maintenance and construction (if feasible) should be within the competence of local technical staff or the users. Prior to construction or upgrading, an assessment should be made of available skills in the community and the authority. The choice of treatment system, as well as its implementation and management, must take into consideration the aspirations and preferences of the community itself.

Community participation has the following dimensions:

- Involvement of all those affected in decision making about what should be done and how.
- Mass contribution to the development effort, i.e. to the implementation of the decisions.
- Sharing in the benefits of the programmes.
- Research has indicated that there is an on-going need for training in the following areas for communities:
  - constituting and running of water committees
  - bookkeeping, accounting and recording of minutes
  - training of plumbers for constructing and maintaining unsophisticated water distribution systems
  - training of borehole pump maintenance personnel
  - training of water storage tank builders
  - training of community health educators
  - training of primary school teachers in the fundamentals of domestic water supply, management, public health awareness and personnel hygiene

## 2.12 ENVIRONMENTAL ASPECTS

The word ‘environmental’ in relation to aspects at a water treatment works is related not only to the natural environment, but also to the environment in which the process controllers have to undertake their daily tasks. It is important to note that the final water for distribution from a water treatment works can have disastrous human health consequences if not adequately treated. The sludge produced by the process can also, if incorrectly treated, cause environmental degradation.

The process controller therefore needs to ensure that good housekeeping is always practiced to ensure that the environment is kept clean and tidy, and that waste products are safely disposed of.

# Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Plants

## SECTION 3 TECHNICAL GUIDELINES

### CONTENTS OF SECTION 3

## 3.1 SUMMARY OF TECHNICAL PRACTICES AND ISSUES AND PROPOSED GUIDELINES

Similar to the tables that were presented for management best practices and guidelines, tables were also drawn up for best practices and guidelines for technical aspects involved in the O & M of small water treatment plants, again in the following sequence:

- Operation and maintenance issues or aspects.
- Proposed practices or actions for effective O & M.
- Consequences of not performing the proposed actions.

Again, these tables do not contain detailed guidelines or proposed actions for improving the O & M; they provide general best practice guidelines with references to more detailed elaboration on these aspects further in the document.

To find more detailed information on any of the best practice guidelines in the table, the user can simply click on the highlighted word in the HTML version and will then be taken to the section in the document where more information and details may be found. The numbers of the relevant sections are also provided for manual cross-referencing.

**It should be noted that the technical issues and aspects in the tables were derived from the plant surveys and inspections. They relate to the types of plants that were targeted in the study, and were specifically intended to address the South African situation.**

| | Operation and maintenance issues / practices | Proposed practices / actions for effective operation and maintenance | Consequences of not taking these proposed actions |
|---|---|---|---|
| | | **OPERATION AND MAINTENANCE** | |
| | | **FLOW MEASUREMENT** | |
| **1** | Flow measurement (raw water or at intake) | Flow meters should be installed at all water treatment plants to measure the inflow. The flow meters reading should be recorded on a daily basis. Flow meters must be kept in good working condition and calibrated once per year.<br>(Section 4.3.2). | Chemical dosages (coagulant; chlorine) cannot be calculated<br>Water treatment costs cannot be determined |
| | | **COAGULATION AND FLOCCULATION** | |
| **1** | Calculation of chemical dosages | Tables and graphs indicating dosages to be applied for a variety of flow rates and raw water turbidity or colour should be drawn up.<br>Procedures for calculating dosages must be available and process controllers trained how to perform the calculations.<br>Jar tests equipment should be able and jar tests carried out regularly when required.<br>(Section 3.2.2 (b)) (Section 4.2.6) | Overdosing or underdosing of chemicals<br>Wastage of chemicals<br>Water quality non-compliance |
| **2** | Chemical storage facilities and practices | Adequate storage facilities that are dedicated to chemicals storage. Procedures for storage of chemicals (e.g. no moisture).<br>Safety guidelines for handling and securing (lock-up) of the chemicals. (Section 3.2.2 (b)) | Safety hazards<br>Wastage of chemicals that may become unusable |
| **3** | Dosing pumps not correct size | Installation of correctly sized dosing pumps.<br>(Section 3.2.2 (b)) | Inaccurate dosing<br>Overdosing or under dosing |

| | Operation and maintenance issues / practices | Proposed practices / actions for effective operation and maintenance | Consequences of not taking these proposed actions |
|---|---|---|---|
| **SEDIMENTATION** | | | |
| **1** | Regular desludging of settling tanks | Regular desludging of settling tanks when required (preferably on a routine basis).<br>Sufficient desludging time.<br>Record time and duration of desludging.<br>(Section 3.2.2 ( c )) (Section 3.3) | Floc carry-over to filters.<br>Overloading of filters.<br>Short filter runs.<br>Water quality non-compliance |
| **2** | Settling efficiency | Optimised coagulation and flocculation processes, through application of correct dosages based on the raw water quality.<br>(Section 3.2.2 (b)) | Floc carry-over to filters.<br>Overloading of filters.<br>Short filter runs.<br>Water quality non-compliance |
| **FILTRATION** | | | |
| **1** | Effective filtration control | Measure and monitor filtration process.<br>Effective filter backwashing or cleaning<br>Record filter backwash time and duration.<br>(Section 3.2.2 (e)) | Filter breakthrough<br>Backwash water wastage<br>Water quality non-compliance |
| **CHLORINATION** | | | |
| **1** | Chlorination operation and control | Clear instructions for operation, maintenance and management of chlorination systems.<br>Procedures and trouble-shooting for chlorination systems.<br>Test kits for measuring chlorine residuals. Check-lists for all necessary chlorination equipment, scale, safety equipment and analysis equipment.<br>(Section 3.2.2 (f)) | Ineffective chlorination.<br>Pathogens in final water.<br>Possible overdosing of chlorine. |
| **SPARE PARTS AND STANDBY EQUIPMENT** | | | |
| **1** | Standby generators | Provision of stand-by generator for the treatment plant, even if it is one shared mobile generator for a number of treatment plants. | Water supply interruptions<br>Poor water quality after unit treatment processes<br>Water quality non-compliance. |

| | Operation and maintenance issues / practices | Proposed practices / actions for effective operation and maintenance | Consequences of not taking these proposed actions |
|---|---|---|---|
| **2** | Spare parts | Lists of which spare parts should be available on a water treatment plant.<br>General spare parts for any treatment plant and specialised items for more sophisticated processes and/or control systems.<br>Guidelines on how to manage ordering, procurement, storage and issuing the spare parts | Plant down-time<br>Water supply interruption<br>Dissatisfied consumers |
| **3** | Availability of parts | Procedures for procurement and storage of essential spare parts and standby equipment on-site or at the local supplier /agent / maintenance contractor (try to obtain access to similar satisfactory parts locally) | Plant down-time<br>Water supply interruption<br>Dissatisfied consumers |
| **UPGRADING REQUIREMENTS** | | | |
| **1** | Overloaded treatment plants | Regular assessment of the current capacity of the treatment plant and relating that to the design capacity of the plant.<br>Assessment of the current condition of the treatment plant and determining upgrading requirements (see also WRC Report 738 on "Guidelines for upgrading of existing small water treatment plants") | Unit treatment processes not able to produce the required performance and removal efficiency<br>Water quality non-compliance |
| **2** | Demand higher than supply ( i.e. plant is overloaded) | As above, and how to decide on when to consider additional treatment facilities as and when this may be required.<br>(Section 2.6) | Unit treatment processes not able to produce the required performance and removal efficiency<br>Water quality non-compliance |

| | Operation and maintenance issues / practices | Proposed practices / actions for effective operation and maintenance | Consequences of not taking these proposed actions |
|---|---|---|---|
| **OPERATING MANUALS** | | | |
| **1** | Operating manuals | Well-written operating manuals specific for the treatment plant.<br>Guidelines for drawing up own operation manual where this is not available for existing plants, showing framework of what information the manual should contain.<br>(Section 3.2.5) | Inability to operate the plant according to the procedures and methods intended by the designers or suppliers of the treatment plant and treatment equipment |
| **MAINTENANCE** | | | |
| **1** | Servicing of specialised equipment | Perform own maintenance of general aspects within the local capabilities.<br>Draw up and manage maintenance agreements with companies that are skilled and equipped to do the required maintenance.<br>(Section 3.2.7) | Unexpected breakdown of equipment<br>Plant down-time<br>Water supply interruption<br>Dissatisfied consumers<br>Water quality non-compliance |
| **2** | Maintenance plan | Draw up and implement a preventative maintenance program for every item of infrastructure and equipment.<br>Ensure effective management of these plans.<br>(Section 3.2.7) | Unexpected breakdown of equipment<br>Plant down-time<br>Water supply interruption<br>Dissatisfied consumers<br>Water quality non-compliance |
| **EMERGENCY PROCEDURES** | | | |
| **1** | Provision for adverse weather conditions or natural disasters | Draw up and implement emergency procedures, and ensure that plant personnel and supervisors are familiar with the contents of the procedures.<br>Provision for potential flooding or wind storms | Plant down-time<br>Water supply interruption<br>Dissatisfied consumers<br>Water quality non-compliance |
| **MATERIALS PROTECTION** | | | |

| | Operation and maintenance issues / practices | Proposed practices / actions for effective operation and maintenance | Consequences of not taking these proposed actions |
|---|---|---|---|
| **1** | Corrosion protection | Provide corrosion protection<br>Procedures on how to monitor the conditions of exposed and vulnerable materials | Regular replacement of materials<br>High treatment costs. |
| **PROCESS CONTROL AND QUALITY CONTROL** | | | |
| **MONITORING AND PROCESS CONTROL** | | | |
| **1** | Effective monitoring programme | Well-designed monitoring program for the treatment plant<br>Clear instructions on which analyses should be performed at the plant as a minimum, but also the recommended monitoring, sampling, analysis and reporting programme, for process control as well as quality control purposes (Section 3.3) | Ineffective control of unit processes<br>Poor quality control<br>Unit process overloading<br>Water quality non-compliance |
| **2** | Laboratory equipment | Minimum suite of laboratory equipment (Section 3.3) | Ineffective control of unit processes<br>Poor quality control<br>Unit process overloading<br>Water quality non-compliance |
| **3** | Raw water quality data | Perform regular raw water quality measurements (Section 3.3) | Delayed (responsive) dosing adjustments when raw water quality changes<br>Water quality non-compliance |
| **4** | Laboratory management | Procedures for effective laboratory management (Section 3.3) | Inaccurate analyses results<br>Neglect of equipment<br>No quality control<br>Unreliable quality data<br>No or insufficient analyses performed<br>Non-compliance with minimum monitoring requirements<br>Water quality non-compliance |

## 3.2 OPERATION AND MAINTENANCE

### 3.2.1 Raw water abstraction/source protection

<u>Guidelines for raw water abstraction</u>

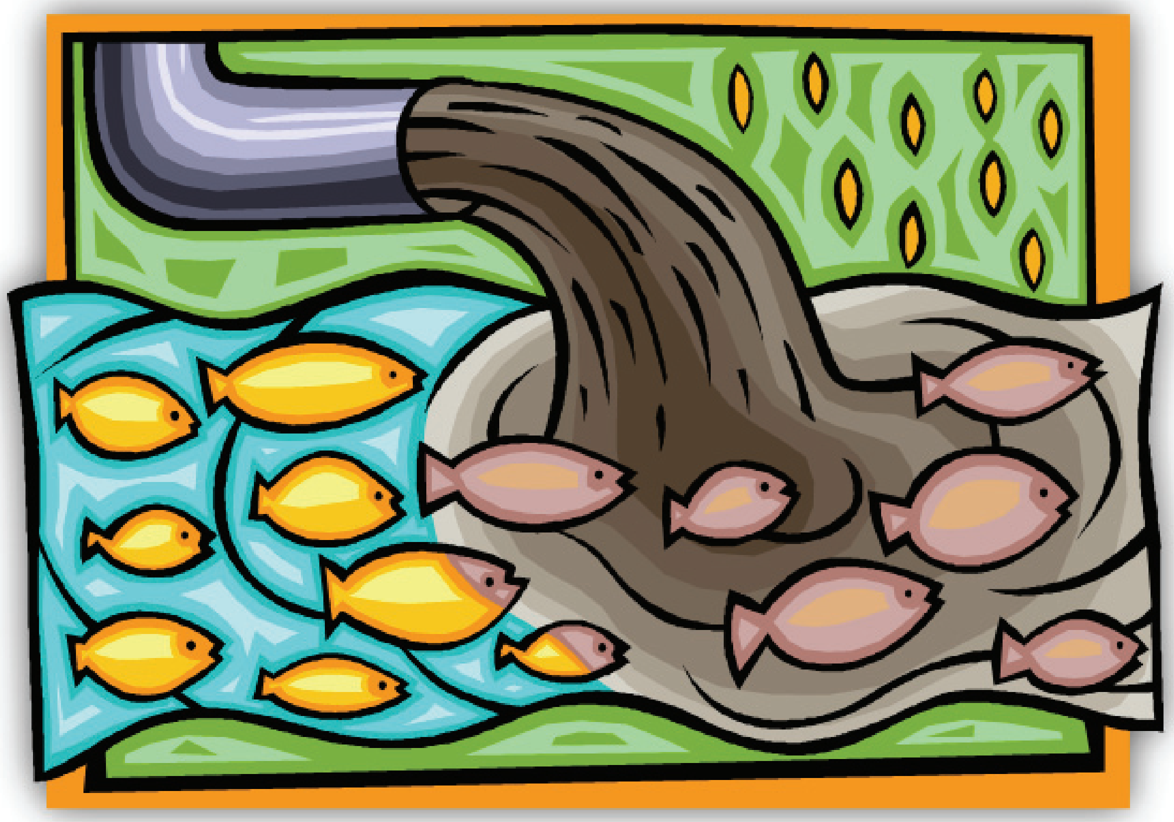
- Know the location of the treatment plant's river or dam abstraction point and/or borehole, and inspect these on a routine basis. Inspecting the abstraction points and boreholes will alert the plant process controller to any deterioration, damage, or other problems.

- Provide secure and intact borehole protections.

- Direct surface and roof runoff away from abstraction points or boreholes. Surface water should not collect near boreholes.

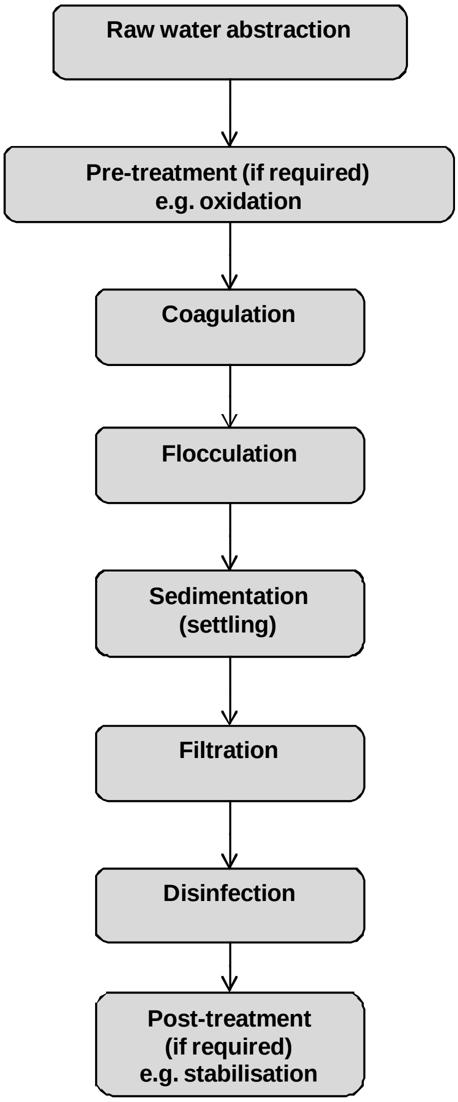
- Protect boreholes from potential vehicle damage. Delivery trucks, lawnmowers and other vehicles may damage boreholes.

- To the extent possible, remove any potential sources of contamination from the area near the dam or river abstraction point, or the borehole. All new abstraction points and boreholes must meet the minimum requirements for separation from potential contaminant sources.



### 3.2.2 Conventional Treatment Processes

Conventional water treatment refers to the configuration of treatment processes (with slight variations in certain instances) that are most widely used in South Africa for purification of surface waters to potable quality complying with SANS 241 of 2006. The conventional treatment processes in South Africa consist of:




A typical conventional water treatment plant is shown on the following page.

Groundwater treatment normally requires special treatment processes (e.g. reverse osmosis desalination; ion-exchange; iron and manganese removal).

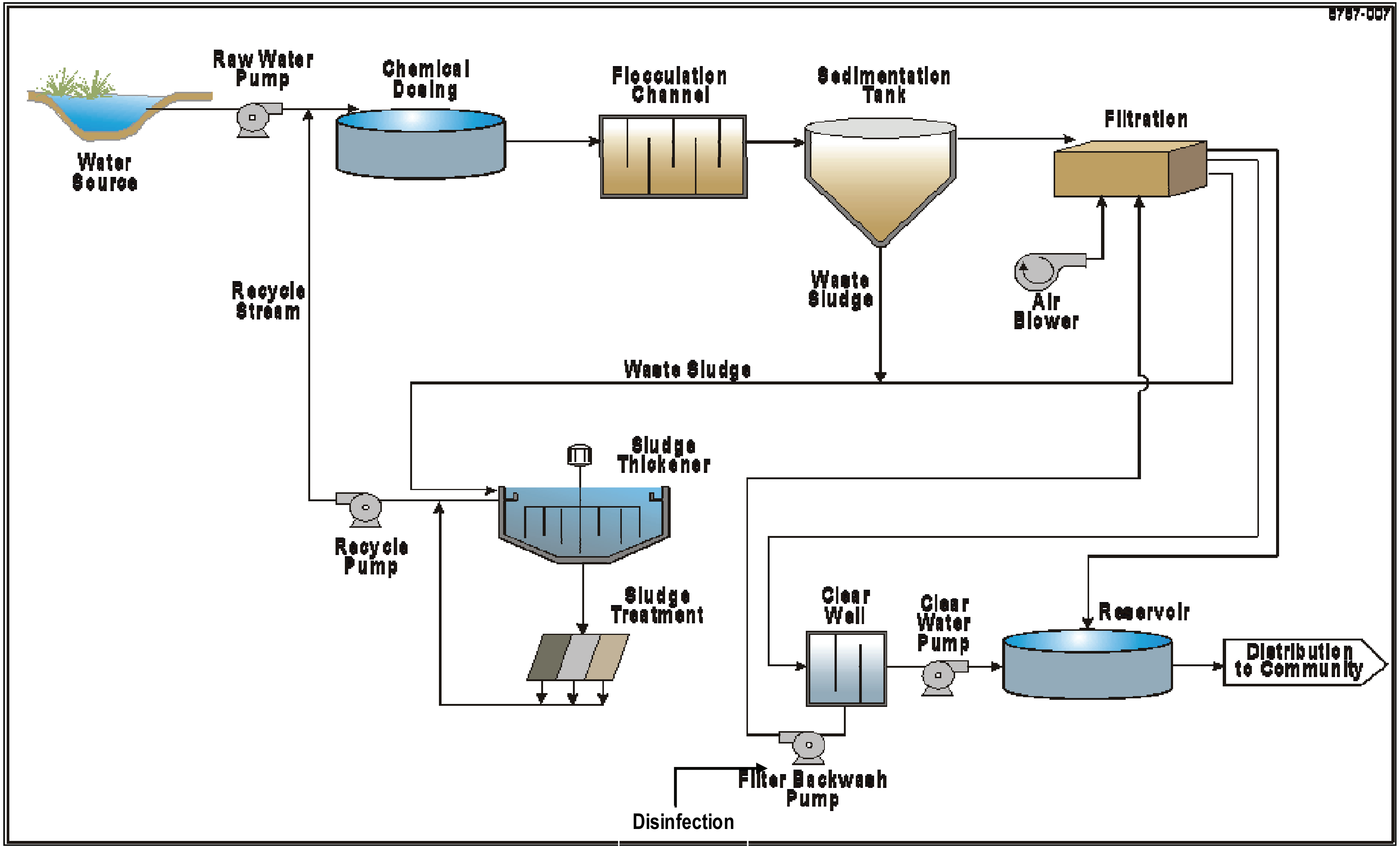



Figure 1: Overview of a typical water purification plant

### 3.2.3 Inflow measurement

Accurate measurement of inflow rate into a water treatment plant is critically important in order to calculate required chemical dosages and loadings on unit treatment processes.

### 3.2.4 Pre-treatment

Pre-treatment processes are required in instances when the quality of the raw water is very poor due to events such as high rainfall, algal blooms or discharges from wastewater treatment plants. These processes are then applied upstream of the normal treatment processes applied at the treatment plant, and could be either temporary or permanent. The processes used could be any of the unit treatment process employed in drinking water treatment, such as settling (plain sedimentation for removing high suspended solids loadings), activated carbon (for taste and odour problems) or oxidation processes.

### 3.2.5 Chemical treatment

**Water treatment chemicals**

***Description of water treatment chemicals:***

In most water purification processes, chemical treatment is the most critical intermediary or unit process. Even when membrane processes are used, namely desalination, microfiltration or ultrafiltration processes, there may be some chemical pre-treatment or chemical cleaning of the membranes.

Chemical usage may be divided into three different stages in the water treatment chain:

- Pre-treatment chemicals
- Coagulants/flocculants
- Disinfection chemicals

The purpose of flocculation and coagulation is to remove colloidal as well as suspended matter from water. This is achieved by adding a chemical which breaks up into ions, which are negatively and positively charged. These ions attract dirt particles which are also charged. The particles collide with each other and grow heavier until they begin to sink.

There are three steps in this process, i.e.

- Flash mixing
- Floc formation
- Floc conditioning

It is essential to dose the optimum amount of flocculant. This can be accomplished with the use of jar stirring equipment. However, this equipment is not available at the majority of small water treatment plants. Under these circumstances flocculant is dosed on a “hit and miss” system where the size of the floc is determined by observation and the dosage is adjusted accordingly. Using jar test equipment determines the actual dosage rate and the operator can adjust the dosage according to the flow at the plant.

It is also important to determine the type of chemical best suited for a particular type of water. For example, using a ferric salt-based flocculant to treat raw water with a high iron concentration will not be suitable.

It is common practice for procurement staff of a particular municipality to supply the same chemicals to all the plants under its control. The officers are under the impression that this would be cost effective. This however could be an expensive exercise.

Flocculation is enhanced by reducing the velocity of the flow through various means. The following methods may be used in this process: channels with baffles; channels with an over and under flow; use of flocculation columns; use of pipe with increasing diameters.

Ideally the minimum time for flow through the flocculation systems should not be less than 10 minutes.

**In order to calculate chemical dosages, it is imperative that inflow meters are installed, in working order and properly and regularly calibrated.**

**Table 3** Types of chemicals that can be dosed at a small water treatment plant

| Treatment stage | Treatment process | Chemical | Dosing | Process / quality control | Maintenance |
|---|---|---|---|---|---|
| Pre-treatment | Oxidation | Chlorine | Chlorinator system | Measurement of residual chlorine | |
| | Disinfection | Hypochlorite | Dosed as a solution via a positive displacement dosing pump | Measurement of residual chlorine | Regular cleaning of precipitate in pipes to avoid blockages |
| | pH adjustment<br><br>Stabilisation | Lime | As a slurry using a pump or powder using a screw feeder | Measurement of pH | Regular cleaning of suction and discharge pipeworks. Clearing lime caking in screw feeder |
| | Coagulant aid | Bentonite | As a slurry, 0.5 to 3% concentration using a positive displacement dosing pump | Clarifier over flow turbidity Dose estimated by jar tests. Check floc size and settling rate | Bentonite slurry can settle in delivery pipes and cause blockages |
| | Oxidation | Ozone (not normally applied to small water treatment systems) | Dosed as a gas into the raw water followed by a static mixer/ contact tank | Residual ozone | Needs careful maintenance regularly |
| | Oxidation | Potassium permanganate | Dosed as a solution for Fe and Mn removal, using a positive displacement pump | Measure Fe and Mn on the raw and final water every 4 hours | For manganese removal need to maintain the permanganate dose at approx. twice Mn level in raw water (1.92 mg/permanganat e per mg/L Mn in raw water) |
| | Adsorption | Activated carbon | As a slurry using a positive displacement pump | Taste and odour in final water. UV absorbance at 254nm | Pump suction and delivery blockages. Regular inspection and cleaning required |
| Coagulation / Flocculation | Coagulation | Organic polyelectrolytes Inorganic coagulants, (alum, ferric chloride) | May be diluted and dosed via a positive displacement pump | Jar tests Turbidity of clarified water and filtered water | Precipitation in suction and delivery pipes. Needs regular cleaning |
| Final water | | Chlorine gas Hypochlorite HTH (calcium hypochlorite) | Chlorinator Dosing pump Dry feeder or pumped as a slurry | Residual chlorine | Regular cleaning of suction and delivery pipes to avoid blockages |

**Table 4** Problems that may be experienced with chemicals at water treatment plants and suggested remedies or actions

| Chemical | Potential problem | Possible causes | Suggested remedies/actions |
|---|---|---|---|
| Chlorine | No chlorine residual | Incorrect measurement<br>Chlorine tank empty<br>Chlorinator faulty<br>High chlorine demand in raw water | Check chlorine analyser<br>Check for leakages<br>Check chlorinator<br>Increase chlorine dose<br>Determine chlorine demand |
| Hypochlorite | No chlorine residual | precipitate in pipes cause blockages | Check for blockages in delivery pipes |
| Lime | Low pH | Suction and discharge pipes blocked.<br>Lime caking in screw feeder | Unblock pipes<br><br>Clean screw feeder |
| Bentonite | Poor settling in clarifier | Blocked delivery pipes | Check for blockages |
| Ozone<br>(not normally applied to small water treatment systems) | No residual ozone in water | ozone analyser faulty<br>Increase ozone demand<br>Faulty ozonator | Check ozone analyser<br>Increase ozone dose<br>Get technical support |
| Potassium permanganate | High iron and manganese<br>Water turns purple | Underdosing permanganate<br>Overdosing permanganate | Check Mn in raw water and adjust permanganate dose accordingly.<br>Reduce permanganate dose |
| Activated carbon | Taste and odour in final water persistent<br>UV abs at 254nm high | Underdosing carbon<br>Pipe blockages | Increase dose. Check final water for taste and odour.<br>Check and clear pipe blockages |
| Organic polyelectrolytes<br>Inorganic coagulants, (alum, ferric chloride) | No separation in clarifier<br>High final water turbidity | Precipitation in suction and delivery pipes.<br>Over/underdosing<br>PH outside coagulant working range | Clear blocked pipes<br>Do jar tests and optimise dosage<br>Check and correct pH to working range |

### 3.2.6 Phase Separation

#### a. Sedimentation

General description of the sedimentation process:

- Sedimentation is a process in which gravitational settling of sediments take place.
- The **objective of sedimentation** is to produce more clear water by settling out sediments (hence it is also referred to as **clarification** or **settling**) before the water is directed to the filtration process, so that the filtration process can be more effective.
- The units in which sedimentation takes place are usually known as sedimentation tanks/basins, settling tanks/basins, or simply as clarifiers.

- Sedimentation can either be plain (without the aid of chemicals) or be aided by coagulant chemicals.
- Plain sedimentation is employed to remove suspended solids that are easily settleable by proving quiescent conditions and sufficient detention times.
- Sedimentation aided by coagulant chemicals is employed to clarify water characterised by colloidal particles that cannot settle on their own.
- Coagulated water must be allowed to flocculate (form large flocs) prior to the sedimentation stage.
- The flow velocity through the tank must be slow enough to allow most of the flocs or particles from the flocculation channels to settle to the bottom before the water leaves the tank.
- Care must be taken to ensure that very little or no turbulence occurs as the water flows to the clarifiers. Turbulence of the water will result in the break-up of the floc and it will be difficult for the floc to re-form.
- The turbidity and clarity of the clarified water should be monitored and recorded to assess the performance of the clarifiers.
- The clarifiers must be desludged regularly, on the accumulation of sludge in the system. During rainy seasons when the turbidity of the raw water is high, sludge should be removed more often than normal.
- The channels from the clarifiers leading to the filters should also be kept clean and free of algae. Any floating material should be removed.
- Clarifiers are usually designed by using the following criteria:

**Table 5** Design criteria for sedimentation processes

| Parameter | Calculation | Unit | Design value |
|---|---|---|---|
| Surface Loading Rate (SLR) | SLR = Inflow to tank ($m^3/h$) / plan area of tank ($m^2$) | $m^3/h/m^2$ or m/h | → 0.5-0.75 (plain sedimentation)<br>→ 1-1.25 (coagulation included) |
| Detention (or retention) time (T) | T = Volume of tank($m^3$) / Inflow to tank ($m^3/h$) | h | → 4-8 (plain sedimentation)<br>→ 2-4 (coagulation included) |
| Weir loading rate (WLR) | WLR = Inflow to tank ($m^3/h$) / length of outlet weir (m) | $m^3/h$ / m weir length | |
| flow velocity ($V_f$) | ($V_f$) = Inflow to tank ($m^3/min$) / cross section area of flow ($m^2$) | m/min | 0.15-0.90 |

Various types of clarifier are available, e.g. horizontal flow, vertical flow and radial flow.

Types of sedimentation designs and processes

The various designs of sedimentation units that can be applied in small water treatment systems are identified by the flow pattern, configuration and operation methods as follows:

- Horizontal flow sedimentation tanks
- Radial flow sedimentation
- Up-flow sedimentation tanks
- Batch sedimentation

The flow in the first three is continuous, while batch sedimentation systems involve intermittent filling, settling and emptying of the tank. Descriptions of each of the above types are provided in the following paragraphs.

***Horizontal flow sedimentation tanks:***

- Conventional sedimentation process made of a rectangular shaped tank, with inlet and outlet structures and a sloping floor, in which water flow slows in the horizontal direction providing quiescent conditions for suspended solids/flocs to settle at the bottom by gravity. See Figures 2 and 3.

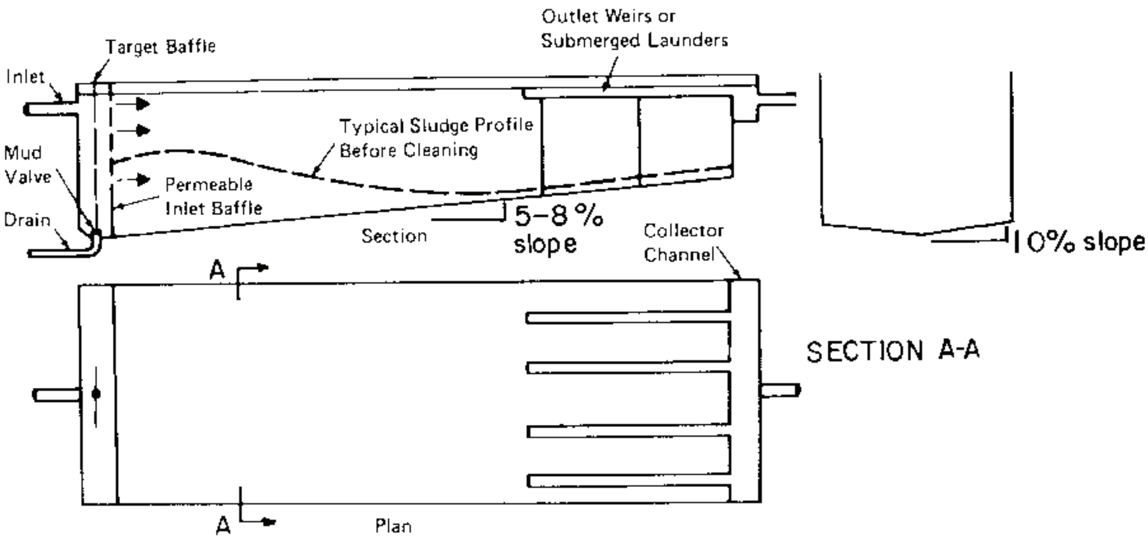



**Figure 2: Conventional horizontal-flow sedimentation basin (*Schulz & Okun, 1994, p. 128)***

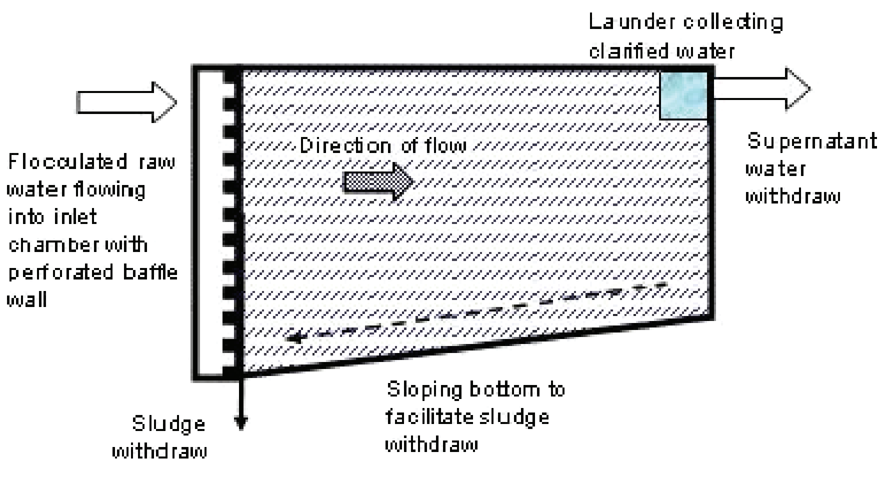



**Figure 3: Conventional horizontal-flow sedimentation basin (*Schutte, 2006, p.90)***

- Chemically coagulated and flocculated water enters through an inlet trough, flows over the first baffle and underneath the second baffle to the main rectangular settling section.
- Water will be forced down towards the deep end, to gradually rise towards the far end of the settling tank in a linear motion. Due to the forces of gravity, particles will tend to end up on the floor of the settler.
- Can also be equipped with a series of inclined plates (lamella plates) in parallel, through which the water flows. The plates are typically placed at an angle of 55° to allow the accumulated sludge to “slip” down the slope of the plate where after it drops to the base of the tank.
- The plates can be designed for four flow patterns: co current flow, counter current flow; diagonal current; cross flow

**Upflow sedimentation tanks (including *sludge blanket clarifiers)***

- Basins with a circular, square or rectangular surface area with conical bottoms in which water flows upwards and settleable solids are returned by the force of gravity.

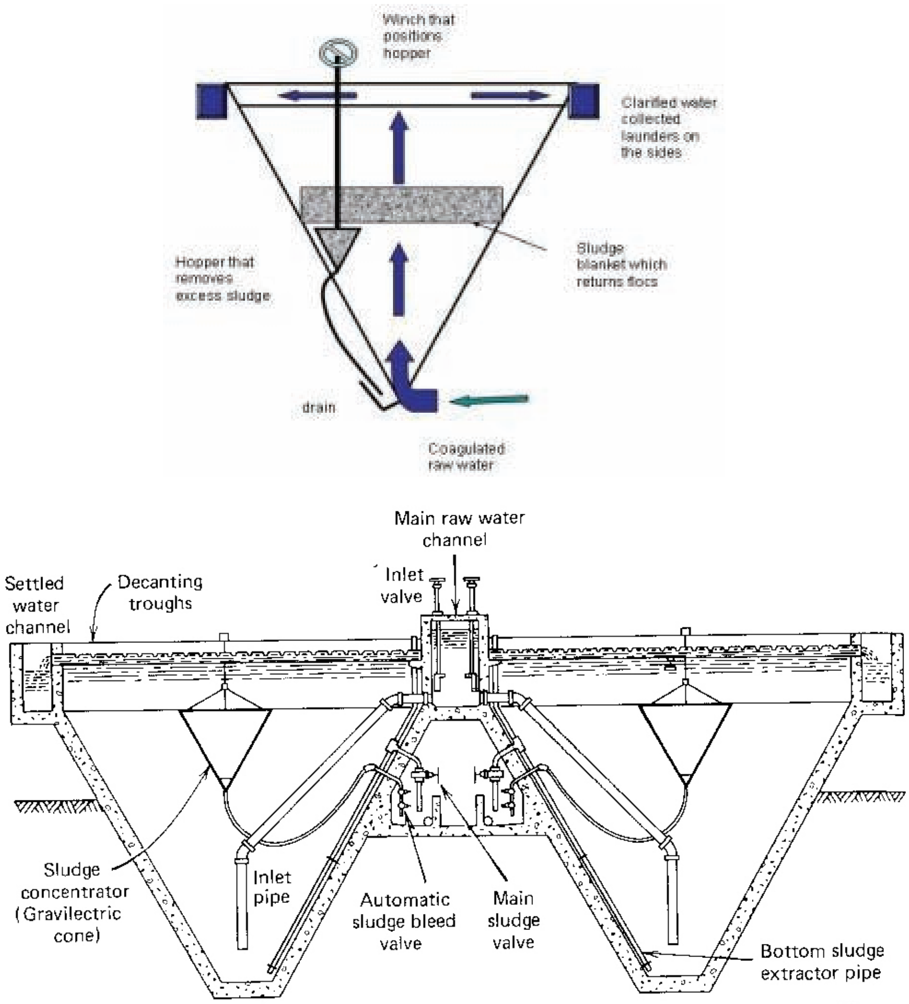



**Figure 4: Up-flow sludge blanket clarifier (*Schulz & Okun, 1994)***

- The system operates on a principle where chemically prepared and flocculated water is discharged near the base of the centre cone, to gradually rise and overflow into a collecting launder at the top of the tank. On the way up, the water will rise at a reducing velocity, due to the increase in area. The reducing velocity will reach a point where the flocs, which are carried with the water, will start settling due to the forces of gravity being greater than the vertical up-flow current. The flocs will tend to form a "hanging blanket" of sludge, which will assist in catching other flocs on their way up. Sludge is drained from the centre portion of the cone and/or tapped from the sludge blanket.

Note: The conical shape of the settler's base is important to enable efficient desludging.

Vertical up-flow velocities, as used on package plants, vary from 1.0 to 1.8 $m^3/m^2/hr$. Care has to be taken not to base the design on high up-flow velocities as the operation becomes sensitive and it may place a high load on the filters.

**Linear Settlers (horizontal flow sedimentation tanks)**

These consist of a rectangular shaped tank with at least two baffle plates and a deep V-shaped floor, as illustrated above. They operate on a principle where chemically prepared and flocculated water enters through an inlet trough and over the first baffle to the main rectangular settling section. Water will be forced down towards the deep end, to gradually rise towards the far end of the settling tank in a linear motion. Due to the forces of gravity, particles will tend to end up on the floor of the settler, so that clean water overflows into a clean water-collecting trough on the far end of the settler.

**Batch sedimentation**

Water can be clarified by filling a large container consisting of a tank/reservoir or other large basin with chemically pre-conditioned water. Water is normally entered at an offset angle to create a stirring motion inside the tank so that chemical distribution can be improved. Chemicals are either introduced as part of a pre-conditioning process using a chemical feeder (e.g. dosing pump) or manually added into the reservoir, while water is being introduced.

Once the tank is full the water inlet is stopped and the water is left in the container allowing the flocs to settle. After settling has taken place the clear water is pumped from the upper area of the settler. The bottom water that contains the settled sludge is then drained to waste at the end of the cycle.

This system operates on a batch concept, whereby a batch of water with sufficient flocculation chemicals is left to settle for a set time of 4 hours.

If a continuous supply of water is required, at least two of these batch settling tanks are required so that settling can take place in one unit while pumping can be done from the second unit. To operate the process, the inlet, withdrawal and desludge valves have to be switched every time a batch has been used up.

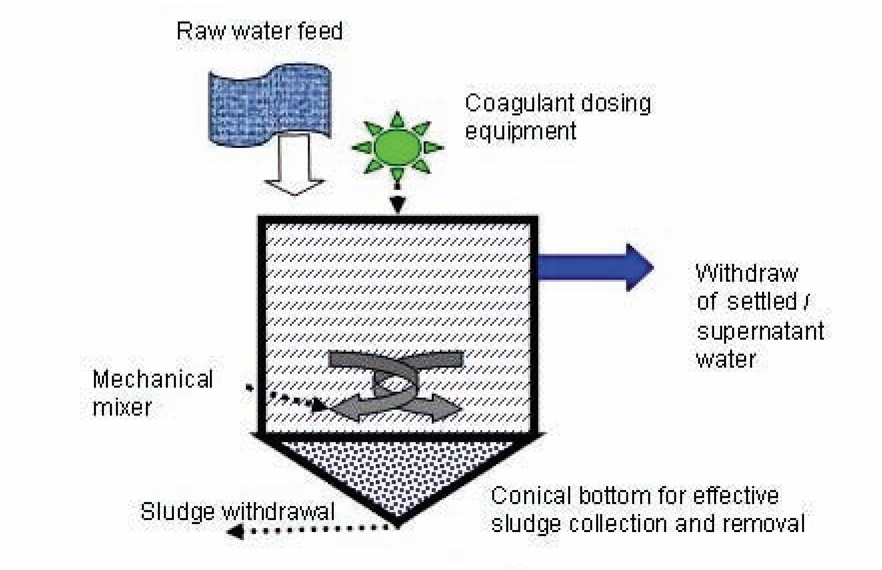



**Figure 5: Schematic illustration of batch sedimentation**

Operation tasks:

- Monitoring of the effluent quality ensuring that the system removes the particles to the desired levels.
- Monitoring the amount of water introduced to each unit ensuring that the basins are not overloaded.

Maintenance tasks:

- Removal of floc or sediment sludge.
- Removal of any floating objects.
- Cleaning of inlet and outlet structures.
- General cleaning of the sedimentation basin walls and settled water launders.

**Table 6** Operation and maintenance requirements for sedimentation processes

| Sedimentation process | Description | Where typically employed | Design parameters | Advantages and disadvantages | Operational parameters and aspects | Maintenance requirements |
|---|---|---|---|---|---|---|
| **Horizontal-flow sedimentation** | Rectangular basin in which turbid raw water that has been coagulated & flocculated flows horizontally and allows flocs to settle at the inclined bottom | Applied to treat coagulated/ flocculated raw water characterised by medium to high suspended solids and turbidity | Retention time<br>Horizontal flow velocity<br>Surface loading rate<br>Weir overflow rate | Advantages:<br>Tolerant to hydraulic and quality variations<br>Unskilled operator and does not require operator presence all the time<br>Lower construction costs & permits oversising<br>Scales up well<br><br>Disadvantages:<br>Large land requirements | Flow velocity monitoring<br>Effluent quality (turbidity) monitoring – both visual and analytical | Regular desludging<br>Leak detection and repair |
| **Up-flow type (Conical settlers including sludge blanket settlers)** | Basin with a circular, square or rectangular surface area with conical bottoms in which water flows upwards and settleable solids are returned by gravity | Applied to treat coagulated raw water characterised by stable turbidity | Up-flow flow velocity $\leq$ 1.5 m/h | Advantages:<br>Efficient removal of sludge<br>Desludging can be carried out without taking unit out of operation<br>Compact design suitable when space is limited, hence attractive for package or modular type plant designs<br><br>Disadvantages:<br>Sensitive to raw water quality and changes in flow velocity<br>Requires skilled supervision and daily operator presence | Flow velocity monitoring<br>Effluent quality (turbidity) monitoring – both visual and analytical | Regular desludging<br>Leak detection and repair |

| Sedimentation process | Description | Where typically employed | Design parameters | Advantages and disadvantages | Operational parameters and aspects | Maintenance requirements |
|---|---|---|---|---|---|---|
| **Batch sedimentation** | Operates intermittently: tank filled with coagulated water, then allowed to stand for desired retention time before supernatant water is withdrawn | Treats turbid water for very small holdings where demand is not high | Detention time | Advantages:<br>Low O & M costs<br><br>Disadvantages:<br>Limited production | Filling and emptying tank<br>Chemical dosages<br>Effluent quality monitoring | Removal of sludge<br>Removal of floating objects<br>Cleaning of inlet and outlet structures |
| **Radial flow sedimentation** | Circular tank in which water to be clarified enters at the centre and flows through the radius (radial) towards launders located on its periphery | Treats turbid water for any capacity | Retention time<br>Radial flow velocity<br>Surface loading rate<br>Weir overflow rate | Advantages:<br>Low O & M costs<br><br>Disadvantages:<br>Sensitive to flow velocity | Flow velocity monitoring<br>Effluent quality (turbidity) monitoring – both visual and analytical | Regular desludging<br>Leak detection and repair |

**Table 7** Problems that may be experienced with sedimentation processes at water treatment plants and suggested remedies or actions

| Sedimentation process | Potential problems | Possible causes | Suggested remedies/actions |
|---|---|---|---|
| Horizontal-flow sedimentation | Poor settling of flocs, hence effluent turbidity not suitable for filtration | Incorrect (higher) flow velocity; poor chemical dosing/ coagulation/flocculation; excessive sludge accumulation | Correct (lower) flow velocity; optimise chemical dosing, coagulation and flocculation processes; desludge sedimentation tank |
| Up-flow type (conical settlers including sludge blanket settlers) | Poor sludge blanket formation leading to floc overflows; inability to empty sludge cones | Poor chemical dosing/ coagulation/ flocculation and/or incorrect upflow velocities | Optimise chemical dosing/ coagulation/ flocculation and/ or correct upflow velocity |
| Batch sedimentation | Poor settling of flocs within desired retention time or long retention times to achieve acceptable effluent quality | Inadequate chemical dosing and/or rapid mixing<br>High turbidity supernatant despite adequate chemical dosing/coagulation | Optimise chemical dosing and coagulation process<br>Increase retention times |
| Radial flow sedimentation | Poor settling of flocs, hence effluent turbidity not suitable for filtration | Incorrect (higher) flow velocity; poor chemical dosing / coagulation/flocculation; excessive sludge accumulation | Correct (lower) flow velocity; optimise chemical dosing, coagulation and flocculation processes; desludge sedimentation tank |

### b. Dissolved Air Flotation

An alternative to the combination of sedimentation and flocculation, especially for the removal of colour causing particles and algae, is a process called dissolved air flotation. Dissolved Air Flotation (DAF) is a solid-liquid separation unit process that transfers solids to the liquid surface through attachment of fine air bubbles to solid particles.

The phenomenon of DAF consists of three processes, namely bubble generation, attachment of solids to the bubbles, and solids separation. The DAF system is actually a water tank with scrapers at the water surface level. Water flows at horizontal level where the air bubbles are formed upon the release of pressure. The air bubbles, together with flocs, float to the water surface and are removed by scrapers.

**Operational input:** The DAF process involves holding recycled effluent for 0.3 to 3 minutes in a retention tank and introducing air at high pressure (4-6 bar). When the pressure is released as the recycle mixes with the feed stream in the flotation chamber, it forms micro-bubbles (4-50 μm diameter), removing a large number of small floc particles by adhesion of air bubbles on the floc surface, entrapment under the floc and absorption into the floc. The attraction between the air bubbles and particles is primarily a result of the particle surface charge and bubble size distribution.

**Process control, quality control and monitoring:** The key process control aspects in DAF involve monitoring the airflow and water inflows. These aspects determine the formation of appropriate bubbles and attachment of particles to the bubbles.

**Table 8** Operation and maintenance requirements for dissolved air flotation processes

| Description | Where typically employed (treatment of which type of waters) | Design parameters | Advantages and disadvantages | Operational parameters and aspects | Maintenance requirements |
|---|---|---|---|---|---|
| Solid-liquid separation unit process that transfers solids to the liquid surface through attachment of fine air bubbles to solid particles. Its phenomenon consists of three processes: bubble generation, attachment of solids to the bubbles, and solids separation. | An alternative to the combination of sedimentation and flocculation, especially for the removal of colour causing particles and algae | Retention time<br><br>Air pressure | Advantages:<br>No operator input<br><br>Disadvantages:<br>Highly mechanical operation<br>High maintenance costs of mechanical equipment | Visual observation of the formation of bubbles<br>Visual observation of flow patterns<br>Sampling of the clarified water for turbidity analysis | Servicing mechanical equipment (air pressure pumps, scrappers, etc) |

**Table 9** Problems that may be experienced with dissolved air flotation processes at water treatment plants and suggested remedies or actions

| Dissolved air flotation process | Potential problems | Possible causes | Suggested remedies / actions |
|---|---|---|---|
| Conventional dissolved air floatation | Poor removal of flocs/floating material<br><br>Poor formation of flocs<br><br>Poor movement of mechanical equipment | Poor air pressure, hence formation of large / insufficient bubbles and/or insufficient retention times<br><br>Poor chemical dosing<br><br>Servicing of equipment required | Optimise air pressures, flow rates and retention times<br><br>Optimise chemical dosing<br><br>Service mechanical equipment |

For more information on the DAF process, refer to the manual of HAARHOFF J and VAN VUUREN LRJ (1993) *A South African Design Guide for Dissolved Air Flotation*. Research Report no. TT 60/93, Water Research Commission Report, Pretoria.

### 3.2.7 Filtration

The process of filtration usually forms the main treatment stage in most water treatment plants. Although there are different configurations, types of filter media and applications of filtration, the process is characterised by similar O & M aspects.

The purpose of the filters is to remove the remaining turbidity in the clarified water, which is required to meet the strict standards set for drinking water quality.

Three types of filters are generally used in the country:

- Rapid gravity sand filters.
- Slow sand filters.
- Dual media pressure filters.

The different types of sand filtration are given in Figure 6.

Rapid gravity sand filters are preceded by flocculation and sedimentation process. The filtration rate applied is usually 5 m/h. The filters are cleaned by a backwash process. In this process the flow to the filters is reversed by passing filtered water upwards through the sand. The process is aided by also passing air through nozzles in the sand. Mud, sludge carried over from the clarifier and other impurities are removed from the sand.

The measurement of turbidity is again important in this process, as this is the final product before disinfection. Ideally the turbidity of this water should be $<0.1$ NTU.

The operator should monitor the following; sand depth; mud balling; cracks in the sand and filter runs. The level of sand should not be below 600 mm. The operator must also be aware of the effects of damaged nozzles and have these repaired or replaced.

Slow sand filters are used because of low maintenance, simplicity of operation and minimum supervision required. Fairly large areas are required for slow sand filters due to the slow rate of filtration (5 m/day). In this system however, the bacteriological quality of the water is enhanced by a dirt layer which forms at the surface of the sand. Again the depth of sand, turbidity and filter runs must be monitored. The level of sand should not be below 300 mm.

As the filter begins to block, the filter runs decrease and the turbidity increases. The filter is cleaned by draining the filter and allowing it to dry. The dry crust, which is a few millimetres thick, is then scraped off.

Dual media pressure filters were generally used to filter water in swimming pools but are increasingly being used in the drinking water industry. In this type of filter, water is pumped under pressure through a layer of sand, as well as a layer of anthracite (dual media). The filter is cleaned by backwashing the media. It is sometimes necessary to physically wash the sand as cracks may occur in the media. The turbidity and filter runs must be monitored and recorded in this process.

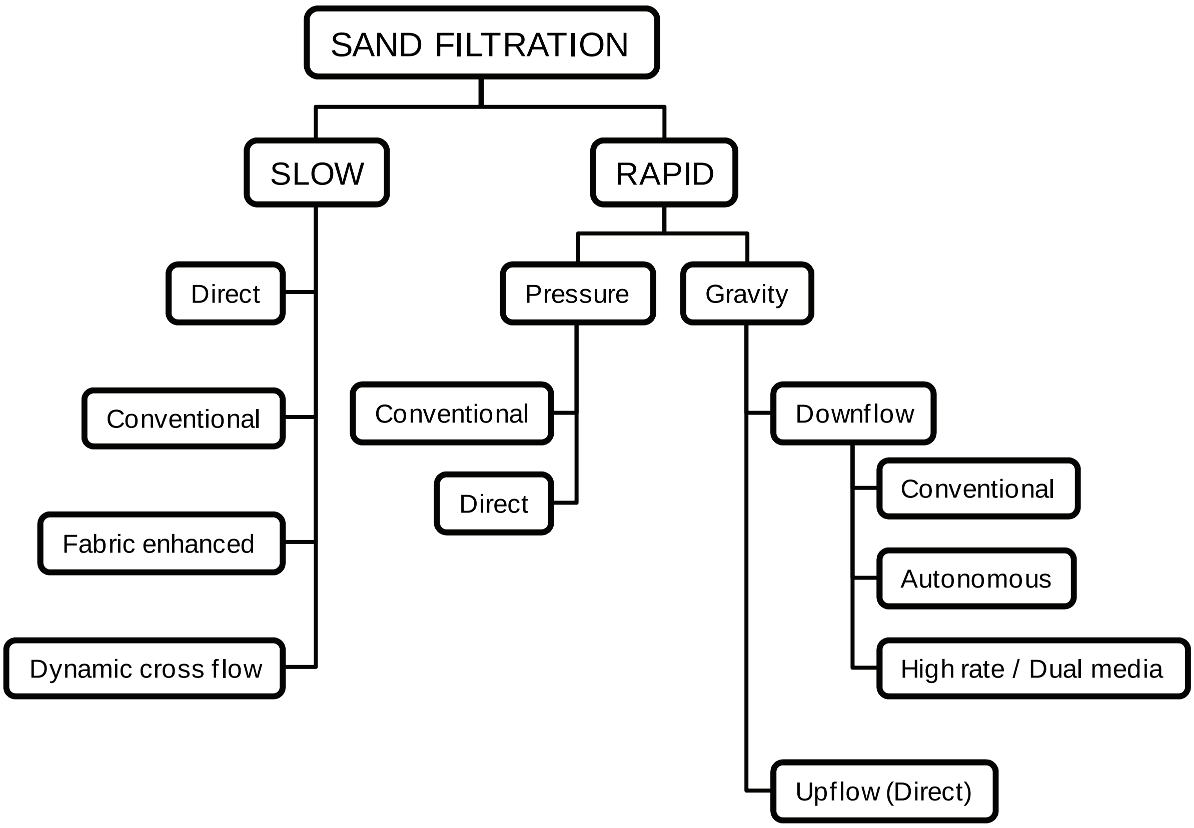



**Figure 6:** Flow diagram of the types of sand filtration

**a. Roughing filtration**

Operational aspects

Filtration rates in roughing filtration must generally be kept below 1 $m^3/h/m^2$ (inflow per unit filter surface area) and the process must be able to produce effluent with turbidity less than 10 NTU.
This effluent quality is recommended since roughing filtration is generally applied prior to slow sand filtration, which is recommended to treat water with turbidity less than 10 NTU.
Visual inspections of the unit's exposed filter media surface for any foreign objects forms part of operational tasks.

Maintenance aspects

The filter media in roughing filtration is cleaned by rapidly draining of the filter unit to dislodge and wash down sludge or sediments of suspended solids retained within the filter media.

Long term maintenance (every 3-5 years) usually entails the complete removal and washing or replacement of the entire filter media.

**b. Slow sand filtration**

Of all the filtration processes, SSF used the finest sand media with the following characteristics:
- Effective diameter ($d_e$) = 0.15-0.35 mm
- Uniformity coefficient (UC) = < 3-5

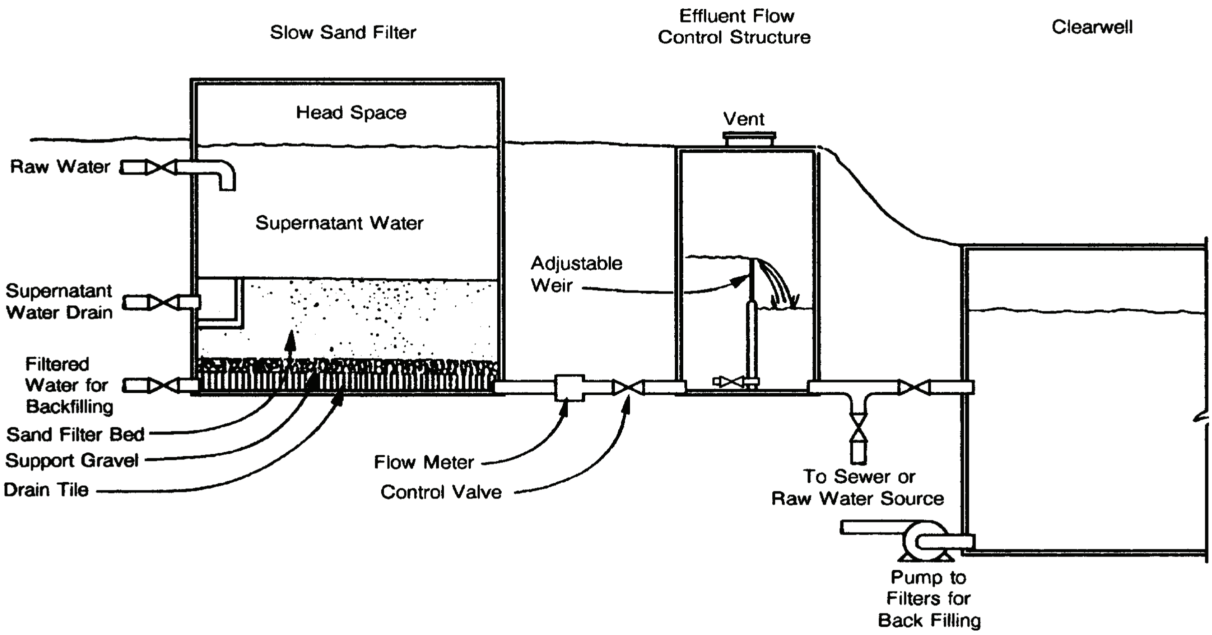



**Figure 7:** Covered slow sand filter with effluent rate control
(U.S. Environmental Protection Agency, 1990)

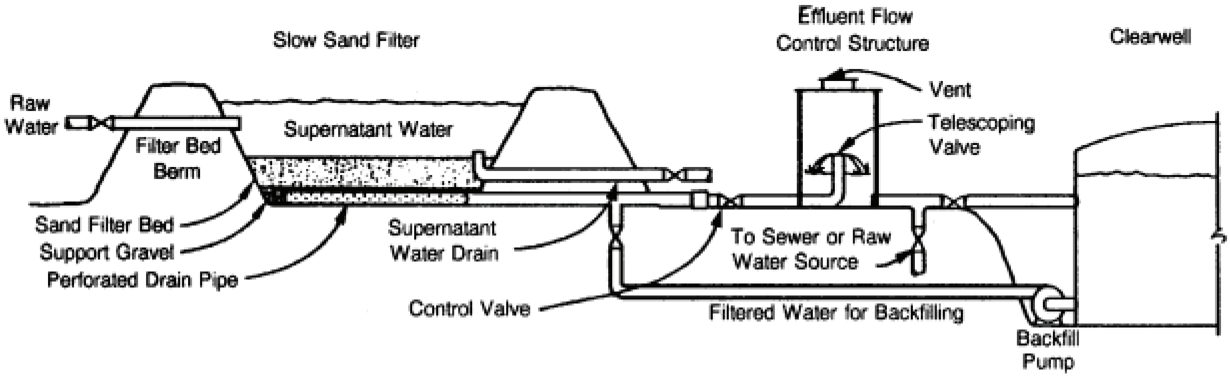



**Figure 8:** Open slow sand filter with effluent rate control
(Logsdon *et al.*, 2003)

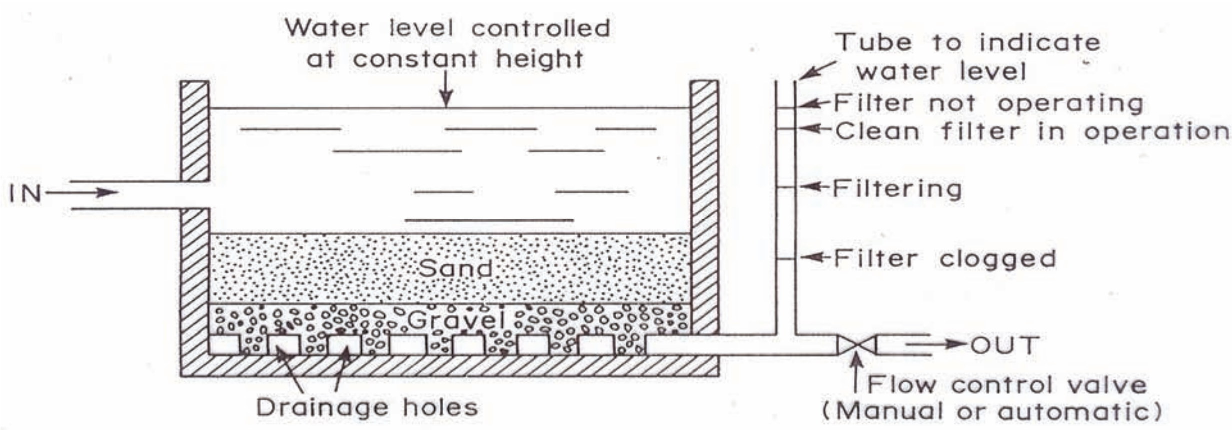



**Figure 9:** Slow sand filter

<u>Operational aspects</u>

Influents to SSF must have a turbidity of less than 10 NTU to prevent rapid clogging.
The control and monitoring of filtration rates in SSF is very crucial. Higher than recommended filtration rates can lead to overloading the process and result in rapid clogging of the filter media. Lower than necessary filtration can still produce acceptable effluent quality but producing less filtered water.

<u>Maintenance aspects</u>

- Since most of the impurities in SSF are returned within the top layer (about 5 cm), the filter performance is restored after scraping-off a thin (1-3 cm) layer of the top dirty layer (called the schmutzdecke) (see figure).
- The sand scraped from SSF units must be thoroughly washed, dried and stored for re-use.

c. **Rapid gravity sand filtration**

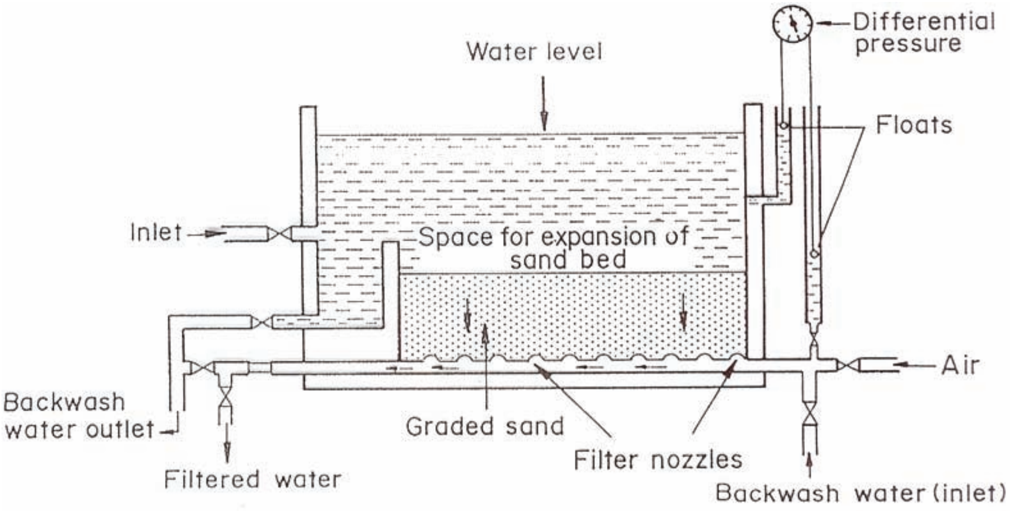



**Figure 10:** Rapid gravity sand filter

Operation aspects

Influents to rapid gravity sand filters (RGSFs) must have a turbidity of less than 2-5 NTU to prevent rapid turbidity break-through due to the coarser filter media.
The control and monitoring of filtration rates in a RGSF is very important as well. Higher than recommended filtration rates can lead to break-through of turbidity, resulting in filtered water not being good enough for effective disinfection.
Effluent turbidity monitoring in RGSFs is very important; they must be able to produce effluents with turbidity less than 1 NTU.
Whether the filter units are covered or not, visual inspections of the unit's exposed supernatant water surface for any foreign objects must form part of operational tasks.
Monitoring of the headloss is an important operational task that gives an indication of the extent of the filter media clogging.

Maintenance aspects

The impurities in RGSFs are returned deeper within the filter media depth as the sand is coarser in comparison to SSFs. Hence the filter media cleaning cannot be achieved by scraping as in a SSF.

Backwashing of the RGSF must be affected in any one of the following three cases:

every time the headloss has reached maximum value,
every time the effluent quality has turbidity > 1 NTU, or
at least once every 24 hrs even though the maximum headloss has not been reached.

This is necessary to ensure that the filter media is kept clean and sudden high turbidity break-through is prevented.

Filter media in RGSFs deteriorates in quality and is also lost through the backwashing processes.

## d. Pressure filtration

Pressure filtration is a type of rapid sand filtration which uses pressure to drive the water through the filter media instead of gravel. The incoming water is thus under pressure and the filtration process takes place in an enclosed unit (see Figure 11).

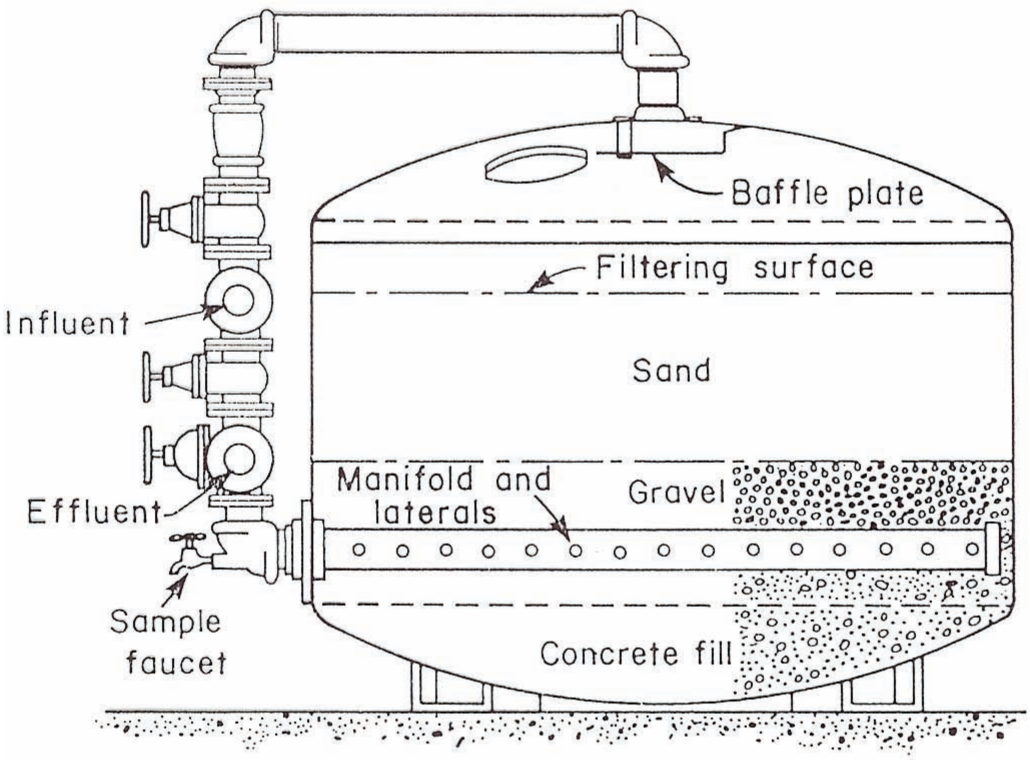



**Figure 11** Pressure filtration units in parallel and diagrammatic lay-out (Source: Water Treatment Instruction Guide – American Water Works Association)

Operational aspects

- Influents to pressure filtration must have much clearer quality; turbidity of less than 2-5 NTU to prevent turbidity break-through due to the coarser filter media.

- The control and monitoring of filtration rates in pressure filtration is also very important. Higher than recommended filtration rates can lead to break-through of turbidity resulting in filtered water not being good enough for effective disinfection.
- Filtrate turbidity monitoring in pressure sand filters is very important as turbidity should be less than 1 NTU to ensure effective disinfection.
- Visual inspections for any leaks should be conducted on a regular basis.
- Monitoring of the headloss is an important operational task that gives an indication of the extent of the filter media clogging.

Maintenance aspects

- Regular maintenance of pressure filters (PFs) involves filter media cleaning by backwashing, which can be achieved by using in-line filters or separate backwashing facilities.
- The same backwashing criteria in rapid gravity filtration are applicable in pressure filtration as well; whichever of the following comes first:
  - when the headloss reaches maximum value,
  - when the effluent quality has turbidity > 1 NTU, or
  - at least once every 24 hrs even though the maximum headloss has not been reached. This is necessary to ensure that the filter media is kept clean and sudden high turbidity break-through is prevented.
- Filter media in PFs deteriorates in quality and is also lost through the backwashing processes, hence long term maintenance tasks include:
- Partial and complete re-sanding with new sand every 3-5 years.

- Pressure filtration backwashing is not as effective as rapid gravity filter backwashing.
- Pressure filtration flow rates should not be too high.

**Table 10:** Operation and maintenance requirements for filtration systems

| **Filtration process** | **Description** | **Where typically employed (treatment of which type of waters)** | **Design parameters** | **Advantages and disadvantages** | **Operational parameters and aspects** | **Maintenance requirements** |
|---|---|---|---|---|---|---|
| Roughing filtration | Filtration process that uses graded gravel as the filter media | Employed before sand filters to reduce turbidity (suspended solids) from raw water to less than 10 NTU with or without the aid of coagulation, depending on raw water quality | Gravel size (1–20 mm)<br>Configuration or layout of filter media<br>Layers, horizontal or upflow<br>Filtration rates (0.3-1 m/h) | *Advantages:*<br>Easier operation & maintenance<br>Can work without coagulation as well<br>Operates with varying raw water quality<br>*Disadvantages*<br>Limited to treating high turbidity (suspended solids) raw water | Filtration rate control<br>Effluent turbidity monitoring<br>Head loss monitoring | Filter media cleaning by draining<br>Filter media replacement after 3-5 years<br>Leak detection and repair |
| Rapid (gravity) sand filtration (RSF) | Filtration process that uses fine sand in which flow is by gravity and is characterised by high filtration rates | Treatment of turbid or colour surface<br>Extensively used in large plants | Grain (sand) size (de = 0.5-0.7 mm)<br>Uniformity coefficient of filter media (<3)<br>Under drain system<br>Filtration rates (5-10 m/h) | *Advantages:*<br>High production rates<br>Compact – filter takes little space<br>Can be automated<br>*Disadvantages:*<br>Stringent O & M<br>Always requires prior coagulation / flocculation & sedimentation | Filtration rate control<br>Effluent turbidity monitoring<br>Head loss monitoring | Daily filter media cleaning by backwashing<br>Maintain mechanical equipment for filter media cleaning<br>Leak detection and repair<br>Maintenance of under-drain system |
| Slow sand filtration | Filtration process that uses fine sand in which flow is by gravity and is characterised by low filtration rates | Treatment of turbid and/or contaminated surface water<br>Used extensively in rural areas and small remote and low income communities | Grain (sand) size (de = 0.15-0.35 mm)<br>Uniformity coefficient of filter media (<3)<br>Under drain system<br>Filtration rates (0.1-0.3 m/h) | *Advantages:*<br>High effluent quality<br>Low O & M demands<br>*Disadvantages:*<br>Large space requirements<br>Low production rates | Filtration rate control<br>Effluent turbidity monitoring<br>Head loss monitoring | Filter media cleaning by scraping<br>Leak detection and repair |
| Pressure filtration | Filtration under pressure<br>Single or multiple models<br>Vertical or horizontal<br>Upflow or downflow | Turbidity removal<br>Used extensively in package plants | Filtration rates up to 15 m/h, but recommend not to exceed 5 m/h<br>Sand particle diameter 0.6-0.9 mm | *Advantages:*<br>Compact<br>Minimal civil works required<br>Can be automated<br><br>*Disadvantages:*<br>Backwash-process cannot be observed | Requires coagulant dosing (as compared to slow sand filtration)<br>Can be backwashed individually<br>Low turbidities: no upstream clarification required (i.e. direct filtration) | Check valves for leaks<br>Check pressure gauges<br>Check filter sand (mud balling)<br>Check filter nozzles |

**Table 11:** Problems that may be experienced with filtration processes at water treatment plants and suggested remedies or actions

| Filtration process | Potential problems | Possible causes | Suggested remedies/actions |
|---|---|---|---|
| Roughing filtration | Unacceptable effluent turbidity (>10 NTU) | Insufficient cleaning of filter media leading to excessive suspended solids retention or<br>Sudden increases of the inflow turbidity | Clean filter media by draining<br>Reduce filtration rates until turbidity levels return to normal |
| Rapid gravity filtration | Turbidity break-through, i.e. unacceptable effluent turbidity (>1 NTU)<br>Short-filter runs or reduced production rates<br>Poor backwashing<br>Mud-ball development | Due to high filtration rates, filter overloaded with high turbidity inflow, hence fouled<br>High head-loss through filter<br>Incorrect back-wash procedures and flows | Lower/correct filtration rates, ensure that turbidity of inflow is not > 2-5 NTU<br>Clean filter at correct frequency<br>Correct backwash procedures by referring to manual or check status of under-drain system and repair if necessary<br>Filter media replacement if mud-balls are excessive |
| Slow sand filtration | Frequent clogging of the filter media<br>Prolonged poor bacteriological quality of effluent after cleaning filter ( long maturation periods) | Turbidity of the inflow water consistently<br>> 10 NTU<br>Immature schumzdecke layer or poor cleaning of filter media (excessive scraping of the filter media /schumzdecke layer) | Lower inflow turbidity by correcting existing pre-treatment processes or add some if not available<br>Correct cleaning procedure and reduce scraping thickness |
| Pressure filtration | Short filter runs (high head loss)<br>Poor filtrate quality ( > 1 NTU)<br>Loss of filter sand | Ineffective backwashing<br>Upstream process problem/failure leading to overloading/rapid clogging of filter<br>Sand severely fouled, too high filtration rates<br>Mudball formation<br>High backwash rates/ poor backwash | Increase backwash duration<br>Check upstream processes<br>Wash or replace sand<br>Reduce filtration rates<br>Check backwash rate |

### 3.2.8 Disinfection

The previous unit processes dealt mainly with clarity of the water, i.e. reducing turbidity. The disinfection process is used to remove bacteria and ensure that the bacteriological quality complies with the required standards. Although the water may appear clear, many bacteria and pathogens remain in the water. It is therefore essential to disinfect the water to prevent the spread of waterborne diseases.

The most common form of disinfection is the use of chlorine or chlorine compounds. Chlorine is also used to eliminate taste and odours in water. Some micro-organisms such as giardia and cryptosporidium however, are resistant to the effects of chlorine. Other forms of disinfection also available are ozonation and ultra-violet (UV) light. Due to the high cost of installation and maintenance, and the fact that there is no residual present, these methods have not been popular.

The operator should ensure that the water is properly disinfected at the plant and in the distribution system. The chlorine levels in the water should measured and recorded at least once a day.

**Disinfection**

Disinfection methods of water treatment kill most of the harmful bacteria, viruses, cysts and worms found in water that can cause acute illness. Disinfection methods include chlorination, pasteurisation, ultraviolet light or UV water treatment and ozonation.

**Chlorination**

The most common, oldest and relatively inexpensive method used to disinfect water is chlorination. A chemical feed pump continuously dispenses chlorine gas into the water supply. Chlorine is a strong oxidising agent, kills most bacteria and some viruses. In the proper concentrations and under adequate exposure time, chlorine is an excellent disinfectant. However, it is a dangerous and potentially fatal chemical if used improperly.

Care must be taken to ensure that only clean, clear water is used. Chlorine reacts with certain metals and organic matter in the water. It is also essential to ensure that the turbidity is sufficiently reduced, as high turbidities have an adverse effect on disinfection.

The major problem with this water treatment system is the potential formation of hazardous, chlorinated, organic chemicals (trihalomethanes) when the chlorine reacts with organic molecules in the water supply. Using an activated carbon filter after chlorination will remove excess chlorine and limited amounts of chlorinated chemicals formed. Chlorination may also oxidise and remove some colour and odour-causing substances including some iron and hydrogen sulphide.

The chemical feed pump requires frequent maintenance. The chemical reservoir must be kept filled and the pump checked at regular intervals for worn parts. Chlorine gas is also hazardous and may be problematic at small plants with unskilled labour.

## Chlorine compounds

Gas chlorination

This form of chlorination is the most commonly used chlorination system in the country, but also the most dangerous in the event of leaks.

Calcium hypochlorite

Calcium hypochlorite is mixed with water and applied in the same way as chlorine dioxide ($ClO_2$). Calcium hypochlorite is supplied in a powder or granular form with a chlorine concentration of between 60% and 70%. It is generally easier to handle than $ClO_2$. A disadvantage in this method is the fact that blockages occur in the pumps and piping.

Sodium hypochlorite

Sodium hypochlorite is applied in the same way as $ClO_2$. It is supplied in a liquid form with a chlorine concentration of between 12% and 15%. It is generally much easier to handle. A disadvantage in this method is the fact that sodium hypochlorite loses its concentration with time.

Salt chlorinator (on-site chlorine generation)

The generation of chlorine or chlorine compounds on-site is achieved by the electrolysis of a salt solution. In this process bulk common salt is supplied to a salt saturator where a 20 to 30% solution is produced. The solution is diluted to 3% and fed to the electrolysis cell. The process involves the application of an electrical current to a salt solution in a specially designed electrolysis cell. In the electrolysis process the salt is converted to chlorine gas or sodium hypochlorite. This is used to disinfect the water.
The main advantage is the elimination of transport, handling and costs of gas chlorine or chlorine compounds. Only a small electric current is required for the process.

Chlorine dioxide disinfection

Chlorine dioxide is used principally as a primary disinfectant for surface waters with odour and taste problems. It is an effective biocide at concentrations as low as 0.1 mg/L and over a wide pH range. Chlorine dioxide penetrates the bacterial cell wall and reacts with vital amino acids in the cytoplasm of the cell to kill the organisms. The by-product of this reaction is chlorite.

Chlorine dioxide disinfects according to the same principle as chlorine, however, as opposed to chlorine, $ClO_2$ has no harmful effects on human health.

Ozone disinfection

Ozone is a very strong oxidation medium, with a remarkably short life span. It consists of oxygen molecules with an extra O-atom, to form $O_3$. When ozone comes in contact with odour, bacteria or viruses, the extra O-atom breaks them down directly, by means of oxidation. The third O-atom of the ozone molecules is then lost and only oxygen will remain.

Disinfectants can be used in various industries. Ozone is used in the pharmaceutical industry, for drinking water preparation, for treatment of process water, for preparation of ultra-pure water and for surface disinfection. The main disadvantage is cost of installation and the fact that there is no residual to eradicate secondary contamination.

Ultra violet light

Ultraviolet irradiation is effective against the chlorine resistant protozoa giardia and cryptosporidium. No negative by-products are formed. Ultraviolet disrupts the genetic nature (DNA) of microorganisms.

The required dose may be affected by the amount of UV light absorbed impurities, suspended matter and dissolved organic compounds in the water. Therefore the higher the turbidity, the higher the UV dosage required. There is no easy method of measuring fluence (dosage).

Ultraviolet light does not produce any residual making it ineffective against secondary contamination or the growth of other microorganisms. It is therefore advisable to follow UV with a chemical based disinfect to produce a residual.

Iodine

Iodine has been used to disinfect water for nearly a century. It has advantages over chlorine in convenience and, probably, efficacy; many travellers find the taste less offensive as well. It appears safe for short and intermediate length use (3-6 months), but questions remain about its safety in long-term usage. It should not be used by persons with allergy to iodine, persons with active thyroid disease, or pregnant women.

Note that Iodine and other halogens appear to be relatively ineffective at killing cyclospora, a troublesome diarrhoea-causing bacterium seen in Nepal only in the late spring and summer months. At these times, it may be reasonable to pre-filter water to remove the large cyclospora (about the size of Giardia cysts), and then treat with iodine.

Bromine

Bromine is not generally used in the disinfection of drinking water in this country. Studies in the United States have indicated that during the ozonation of water containing bromine, especially along coastal regions, the by-products of bromine were carcinogenic to laboratory animals.

**Table 12:** Operation and maintenance requirements for disinfection processes

| **Disinfection process** | **Description** | **Where typically employed (type of water)** | **Design parameters** | **Advantages and disadvantages** | **Operational parameters and aspects** | **Maintenance requirements** |
|---|---|---|---|---|---|---|
| Gas Chlorine | Chlorine dispensed from a gas cylinder | Filtered water | 100% chlorine<br>Free residual chlorine of between 0.2 and 0.5 mg/l in tap water | *Advantages*<br>Cost effective<br>Most commonly used<br>Stable<br>Strong oxidising agent<br>Kills most bacteria<br>*Disadvantages*<br>Potentially fatal if used incorrectly.<br>Formation of trihalomethanes<br>Some micro-organisms are resistant to chlorine | Low turbidity required (clear water) | High maintenance |
| Sodium Hypochlorite | Liquid chlorine pumped | Filtered water | 12-15% chlorine<br>Free residual chlorine of between 0.2 and 0.5 mg/l in tap water | *Advantages*<br>Relatively cheap initially<br>Kills most bacteria<br>Easier to handle<br>*Disadvantages*<br>Short shelf-life<br>Unstable loses concentration with time | Low turbidity required (clear water) | Increasing dosage as the concentration reduces |
| Calcium hypochlorite | Granular or powder form | Filtered water | 60-70% chlorine<br>Free residual chlorine of between 0.2 and 0.5 mg/l in tap water | *Advantages*<br>Relatively cheap initially<br>Kills most bacteria<br>*Disadvantages*<br>Blockages in pumps and pipes | Low turbidity required (clear water) | Has to be dissolved in water before use<br>Constant blockages to pipes and pumps |

| Disinfection process | Description | Where typically employed (type of water) | Design parameters | Advantages and disadvantages | Operational parameters and aspects | Maintenance requirements |
|---|---|---|---|---|---|---|
| Salt chlorinators | Chlorine generated on-site | Filtered water | Electrolyses of a salt solution where salt is converted to chlorine gas | *Advantages*<br>Cheap<br>Kills most bacteria<br>Low electrical current<br>*Disadvantages*<br>Blockages in pumps and pipes | Low turbidity required (clear water) | Maintaining salt level in system;<br>Blockages |
| Ozone<br>Not normally applied at small water treatment plants | Oxygen molecule with an extra oxygen attached | Filtered water | Generated on-site | *Advantages*<br>Very strong oxidising agent<br>Kills most bacteria<br>*Disadvantages*<br>Very expensive to install<br>Short life span<br>No residual disinfection | Low turbidity required (clear water) | High maintenance<br>Highly trained staff required for operation |
| Ultra Violet<br>Not normally applied at small water treatment plants | Ultra-violet light absorbs impurities | Filtered water | Water passes over ultra-violet lamps | *Advantages*<br>Effective against chlorine resistant organisms<br>Kills most bacteria<br>*Disadvantages*<br>High cost of installation<br>Short life span<br>Fouling of lamps<br>No residual disinfection | Low turbidity required (clear water) | High maintenance<br>Highly trained staff required for operation<br>Cleaning and replacing ultra-violet lamps |

**Table 13:** Problems that may be experienced with disinfection processes at water treatment plants and suggested remedies or actions

| Disinfection process | Potential problems | Possible causes | Suggested remedies/actions |
|---|---|---|---|
| Chlorine | No chlorine residual | Incorrect measurement<br>Chlorine tank empty<br>Chlorinator faulty<br>High chlorine demand<br>Pump inoperative | Check chlorine analyser<br>Check DPD tablets<br>Check for leakages<br>Check chlorinator<br>Check pump<br>Increase chlorine dose<br>Determine chlorine demand |
| Hypochlorite | No chlorine residual | Precipitate in pumps or pipes cause blockages | Check for blockages in pumps and delivery pipes<br>Increase chlorine dose |
| Ozone<br>(not normally applied to small water treatment systems) | Water contaminated | Ozone analyser faulty<br>Increase ozone demand<br>Faulty ozone generator | Check ozone analyser<br>Increase ozone dose<br>Get technical support |
| Ultraviolet<br>(not normally applied to small water treatment systems) | Water contaminated | Lamps faulty<br>Lamps fouled | Clean lamps or replace lamps<br>Get technical support |
| Salt Chlorinators | No chlorine residual | No salt in system<br>Low current | Replace salt<br>Increase current |

### 3.2.9 Stabilisation

Before delivering water to the distribution systems it must be chemically stable. Stable water is that which is neither corrosive nor deposit (chemical scales) forming in pipes and fixtures.

Stabilisation in water treatment is a unit process which involves the addition of chemicals to water in order change its chemical properties and render it **stable**.

Stabilisation is achieved by adding chemicals to water to produce calcium carbonate precipitation potential (CCPP) of 4 mg/l. The calculation of the CCPP is complex and can only be done by qualified chemists.

The two common chemicals mostly used for stabilisation are slaked lime ($Ca(OH)_2$) and carbon dioxide ($CO_2$).

- **Lime** is used to stabilise soft water (low calcium content), and water with low pH.
- **Carbon dioxide** is used to stabilise water with high pH and also to add alkalinity to water.

Other chemicals used include soda-ash (sodium carbonate – $Na_2CO_3$), sodium hydroxide (caustic soda – NaOH) and limestone (partial stabilisation).

The Water Research Commission of South Africa has developed a programme called '**Stasoft'** for the calculation of stabilisation chemical dosages for given water.

**Table 14:** Operation and maintenance requirements for stabilisation processes

| **Stabilisation process** | **Description** | **Where typically employed (treatment of which type of waters)** | **Advantages and disadvantages** | **Operational parameters and aspects** | **Maintenance requirements** |
|---|---|---|---|---|---|
| Lime (limestone) | Lime powder made up in feed tanks and dosed as a slurry | Water with low calcium content (soft water) | *Advantages*:<br>Cheap and readily available<br>Less control on dosages<br>Has double function<br>*Disadvantages*:<br>Clogging of solution tanks and feed tanks | Flow control<br>pH / alkalinity measurement<br>Applying / maintaining correct dosages | Cleaning lime solution tanks and feed lines<br>Refilling of limestone filters/tanks |
| Recarbonation (Carbon Dioxide) | Process of passing carbon dioxide through water from the sedimentation process | Water with high pH and precipitates of carbonate and magnesium hydroxide | Effective for pH reduction | $CO_2$-gas relatively expensive | |
| Soda-ash (sodium carbonate-$Na_2CO_3$) | Soda-ash powder made up in feed tanks and dosed as a solution | Soft, aggressive water | *Advantages*:<br>Easily soluble, hence less difficulty in adding it<br>Provide $CO_3$ ions to aid in corrosion control<br>*Disadvantages*<br>High cost compared to lime<br>Can cake in storage bins due hydroscopic nature | Ensure correct make-up concentrations | Clean Soda-ash lines<br>Service dosing pumps |
| Caustic Soda (sodium hydroxide - NaOH) | Caustic Soda dosed as a liquid | Small treatment plants (not used in South Africa in drinking water treatment plants) | *Advantages*:<br><br>*Disadvantages*:<br>High cost<br><br>Extreme care when handling | Extreme care when handling | |

### 3.2.10 Treated water storage

After the water is treated it is generally stored in a reservoir before being pumped to other supply reservoirs. These reservoirs should be inspected at least twice a year to monitor leaks and the level of sludge accumulating in them. The reservoirs should be cleaned and flushed annually. This will eliminate sludge mixing with clean water when the levels in the reservoirs are low, which sometimes results in this water being supplied to the public. The quality of the water from the reservoirs must be monitored regularly (at least once a month). It may be necessary to disinfect the water in the reservoirs depending on the distance from the plant and the chlorine levels in the water.

It also may be necessary to shock dose the reservoirs to eliminate secondary contamination.

**Water storage checklist:**

- Check sedimentation in raw water storage reservoirs on a six-monthly basis. Decommission and clean reservoir if the sediment comes within 150 mm of the outlet en route to the purification works.
- Check for excessive secondary flocculation in clear water storage facilities.
- Check that bird-proofing is in place on all clear water facilities on a daily basis.
- Check for tampering on locks, fences and gates, securing clear water storage facilities on a daily basis.
- Check for structural integrity on a monthly basis. Possible indications of poor structural integrity are as follows:
  - Cracks on concrete wall and earth dams.
  - Leaks and moist appearance on concrete walls that are clearly not contributed by overflow spillage or pipe leaks.
  - Check that flow control switchgear does not become tangled.

### 3.2.11 Water losses

Water losses at a treatment plant can result in major expenses. It is therefore essential for the incoming and outgoing water to be recorded. This will enable the operator to determine the amount of water lost through the treatment processes. Some water is lost during the desludging of the clarifiers and the backwashing of the filters. The percentage of water lost during these processes is usually constant. If major increases occur in the water losses then immediate attention is required.

Water may also be lost by leaks in the reticulation system and from reservoirs. There is also an increase in illegal water connections which result in water losses. It is therefore essential for regular checks to be conducted on all systems where water leaks could occur. Private companies who specialise in water leak detection are also available in the marketplace.

### 3.2.12 Operating manual

It is imperative that a detailed operating manual is available on a water treatment plant for use by the plant personnel. The consulting engineer is responsible for ensuring that a set of operating manuals is provided to the client prior to or during commissioning of a new plant, and that the manual contains all information required for the trouble-free operation of the plant. The operating manual should include the following:

- overall description of the plant (with flow diagrams)
- treatment philosophy
- process flow diagrams
- description of pre-treatment processes
- description of main treatment process
- description of post-treatment processes
- description of residuals management procedures
- design criteria
- start-up procedures
- normal operating procedures (day-to-day)
- cleaning procedures (chemical cleaning)
- shut-down procedures
- process control and quality control procedures (monitoring)
- trouble-shooting
- summary of technical specifications
- safety aspects
- glossary/index

During commissioning, designated operating personnel and supervisors should receive training on the operation of the treatment plant, using the *Operating Manual* as the basis of the training. The municipal engineer should ensure that his operating personnel are fully conversant with the operation of the plant before handing over of the plant takes place.

### 3.2.13 Emergency procedures

A new Water Research Commission project has recently commenced (2008) in which guidelines will be developed for *Emergency Disinfection of Drinking Water*. This research report will include details of measures to be taken during emergency situations, both natural and man-made.

The Technical Assistance Centre for Small Water and Wastewater Treatment Plants provides support to the water and wastewater treatment sector, and can be contacted at cswartz@mweb.co.za, on the call centre number 082 819 6862 or the centre coordinator directly on 082 820 4481 (Chris Swartz) (www.watersupport.co.za).

### 3.2.14 General maintenance aspects

#### a. Introduction

No matter how well a water treatment works is designed, or how well the equipment operates, it will fail if not maintained properly. It is in this area where the process controller has the opportunity to make the best (or worst) of his/her treatment plant.

The secret of successful maintenance lies in two main aspects: planned preventative maintenance and good record keeping.

#### b. Preventative maintenance

For each piece of equipment on a water treatment works there are regular checking procedures, adjustments and services that should be performed on such equipment. If these procedures are carried out, the chances of breakdown are reduced drastically.

To implement such a system, tasks for each process controller or technician should be carefully planned. Some items should be checked daily, but others less frequently, based on calendar days and actual number of hours that the equipment has worked.

Each person must know which points he must check during his shift. For items requiring less frequent checking, it is better to draw up a timetable. The timetable should be posted on a notice board and the tasks should be spaced to provide an even workload.

#### c. Mechanical maintenance

Mechanical maintenance is of primary importance, because equipment should be kept in a good operating condition so that the plant can always be operated at optimal operating conditions.

Suppliers normally provide sufficient information regarding the mechanical maintenance of the equipment, e.g.:-

- type and grade of oils and lubricants
- intervals of oil change, grease, etc.
- level to where it should be filled with oil

The worker must also be able to identify tasks that he is not able to correct himself, and to get assistance where necessary.

For a successful maintenance program, the process controller and his supervisor must understand the need for equipment that must be operated on a continuous basis.

## d. Maintenance of equipment

i. Maintenance of pumps

The process controller should have a maintenance and management plan that meets the specific features of the equipment.

ii. Pump lubrication

Pumps, motors and power sources must be oiled and lubricated according to the prescriptions and recommendations of the suppliers.

iii. Gland seals

The seals should be checked for oil leaks during operation.

iv. Electrical motors

Motors should be kept free of dust and excessive humidity. The operating space should be kept free of items that could alter the air ventilation.

The process controller must always be aware of any unnatural conditions, e.g.:-

- unusual noises or vibrations during operation
- a motor that will not switch on or obtain normal running speed
- a motor or bearings that overheat
- continuous sparking of brushes

v. Lubrication of motors

Three-phase motors require little attention and under normal operating conditions the factory lubrication should last for about a year.

vi. Switchgear

Maintenance to switchgear must be done on a regular basis

- check for loose electrical contacts
- keep free of dust
- control voltage while the motor is in operation
- check that the ammeters register correctly

vii. Belt drives

The lifetime of belts and pulleys can be increased by ensuring correct tension and alignment.

- keep belts and pulleys free of oil
- never only replace one V-belt on a multiple drive system (replace the full system)

## e. Preventative maintenance records

Preventative maintenance programmes help operating personnel to keep equipment in a satisfactory operating condition. The only way a process controller can control his maintenance program is through good record keeping.

An equipment service chart (Master Chart) should be completed for each piece of equipment in the plant, e.g.:-

- name and type of equipment
- name and address of agent
- type of lubricants and frequency of application
- sizes of bearings

A second chart should be kept on record (Service Record Chart) and must contain the date of service and spares used. It should also indicate, where possible, the repair cost.

**f. Infrastructure maintenance**

i. <u>Building maintenance</u>

Building maintenance is also a program that should be carried out on a regular basis. The maintenance program depends on the age of the buildings. Attention should be given to a variety of items in the treatment plant buildings, amongst which are electrical systems, plumbing, ventilation, floors, windows, roofs and drainage around the buildings. At each building the stairs, ladders, walkways and free-boards should be checked on a regular basis. Protection should be provided to all moving parts.

ii. <u>Plant grounds</u>

Treatment plant grounds that are well kept and maintained in a neat condition improve the overall impression of the plant. This is important for the operator in the maintenance of good relations with his neighbours as well as the broad public. This also reflects your abilities as process controller with management.

## 3.3 PROCESS CONTROL AND QUALITY CONTROL

Every water treatment plant treating water for drinking purposes should have a monitoring programme to ensure that the water it produces is safe for human consumption. The extent of the monitoring will normally depend on the size of the plant or the number of persons served. A comprehensive record should be kept of the data as part of the monitoring programme.

Because of financial constraints, both in terms of purchasing measurement apparatus or appointing suitable operating staff, small treatment plants normally cannot implement a monitoring programme similar to that of the larger water suppliers. However, every treatment plant should have at least an absolute minimum monitoring programme consisting of daily analysis of pH and free chlorine residual of the final water to ensure a safe and wholesome supply of drinking water to the consumer.

The recommended monitoring programme for small treatment plants is given in the table below. It should be noted that frequency of monitoring the quality of the raw water depends on what the raw water source is. For a large reservoir (dam), weekly monitoring may be sufficient (as indicated in the tables), but if the water is withdrawn from a river, the quality may change hourly, and more frequent analysis of raw water quality will be necessary.

### 3.3.1 Monitoring by external consultants

Where it is not feasible for a plant owner to have the overall monitoring performed by plant personnel themselves, a consultant can be contracted to do the monitoring on their behalf on a monthly basis. The monitoring conducted by this consultant will be additional to the basic monitoring, which must be performed by the plant process controller(s).

**Table 15:** Recommended monitoring programme for small water treatment plants

| Measurement | Sample | Frequency |
|---|---|---|
| pH | Raw water<br>Coagulated water<br>Final water | Hourly, but preferably chart<br>Hourly or chart |
| Colour (true)<br>or<br>UV absorbance | Raw water<br>Settled water<br>Filtered water<br>Final water | Daily and Monthly<br>Monthly<br>Monthly<br>Daily |
| Turbidity | Raw water<br>Settled water<br>Filtered water<br>Final water | Daily<br>Daily<br>Daily<br>8-hourly or chart |
| Alkalinity | Final water | Weekly |
| Ca, Mg hardness<br>Total hardness | Filtered water<br>Final water | Monthly<br>Monthly |
| Conductivity | Raw water<br>Final water | Weekly |
| Iron | Final water | Monthly |
| Aluminium | Final water | Monthly |
| Free chlorine residual | Final water | 4-hourly |
| Total plate count | Final water | The frequency is prescribed by DWEA and depends on the population served |
| Total coliforms | Final water | |
| Faecal coliforms (*E. coli*) | Final water | |

(Note: The highlighted measurements indicate minimum requirements at any water treatment plant)

### 3.3.2 Operational Information Tool

Several spreadsheets have been developed as part of an Operational Information Tool for small water treatment plants, to ensure effective communication and reporting of results, both to management as well as to the regulating authorities (monthly summary data). It is the intention to standardise all operational information sheets at small water treatment plants in the country.

The spreadsheets appear on the following pages, and consist of:

| | | |
|---|---|---|
| Sheet 1 | - | Process Controllers |
| Sheet 2 | - | Flow Figures |
| Sheet 3 | - | Chemical Dosing |
| Sheet 4 | - | Operational Control |
| Sheet 5 | - | Water Quality Measurements |
| Sheet 6 | - | Water Quality Monitoring in Distribution Network |
| Sheet 7 | - | Tasks, Events and Incidents |
| Sheet 8 | - | Summary of Main Daily Parameters per Month |
| Sheet 9 | - | Monthly Cost and Quality Summary |

## SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 1 – PROCESS CONTROLLERS

| WSP | Plant Name | Date | Plant Superintendent | Signature |
|---|---|---|---|---|
| | | | | |

| Shifts | Shift Working Time | | Process Controllers | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Start | End | Name | DWAF PC Classification | Time on | Time off | Overtime | Signature |
| **Morning Shift** | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| **Afternoon Shift** | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| **Night Shift** | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

| SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 2 – FLOW FIGURES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| WSP | | Plant Name | | Month | Superintendent | Plant Capacity: (enter in the cell on the right) | | Signature: |
| | Date | INFLOW METER (Raw Water) | | OUTFLOW METER (Final Water) | | CALCULATED LOSSES = 24 h INFLOW – 24 h OUTFLOW (kL/d) | PERCENTAGE WATER LOSS FOR THE DAY (%) (5) | **COMMENTS** (on any flows or losses not within desired operational limits, e.g. plant shutdowns, power interruptions, high inflows, etc.) |
| | | Start (kL) | 24 hour inflow (kL/d) | Start (kL) | 24 hour outflow (kL/d) | | | |
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |
| 7 | | | | | | | | |
| 8 | | | | | | | | |
| 9 | | | | | | | | |
| 10 | | | | | | | | |
| 11 | | | | | | | | |
| 12 | | | | | | | | |
| 13 | | | | | | | | |
| 14 | | | | | | | | |
| 15 | | | | | | | | |
| 16 | | | | | | | | |
| 17 | | | | | | | | |
| 18 | | | | | | | | |
| 19 | | | | | | | | |
| 20 | | | | | | | | |
| 21 | | | | | | | | |
| 22 | | | | | | | | |
| 23 | | | | | | | | |
| 24 | | | | | | | | |
| 25 | | | | | | | | |
| 26 | | | | | | | | |
| 27 | | | | | | | | |
| 28 | | | | | | | | |
| 29 | | | | | | | | |
| 30 | | | | | | | | |
| 31 | | | | | | | | |
| **Average for month** | | | | | | | | |
| **Monthly minimum** | | | | | | | | |
| **Monthly Maximum** | | | | | | | | |

# SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 3 – CHEMICAL DOSING

## Name of Treatment Plant:

| Shift | Plant Module | Coagulant/ Flocculant 1 Name *(1)* | | Coagulant/ Flocculant 2 Name *(2)* | | Alkali type (for pH adjustment) *(3)* | | Pre-oxidant Name *(4)* | | Disinfectant type *(5)* | | Stabilisation chemical *(6)* | | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mg/L) | |
| Morning Shift | Module 1of WTP | | | | | | | | | | | | | |
| | Module 2of WTP | | | | | | | | | | | | | |
| Afternoon Shift | Module 1of WTP | | | | | | | | | | | | | |
| | Module 2of WTP | | | | | | | | | | | | | |
| Night Shift | Module 1of WTP | | | | | | | | | | | | | |
| | Module 2of WTP | | | | | | | | | | | | | |
| Daily Chemical Dosing Summary | | Average Coagulant *(1)* Dosing | | Average Flocculant *(2)* Dosing | | Average Alkali *(3)* Dosing | | Average Pre-oxidant *(4)* Dosing | | Average Chlorine *(5)* Dosing | | Average Stabilising Chemical *(6)* Dosing | | Remarks |
| | | | | | | | | | | | | | | |
| | | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mg/L) | (mL/min) | (mL/min) | (mL/min) | (mg/L) | |

## CHEMICAL MAKE-UP TANK LEVELS

| Shift | Indicator | Coagulant *(1)* | Flocculant *(2)* | Alkali *(3)* | Pre-oxidant *(4)* | Disinfectant *(5)* | Stabilisation | Remarks |
|---|---|---|---|---|---|---|---|---|
| Morning Shift | Level at start of morning shift previous day*(6)* | | | | | | | |
| | Level at start of morning shift today *(7)* | | | | | | | |
| | Number of times replenished to max level *(8)* | | | | | | | |
| | Quantity Used for the Day (L or kg) | | | | | | | |
| | Strength of Chemical Make-up Solution (% or g/L) | | | | | | | |
| | Average Dosage for Day Calculated from the Above (mg/L) | | | | | | | |

| INSTRUCTIONS FOR SUPERVISORS ON HOW TO CUSTOMISE AND USE THE LOG SHEETS FOR EACH PLANT |
|---|
| ***Setting up names of chemicals used on the treatment plant:*** |
| *(1) In Cells C5, C13 and C18, fill in the name of the type of coagulant used on the treatment plant,* e.g. *alum (aluminium sulphate).* |
| *(2) In Cells E5, E13 and E18, fill in the type of flocculant used on the treatment plant.* |
| *(3) In Cells G5, G13 and G18, fill in the type of alkali used on the treatment plant,* e.g. *lime.* |
| *(4) In Cells I5, I13 and I18, fill in the type of pre-oxidant used on the treatment plant,* e.g. *ozone.* |
| *(5) In Cells K5, K13 and K18, fill in the type of disinfectant used on the treatment plant,* e.g. *chlorine.* |
| |
| ***Recording of chemical dosages by Process Controllers:*** |
| *Process Controllers record the various chemical dosages in mL/min (or dosing pump setting) during the start of each shift (morning; afternoon; night) in Rows 7-12.* |
| *If the dosage changes during a shift, indicate the new dosage on the next shift only.* |
| *If there is only one treatment module on the plant, complete only the rows indicated by "Module 1".* |
| |
| ***Calculation of average daily dosages:*** |
| *In Row 14, average daily dosages for each of the chemicals are calculated automatically by the spreadsheet.* |
| |
| ***Calculation of chemical quantities used per day:*** |
| *(6) In "Level at start of morning shift previous day" row, carry-over recorded level of chemical in the make-up tank from previous day's sheet.* |
| *(7) In "Level at start of morning shift today" row, record level of chemical in the make-up tank at beginning of morning shift today.* |
| *(8) In "Number of times replenished to max level", indicate the number of times that the tank was refilled to the maximum level during the previous 24 hours.* |
| *In Row 22, the quantity of chemical used during the preceding 24 hour period is calculated.* |
| |
| ***Calculating average daily dosing based on amount of chemical used, and comparing with actual dosage recorded and average calculated:*** |
| *In Row 23, record the strength of the chemicals in the make-up tanks (take note of any dilutions that may have been made).* |
| *In Row 24, the average daily dosage of chemical is calculated based on the quantity of chemical used during the previous 24 hours.* |
| *Rows 14 and 24 may then be compared and should produce approximately the same value.* |
| |

## SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 4 – OPERATIONAL CONTROL

**Name of Treatment Plant:**

| Shift | Settling Tanks | | | Filters | | | |
|---|---|---|---|---|---|---|---|
| | Settling Tank No. | Time of Sludge Withdrawal *(1)* | Sludge Withdrawal (minutes) *(2)* | Filter No | Time of Backwashing *(3)* | Washing Time (minutes) *(4)* | Air Blow Time (minutes) *(5)* |
| Morning Shift | 1 | | | 1 | | | |
| | 2 | | | 2 | | | |
| | 3 | | | 3 | | | |
| | 4 | | | 4 | | | |
| | | | | | | | |
| Afternoon Shift | 1 | | | 1 | | | |
| | 2 | | | 2 | | | |
| | 3 | | | 3 | | | |
| | 4 | | | 4 | | | |
| | | | | | | | |
| Nigh Shift | 1 | | | 1 | | | |
| | 2 | | | 2 | | | |
| | 3 | | | 3 | | | |
| | 4 | | | 4 | | | |

| INSTRUCTIONS FOR SUPERVISORS ON HOW TO CUSTOMISE AND USE THE LOG SHEETS FOR EACH PLANT |
|---|
| ***Desludging of Settling Tanks:*** |
| *Desludging of Settling Tanks to be recorded every time that desludging takes place.* |
| *If there are more than 4 settling tanks, create additional rows in the sheet.* |
| *(1) Time of day when desludging is performed to be recorded.* |
| *(2) Duration of the desludging (in minutes) to be recorded.* |
| |
| ***Backwashing of Rapid Sand Filters or Pressure Sand Filters, or raking of slow sand filters:*** |
| *Backwashing of Rapid Sand Filters or Pressure Filters, or raking of slow sand filters, to be recorded every time that desludging takes place.* |
| *If there are more than 4 filters, create additional rows in the sheet.* |
| *(3) Time of day when backwashing is performed to be recorded.* |
| *(4) Duration of the backwashing (in minutes) to be recorded).* |
| *(5) Duration of the air blow (in minutes) to be recorded).* |
| |

# SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 5 – WATER QUALITY MEASUREMENTS

**Name of Treatment Plant:**

| | | Turbidity (NTU) *(1)* | pH *(1)* | Electrical Conductivity (mS/m) | Coagulant residuals (mg/L) *(5)* | | Colour (mg/L as Pt) | pH *(1)* | Floc formation *(2)* | Turbidity (NTU) *(1)* | pH *(1)* | Floc carry-over *(3)* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Al | Fe | | | | | | |
| **Alert Level** | | | | | | | | | | 3.0 | | 3 |
| Morning | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| Afternoon | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |
| Night | 1 | | | | | | | | | | | |
| | 2 | | | | | | | | | | | |
| | 3 | | | | | | | | | | | |

| Shift | Module No. | Filtered Water | | | Final Water | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Turbidity (NTU) *(1)* | pH *(1)* | Colour (mg/L as Pt) | Turbidity (NTU) *(1)* | pH *(1)* | Free chlorine residuals (mg/L) *(1)* | Electrical Conductivity (mS/m) | Coagulant residuals (mg/L) *(4)* | | Colour (mg/L as Pt) |
| | | | | | | | | | Al | Fe | |
| **Alert Level** | | >1.0 | | >10 | >0.5 | | <0.5 | | >0.3 | >0.2 | |
| South African National Standards (SANS) 241 | | | | | | | | | | | |
| Morning | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | | | | | | | | | | |
| Afternoon | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | | | | | | | | | | |
| Night | 1 | | | | | | | | | | |
| | 2 | | | | | | | | | | |
| | 3 | | | | | | | | | | |

***(1) Compulsory measurements at all water treatment plants***
***(2) Pin Point; Small; Medium; Large flocs***
***(3) None; Slight; Some; Substantial carry-over***
***(4) Only measure those relevant to the treatment plant***

**SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 6 – WATER QUALITY MONITORING IN DISTRIBUTION NETWORK**

| **Town:** | | | | | | **Date:** | |
|---|---|---|---|---|---|---|---|
| **Sample ID** | **Where taken** | **Time** | **Temp (deg. C) *(1)*** | **pH *(1)*** | **Free chlorine (mg/L) *(1)*** | **Turbidity (NTU)** | **Comments** (visual observations at sampling location; other quality parameters measured (e.g. Colour, Fe, AL)) |
| **RESERVOIRS** | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| **END-USERS (CONSUMER POINTS)** | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

***(1) Should be measured on-site when taking the samples***

## SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 7 – TASKS, EVENTS AND INCIDENTS

| WSP and WSA | Plant Name | Date | Plant Superintendent | Signature |
|---|---|---|---|---|
| | | | | |

| Task / Event / Incident | Description | Signature of PC on duty |
|---|---|---|
| **Inspection of Site Security conditions** | | |
| **Safety Issues** | | |
| **Communications (internal/external)** ***(full details) include any complaints*** | 1 | |
| | 2 | |
| | 3 | |
| **Maintenance work carried out** | 1 | |
| | 2 | |
| | 3 | |
| **Visits to the treatment plant** | 1 | Visitors Signature: |
| | 2 | Visitors Signature: |
| | 3 | Visitors Signature: |
| **Deliveries received** | 1 | |
| | 2 | |
| **Changes of chemical dosage** | 3 | |
| **General comments (continue on the back if necessary)** | | |

## SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 8 – SUMMARY OF MAIN DAILY PARAMETERS PER MONTH

| WSP | Plant Name | Month | Plant Superintendent | Plant Capacity: | Signature: |
|---|---|---|---|---|---|

| | Date | 24 hour inflow | 24 hour outflow | Calculated losses | No of hours in operation per day | Plant Capacity | CHEMICAL USE | | | | | | | | | | | | QUALITY | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | Coagulant/ Flocculant 1 Name | | Coagulant/ Flocculant 2 Name | | Alkali type (for pH adj.) | | Pre-oxidant Name | | Disinfectant type | | Stabilisation chemical | | Raw Water | | | | Flocculation | Mix after Settling | Mix after Filters | Final Water | | | | | |
| | | | | | | | mg/L | Kg | mg/L | Kg | mg/L | Kg | mg/L | Kg | mg/L | Kg | mg/L | Kg | Turb | pH | EC | Colour | pH | Turb | Turb | Turb | pH | Cl residual | EC | Colour | Metals |
| 1 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 2 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 3 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 4 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 5 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 7 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 10 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 11 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 12 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 13 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 14 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 15 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 16 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 17 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 18 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 19 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 20 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 21 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 22 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 23 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 24 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 25 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 26 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 27 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 28 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 29 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 30 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 31 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Average for month | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monthly minimum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Monthly Maximum | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |

# SMALL WATER TREATMENT PLANTS OPERATIONAL INFORMATION TOOL: SHEET 9 – MONTHLY COST AND QUALITY SUMMARY

| Name of Treatment Plant | KZ number | Month and Year Reported | Province |
|---|---|---|---|
| Prepared by | Position | Date | Water Scheme |

| Indicator | Units | Daily Average | Total for Month | Indicator | Quality Parameter | Value | Remarks |
|---|---|---|---|---|---|---|---|
| Total Raw Water | $m^3$ | | | Average Raw Water Quality | Turbidity (NTU) | | |
| Clear Water Produced | $m^3$ | | | | pH | | |
| Production Losses | % | | | | Colour (mg/L as Pt) | | |
| Operating Hours per Day | Hours | | | | Alkalinity (mg/L as $CaCO^3$) | | |
| Energy Consumption | kW | | | | Metal (Al/Fe/Mn)(mg/L) | | |
| Diesel Consumption | L | | | Average Final Water Quality | Chlorine Residual (mg/L) | | |
| Coagulant Consumption | kg | | | | Turbidity (NTU) | | |
| Flocculant Consumption | kg | | | | pH | | |
| Alkali Consumption | kg | | | | Alkalinity (mg/L as $CaCO^3$) | | |
| Gas Chlorine Consumption | kg | | | | Metal (Al/Fe/Mn)(mg/L) | | |

| TOTAL COSTS FOR MONTH | | | | OPERATING COSTS FOR MONTH (per $m^3$ of clear water produced) | | | | Remarks |
|---|---|---|---|---|---|---|---|---|
| Indicator | | | | | | | | |
| Raw Water | $m^3$ | | | Raw Water Cost ($R/m^3$) | | Personnel Cost ($R/m^3$) | | |
| Energy | kW | | | | | | | |
| Diesel | L | | | | | | | |
| Coagulant | kg | | | Energy Cost ($R/m^3$) | | Maintenance Cost ($R/m^3$) | | |
| Flocculant | kg | | | | | | | |
| Alkali | kg | | | | | | | |
| Gas Chlorine | kg | | | Chemicals Cost ($R/m^3$) | | Monitoring Cost ($R/m^3$) | | |
| Salaries | R | | | | | | | |
| Maintenance | R | | | | | | | |
| Monitoring | R | | | Diesel Cost ($R/m^3$) | | Total Operating Cost ($R/m^3$) | | |
| | | | | | | | | |
| Total Operating Cost | R | | | | | | | |

### 3.3.3 Sampling

A good understanding of what needs to be sampled, sampling frequency, approved or recommended sampling techniques, storage of samples with respect to time and care, and transportation of samples is essential prior to commissioning a sampling programme. The objectives of the sampling and analysis programme are determined by information that is required from the anticipated water quality analysis results. Such information includes:

a. Final water quality to be achieved by a given treatment method in comparison to existing local standards.

b. Efficiency of the treatment method.

c. Levels of contamination in distribution systems.

d. Impacts of the water quality on fixtures and infrastructure such as pipes, concrete reservoirs, etc.

Sampling of raw water must cover all periods or seasons in which the quality of water changes widely and comparatively.

Analysis of samples must preferably be conducted by laboratories accredited by the South African National Accreditation System (SANAS). Trained personnel can conduct in-house analysis with basic equipment for process monitoring and control purposes. It is important that analytical results can be practically interpreted and that trends are observed and recorded for easier extrapolations, as necessary.

Plant laboratories should be of high standard and audited (some form of external analysis quality control). For small plants, management must ensure that the equipment used is providing reliable and accurate results – they should either check themselves or use an external chemist/consultant. Look at regular calibration of meters, age of reagents, etc.

Water treatment systems are characterised by different sampling and analysis needs. These needs will determine the operational and complexity levels (skills). Therefore, careful consideration of O & M needs to be taken in account when selecting a water treatment technology. Such considerations are determined by the number of samples, and the frequency and level of required analyses (physical, chemical, microbiological, or combinations of these).

<u>Sampling techniques: River, stream, lake, dam or reservoir</u>

Table 16 below provides the recommended and minimum number of samples and sampling frequencies to be taken at different points in the overall water supply system, i.e. water source, treatment plant and distribution network.

**Table 16** The minimum and recommended number of samples and sampling frequencies for different points in the water supply system

| SAMPLING POINT | | MINIMUM PER POINT | | RECOMMENDED PER POINT* | |
|---|---|---|---|---|---|
| | | **No of samples/year** | **Sampling frequency** | **No of samples/year** | **Sampling frequency** |
| **SOURCE** | **River/stream/ spring/dug-well** | 4 | 3-monthly | 26 | 2-weekly |
| | **Dam** | 2 | 6-monthly | 12 | 2-monthly |
| | **Borehole** | 1 | - | 2 | 6-monthly |
| **Treatment works** | | 4 | monthly | 12/52/365 | Monthly/ weekly/ daily** |
| **Point of use** | | 4 | monthly | 12/52/365 | Monthly/ weekly/ daily** |

* Also refer to SABS Code of Practice, *South African Bureau of Standards: Drinking Water Specifications. SABS 241-1999.*

** *Depends* on size of treatment works, the variability in the water quality, and the number of people supplied with water.

**NOTE**

**It is the goal to collect the optimal number of samples that would provide reliable results.**

**If the frequency is too low, then results will not reflect the correct variations in water quality changes at a specific site. On the other hand, if the sampling frequency is too high, then money would be wasted on unnecessary sampling and analyses and the results obtained would not reveal new information, but would only confirm existing results.**

**Table 17:** Type of sample bottles required for domestic water quality sampling

| Substance | Type of sample bottle to be used | | Minimum sample size required (ml) | Special remarks |
|---|---|---|---|---|
| | Glass | Plastic | | |
| **Biological Quality** | | | | |
| Faecal coliforms | ✓ | ✓ | 500 | Sample bottles must be sterilised |
| Total coliforms | ✓ | ✓ | 500 | Sample bottles must be sterilised |
| Free residual chlorine (residual) | ✓ | ✓ | 500 | Measured on site |
| **Physical Quality** | | | | |
| Electrical conductivity/total dissolved salts | ✓ | ✓ | 300 | Should preferably be measured immediately at site |
| pH | ✓ | ✓ | 50 | Should preferably be measured immediately at site |
| Turbidity | ✓ | ✓ | 300 | |
| **Chemical Quality** | | | | |
| Arsenic | | ✓ | 300 | |
| Cadmium | | ✓ | 300 | |
| Calcium | ✓ | ✓ | 300 | Use borosilicate glass bottles. Ask laboratory for more information. |
| Sodium | | ✓ | 300 | |
| Chloride | ✓ | ✓ | 300 | |
| Fluoride | | ✓ | 300 | |
| Iron | | ✓ | 300 | |
| Manganese | | ✓ | 300 | |
| Total hardness | ✓ | ✓ | 100 | |
| Magnesium | ✓ | ✓ | 300 | Use borosilicate glass bottles. Ask laboratory for more information. |
| Nitrate | ✓ | ✓ | 300 | |
| Nitrite | ✓ | ✓ | 300 | |
| Potassium | | ✓ | 300 | |
| Zinc | | ✓ | 300 | |
| **Please note** the minimum sample size required is only adequate for determining the concentration of that specific substance. In practice a 1000 ml (or 1 L) sample is normally collected to determine the concentration of a range of substances in the sample. Consult the laboratory on the type of sample bottle(s) required for the different types of substance(s) to be analysed. | | | | |

**Table 18: Domestic water quality sampling equipment checklist**

| **Sampling Equipment** | **Tick** |
|---|---|
| Stopwatch (if required for flow measurements) | |
| pH meter and buffers or pH indicator strips | |
| Turbidity meter | |
| Temperature meter | |
| Additional batteries for field apparatus | |
| Electrical conductivity meter | |
| Copies of manufacturers’ manuals for calibrating field instruments | |
| Map indicating all sampling locations | |
| Field notebook | |
| Waterproof pens, markers and pencils | |
| Field data forms and data labels | |
| Containers for purging the borehole (if no pumps are available) | |
| Electric generator (if necessary) | |
| Calibrated bucket | |
| Sealed cooler bags | |
| Glass sample bottles (sterile glass bottles for microbiological sampling) | |
| Plastic sample bottles | |
| Bags of ice or freezer ice packs | |
| Paper towels | |
| Disposable latex gloves (if required) | |

## Laboratory management

To implement the monitoring programmes as proposed above, the treatment plant management should set up and equip a laboratory at the treatment plant to do the required basic physico-chemical analyses on site, apart from the other analyses that can be conducted at a centralised laboratory of the authority, or by an external consultant.

Minimum laboratory equipment requirements for small water treatment plants are provide in Table 19.

**Table 19:** Recommended minimum laboratory requirements for small water treatment plants

| Equipment/apparatus | Reason needed |
|---|---|
| **Jar test equipment** | To determine optimal chemical dosage and coagulation pH |
| **pH meter**<br>(Preferably in-line in flocculation chamber and in final water, and/or a good quality bench model) | Accurate control of coagulation pH for clarification of water<br><br>Control of stabilisation of final water<br><br>Also measure temperature |
| **Turbidimeter** | Control of the settlement and filtration processes |
| **Colorimeter**<br>(for southern coastal belt waters) | Measure colour as indicator of amount of natural organic matter in the raw and final water |
| **Comparator for measurement of chlorine residuals** | To control disinfection of the final water |
| **Conductivity meter** | To measure conductivity of final water to allow determination of the stability of the final water |

## Jar tests

Jar tests (also referred to as beaker tests) are done at a treatment plant on the raw water to determine the optimum coagulant dosage to be implemented on the full-scale plant.

The procedure is as follows:

a. Collect enough water to fill the jars. Measure and record all initial parameters of interest (temperature, pH, turbidity, colour, metals, etc.) from the head of the treatment plant or sample location.

b. Pour 1 L of sample into each beaker.

c. Position the beakers under the multi-stirrer so they are centred with respect to the impeller shaft.

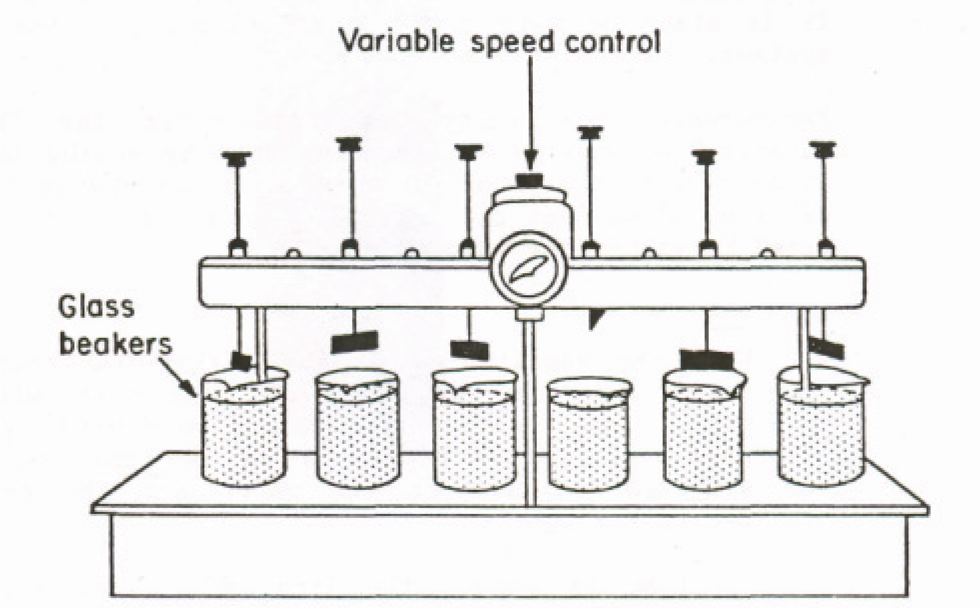



**Figure 12:** Multi-stirrer with beakers in place

d. Lower the impellers so that each impeller is about one-third from the bottom of the jar.

e. Begin rapid mix period based on the predetermined speed and duration to simulate full scale on the treatment plant (usually 2 minutes at 100 rpm).

f. Using syringes, dispense the desired doses of coagulant to each of the beakers.

g. To each of the beakers, add lime or other chemical if required for pH adjustment.

h. Continue rapid mix as required to simulate full scale.

i. Reduce mixing speed to simulate slow mixing conditions during flocculation in the full-scale process (usually 25 rpm). Flocculate for the time necessary to simulate full scale usually 10-15 minutes).

j. Stop the mixer, pull up the paddles, and allow sedimentation to occur for 30 minutes.

k. On completion of the settling period, supernatant samples are withdrawn just below the water surface with suitable syringes. A portion of the sample is used directly for determination of turbidity, while the rest of the sample is filtered through a 0.45 micron membrane filter and subject to analysis for colour, UV absorbance, and metals, if required additionally. The syringe should be rinsed with distilled water before sampling from a different jar.

Record keeping

All records relating to the plant are important to ensure adequate management and control of the plant. Records are used in identifying any change that may occur in the conditions at the plant. Records are also used to establish future extensions and design of the plant.

It is a futile exercise for the operator to maintain records if these records are not monitored by the supervisor or other official on a regular basis. The supervisor should take a keen interest in all the records. He should be able to determine the cost of treating the water on a monthly basis from all the records available.

Initial records of the plant design, size, dimensions of each unit and capacities, plant classification and other relevant information should be available on-site or kept in a safe place.

All other information relating to the plant should be recorded by the operator.

Daily records must be kept of the following:
Flow rate
Turbidity through the processes
Chemical dosage rates
Chemical stocks (so that orders can be placed timeously)
pH
Free residual chlorine at the plant and in the reticulation system

The following records will also be useful:
A record of all pumps and pump hours; service and maintenance records of the pumps; electricity; desludging clarifiers; backwashing filters etc.
Flow diagrams, updated graphs of flow rates, turbidities etc. are also useful in the operation of the plant.

If possible records of the physical, chemical and bacteriological quality should be available.

## 3.4 TROUBLE SHOOTING

This section provides guidelines on what possible action(s) the process controller should take if a specific problem occurs. It is hoped that this section will provide the process controller and the manager (supervisor) with a better understanding of the importance of self-assessment of the small water treatment plant, whether it be a daily self-assessment or an external inspection. It is important to note that this section should be read in conjunction with Section 3.2 of this manual.

The word ‘supervisor’ has been used very generally and may be replaced with manager, senior operator or other similar titles.

| | | Notes | Possible Actions |
|---|---|---|---|
| **3.4.1 ABSTRACTION** | | | |
| **ABSTRACTION POINTS – DAMS AND RIVERS** | | | |
| 1 | Is the mouth of the suction point underneath the water? | To ensure that there is a constant supply of water to the treatment plant it is important that the mouth of the suction plant is submerged at all times. Failure to do this may cause problems at the WTW. | The process controller must check daily that the mouth of the suction plant is submerged. Should it appear that there will be a problem the process controller must alert management timeously so that action can be taken. |
| 2 | Is the screen at the abstraction point clear of debris? | Always check that the screen at the abstraction point is free of debris to allow a constant flow of water. | The process controller must check daily that the screen is free of debris. |
| 3 | Are there any leaks along the pipe to the treatment works? | Puddles around the pipe or areas where grass is growing profusely may indicate that there is a leak. | The process controller must walk/drive along the pipeline from the abstraction point to the WTW. |
| **ABSTRACTION POINT – CANALS** | | | |
| 4 | Is the valve at the weir in working order, i.e. can it be moved up and down to regulate the volume of flow? | The valve may need to be opened or closed depending on the water level. In this respect it must be kept in working order. | The process controller should regularly check that the valve can be opened and closed and if there is a problem report it to the supervisor or maintenance team. |
| 5 | Is the inlet clear of debris? | Always check that the inlet to the canal is free of debris to allow a constant flow of water. | Check daily that the canals are fee of debris. Report the concerns and request action as required. |
| **PUMP STATIONS** | | | |
| 6 | Are the pumps at the pump station operational? | Unusual noises or vibrations may indicate that there is a problem or a potential problem with the pump. | Look and listen to all moving parts to determine if the equipment is functioning properly. Feel to check that there are no odd vibrations. If possible ascertain the root of the problem. Report the problem to the supervisor or maintenance personnel. |
| 7 | Are their unusual noises or vibrations coming from the pumps? | | |
| 8 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns. |
| **ENVIRONMENTAL AND SAFETY** | | | |
| 9 | Is water quality sampling being undertaken at the abstraction point? | It is important to know the quality of the water that is being abstracted to ensure that the treatment works can be optimally operated. | The process controller must take samples for water quality analysis. |
| 10 | Are the results being interpreted and acted upon? | | The supervisor must interpret the results and give instructions to the process controllers to ensure optimal operation of the treatment process. |

| | | Notes | Possible Actions |
|---|---|---|---|
| 11 | Are personnel wearing correct PPE? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required. | Ensure that PPE is available on site and is correctly worn. |
| 12 | Is good housekeeping practiced at the abstraction points? | The area around the abstraction points must be kept clean and tidy. Any debris removed from the screens must be correctly disposed of. No debris should be allowed to accumulate on the side of the abstraction point. | Keep grass short or paving free of weeds. Safely dispose of any debris removed from the screens or inlet weir. |
| **3.4.2 CHEMICAL DOSING** | | | |
| **LIME DOSING** | | | |
| 1 | Is the lime safely stored? | In all cases where chemicals are used they will need to be stored and due to the nature of the chemicals must be stored in such a way as to keep the bags dry. Also, it is preferable that the storage area is bunded so that if spillage does occur the chemical will be contained. | Ensure that the bags of lime are stored on pallets in an enclosed area and that the storage area is bunded. The supervisor must take this up with management if it is not.<br><br>Make sure that when chemicals are delivered they are correctly transferred into the storage area. Always keep the storage area clean to avoid accidents.<br><br>Always work on a first in – first out basis. |
| 2 | Is the area around the lime dosing area kept clean? | | |
| 3 | Is there lime in the dosing unit? | For the WTW process to be effective the initial chemical dosing must be correct. | The process controller must check that there is always lime available and if stocks are running low must report it to the supervisor who must order further supplies.<br><br>The process controller must check regularly that mixing is occurring properly, and if not report the concerns to the supervisor who must help the process controller to find the problem. |
| 4 | Are the lime and water being adequately mixed in the mixing tank? | | |
| 5 | Is the mixture entering the flocculation tank? | | |
| 6 | Are the motors making strange noises or vibrating, or overheating? | Unusual noises, vibrations or excessive heat may indicate that there is a problem or a potential problem with the. | Look and listen to all moving parts to determine if the equipment is functioning properly. Feel to check that there are no odd vibrations. If possible ascertain the root of the problem. Report the problem to the supervisor or maintenance personnel. |
| **FLOCCULANT DOSING** | | | |
| 12 | Is the flocculant storage tank in working order – can levels of flocculant be checked? | The flocculant is usually stored in tanks and must be within a bunded area so that if leaks or spillages occur the chemical is contained. The | The process controller must check the flocculant levels each day and report to the supervisor when these are low so that more chemical can be ordered. |

| | | Notes | Possible Actions |
|---|---|---|---|
| 13 | Is the mixing tank in working order – is the mixer turning? | mixing tanks should also be within this bunded area. | The process controller must report any malfunctions to the supervisor or maintenance personnel. |
| 14 | Has the beaker test been undertaken to determine the correct dosage of flocculant? | For the WTW process to be effective it is essential that chemical dosing is carried out correctly. In this respect the beaker test must be undertaken to determine the correct dosage to ensure that optimal flocculation does occur. It is important to note that if too much of the chemicals are used, money is wasted; if insufficient chemicals are used, increased disinfection chemicals will be needed and also the disinfection process may be ineffective, leading to illness. | The supervisor or laboratory personnel must undertake the beaker test and then inform the process controller of the dosage.<br><br>Maintaining the correct dosage is vital. In this respect the process controller must take a weekly sample (over a set period of 2 minutes) from the flocculation channel. The supervisor must then determine whether the dosage is correct. If necessary the process controller must then be instructed to make adjustments to the dosage. |
| 15 | Is the dosing pump dosing at the correct rate? | | |
| 16 | Is the mixture entering the flocculation tank? | | |
| **MAINTENANCE** | | | |
| 17 | Are there any strange noises or vibrations coming from the dosing pump? | Unusual noises or vibrations may indicate that there is a problem or a potential problem with the pump. | Look and listen to all moving parts to determine if the equipment is functioning properly. Feel to check that there are no odd vibrations. If possible ascertain the root of the problem. Report the problem to the supervisor or maintenance personnel. |
| 18 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns. |
| **ENVIRONMENTAL and SAFETY ISSUES** | | | |
| 19 | Are personnel wearing correct PPE? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required | Ensure that PPE is available on site and is correctly worn. |
| 20 | Is good housekeeping being practiced in the dosing area? | The dosing area must be kept clean to ensure that accidents to not occur. | The process controller must ensure that the area is kept clean and report any spills to the supervisor who must ensure that the spill is cleaned up and also after ascertaining the reason for the spill, ensure that it does not recur. |
| 21 | Are the chemicals correctly stored? | All chemicals must be stored according to their specifications, in enclosed, bunded areas. | The process controller must check on the storage areas to ensure that chemicals are being stored correctly and report any concerns to the supervisor who must take the concern to the safety committee for action if necessary. |

| | | Notes | Possible Actions |
|---|---|---|---|
| **3.4.3 FLOCCULATION** | | | |
| **HYDRAULIC FLOCCULATION** | | | |
| 1 | Is flocculation taking place? | For the WTW process to be effective it is essential that flocculation does occur. It is easy to see whether flocculation is occurring or not. | The process controller must visually inspect the WTW several times each day and record and report all concerns. |
| 2 | Is there sludge build-up in the channel? | Chemical usage may lead to the build-up of sludge on the sides of the flocculation tank and occasionally scum may form in the channel. | The process controller must brush the walls regularly to prevent sludge build-up and remove scum using a net should it build-up in the channel. |
| 3 | Is there scum in the flocculation channel? | | |
| **MECHANICAL FLOCCULATION** | | | |
| 4 | Is flocculation taking place? | For the WTW process to be effective it is essential that flocculation does occur. It is easy to see whether flocculation is occurring or not. | The process controller must visually inspect the WTW several times each day and record and report all concerns. |
| 5 | Is the bridge rotating and are the propellers working? | In a mechanical flocculation unit, the bridge must rotate slowly to allow settling, while the propellers within the flocculation unit must be in working order to ensure mixing. | The process controller must check that the bridge and propellers are in working order and report any problems to supervisor or maintenance personnel. |
| **MAINTENANCE** | | | |
| 6 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns. |
| 7 | Are all malfunctions recorded and reported? | To ensure that the WTW operates optimally to produce good quality potable water, all malfunctions must be rectified as soon as they are reported. | A record must be kept of all malfunctions and the process controller must follow up with the supervisor if maintenance does not occur as requested. |
| **ENVIRONMENTAL and SAFETY ISSUES** | | | |
| 8 | Is correct PPE worn? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required | Ensure that PPE is available on site and is correctly worn. |
| 9 | Is good housekeeping practiced around the flocculation channels/ tanks? | The area around the flocculation channels/tanks must be kept clean to avoid contaminating the water as well as accidents that may be caused if sludge/scum removed is left lying around. | The process controller must keep the area clean and safely dispose of the sludge and scum. |
| **3.4.4 SEDIMENTATION** | | | |
| **ROUND TANKS** | | | |
| 1 | Is the bridge rotating? | For the sedimentation process to work the | The process controller must check that the wheel |

| | | Notes | Possible Actions |
|---|---|---|---|
| 2 | Is the wheel alignment in the centre of the running surface? | bridge must rotate slowly allowing settling to occur. In this respect the wheel alignment must be in the centre of the running surface. | alignment is correct and that the bridge is moving. Any concerns must be reported to the supervisor or the maintenance personnel. |
| 3 | Are the overflow weir plates maintained? | The overflow weir plates may occasionally break off and sludge/scum accumulation may occur. | The process controller must inspect the weirs and report any loose or broken weir plates to the supervisor or maintenance personnel. The process controller must regularly brush the weir plates to remove any sludge/scum accumulation. |
| 4 | Is the desludging mechanism working? | Desludging is important for the optimum working of the WTW, to ensure that accumulated sludge does not become re-suspended and carried over to the next process if it is not removed. | The process controller must visually inspect the desludging mechanism and report any malfunctions to the supervisor or maintenance personnel. |
| 5 | Is the desludging valve in working order? | | |
| 6 | Is the rate of desludging adequate? | | |
| **RECTANGULAR TANKS** | | | |
| 7 | Is there even flow over the outlet weir? | Uneven flow over the weirs may indicate that there are blockages along the top of the weir. | The process controller must visually inspect the weirs to ensure that flow is even, and if not must brush the weirs to remove any build-up. |
| 8 | Is the desludging valve in working order? | Desludging should be conducted at least once per shift so it is important that the valves are maintained. | The process controller must record and report any malfunctions to the supervisor or maintenance personnel. |
| 9 | Is the rate of desludging adequate? | | |
| **MAINTENANCE** | | | |
| 10 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns. |
| 11 | Are all malfunctions recorded and reported? | To ensure that maintenance occurs when a fault is reported it is important to keep a record of the malfunctions and date on which they were reported. | The process controller must record and report all malfunctions and must follow up with the supervisor if they are not timeously dealt with. |
| **ENVIRONMENTAL and SAFETY ISSUES** | | | |
| 12 | Is correct PPE worn? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required. It is important that a life jacket is worn when the process controller is on the sides of the tank cleaning the weirs. | Ensure that PPE is available on site and is correctly worn. |

| | | Notes | Possible Actions |
|---|---|---|---|
| 13 | Is good housekeeping practiced around the tanks? | The area around the sedimentation tanks must be kept clean to avoid contaminating the water as well as accidents that may be caused if sludge/scum removed is left lying around. | The process controller must keep the area clean and safely dispose of the sludge and scum. |
| **3.4.5 FILTRATION** | | | |
| **RAPID GRAVITY FILTRATION** | | | |
| 1 | Is the level of water being monitored during each shift? | A rise in water level to a specific level would indicate that the backwash procedure needs to be started. | Monitor water levels in the filters on each shift. |
| 2 | During the backwash cycle, is there even air flow? | An uneven airflow may indicate that the nozzles are blocked or broken. A hole forming in the media may also be an indication of a broken nozzle.<br><br>Mudballing or cracks in the medium would mean that the water would flow through the sand without being filtered. | Monitor the filters to ensure that there is even airflow through the nozzles. Report uneven airflow to the supervisor.<br><br>Monitor the filter for mudballing or cracks. Rake and treat with chlorine if this situation does occur or replace the medium if necessary. |
| 3 | Are the blowers in working order? | In order for the backwashing procedure to work optimally, the valves, pumps and blowers need to be in working order. | The process controller must report any malfunctioning blowers, pumps or valves to the supervisor or maintenance personnel as soon as the problem is noticed. The process controller must not attempt to fix the blowers, pumps or valves. |
| 4 | Are all the valves in working order? | | |
| 5 | Are the pumps in working order? | | |
| 6 | Is there sand in the clear water sump? | Sand in the clear water sump may be an indication that there are broken nozzles. | Monitor the clear water sump for the presence of sand and report to the supervisor if this is noticed. |
| **SLOW SAND FILTRATION** | | | |
| 7 | Is there sludge build-up on the filter media? | Sludge build-up on the filter would hamper the optimal working of the filter. | The process controller must report the sludge build-up to the supervisor and then close the inlet valve to take the filter out of operation. The top layer of the filter must be scraped off being careful not to disturb the deeper layer. New sand must replace the lay that has been removed, and must be evenly spread over the filter. |
| **HIGH PRESSURE FILTRATION** | | | |
| 8 | Is the pressure meter in working order? | In order operate the filter optimally and know when to backwash, the process controller must | The process controller must inspect the meters on each shift to ensure that they are in working order and |

| | | Notes | Possible Actions |
|---|---|---|---|
| 9 | Is the flow meter in working order? | make sure that the pressure and flow meters are in working order. A normal reading indicates that there is a high flow rate and low head loss, while a low flow rate and high head loss would be an indication that the filter needs to be backwashed. | immediately report any malfunctions to the supervisor. |
| 10 | Are the pumps in working order? | In order for the high pressure filtration unit to work optimally, the pumps and blowers need to be in working order. | The process controller must report any malfunctioning blowers or pumps to the supervisor or maintenance personnel as soon as the problem is noticed. The process controller must not attempt to fix the blowers or pumps. |
| 11 | Are the blowers in working order? | | |
| **MAINTENANCE** | | | |
| 12 | Is there good housekeeping around the filter? | The area around the filters must be kept clean and tidy | The process controller must maintain the area around the filters to ensure that contamination of the filtered water does not occur. |
| 13 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns. |
| 14 | Are all malfunctions recorded and reported? | To ensure that maintenance occurs quickly and efficiently it is important to keep a record of the malfunctions and date on which they were reported. | The process controller must record and report all malfunctions and must follow up with the supervisor if they are not timeously dealt with. |
| **ENVIRONMENTAL and SAFETY ISSUES** | | | |
| 15 | Is correct PPE worn? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required and correct safety signage must be in place. | Ensure that PPE is available on site and is correctly worn.<br><br>Top management needs to understand the consequences if correct safety equipment, capacity building and signage is lacking or not properly maintained.<br><br>It would be the process controllers' responsibility to highlight these concerns to the management and request funding. |
| 16 | Is correct safety signage visible? | | |
| **3.4.6 DISINFECTION** | | | |
| 1 | Is the gas alarm in working order? | Apart from being corrosive, chlorine is also very poisonous. All personnel working with chorine must undergo relevant training on the use and handling of chlorine (often on offer from the | The supervisor must request that all process controllers who handle the chemicals attend a course in their use and handling. |
| 2 | Does the process controller know how to detect a leak using ammonia vapour? | | |

| | | Notes | Possible Actions |
|---|---|---|---|
| 3 | Is there an extraction fan in the chlorine building? | supplier) and the consequences of not maintaining the alarm systems and fans. | Record and report any malfunctions of the dosing equipment immediately to the supervisor. Include date reported and date repaired.<br><br>Monitor the mass of chemical dosed per day. |
| 4 | If yes, is it in working order? | | |
| 5 | Is the gas flow rate measuring equipment in working order? | In order to provide consumers with a safe supply of water, it is essential that chlorine is dosed accurately and continuously. | The supervisor must ensure that laboratory results are accurately interpreted and the information supplied to the process controller, so that correct dosage levels are maintained.<br><br>Malfunctions of the dosing equipment must be reported immediately and a record kept of the date reported and date repaired. |
| 6 | Does the process controller know at what dosage level the flow should be maintained? | | |
| 7 | How does the process controller detect when the gas is low? | The process controller must be trained in how to detect when the gas is low, and if an electronic display is used, is it working and what actions must be taken in the event of a fault. It is important that all process controllers at a WTW understand the importance of disinfection, and the consequences if dosing is not continuous. | The supervisor must ensure that all process controllers are adequately trained in all aspects of chlorine dosing. |
| 8 | If loading cells are used, is the electronic display in working order? | | |
| 9 | Has the process controller undergone chlorine handling training? | | The supervisor must request that all process controllers who handle the chemicals attend a course in their use and handling. |
| 10 | Is the process controller taking samples for water quality testing prior to distribution? | Water quality testing must be undertaken at the end of the treatment process prior to distribution to consumers. The analysis needs to be carried out in accordance with SANS 241 for drinking water. | The process controller must be trained in the correct method of taking samples for water quality analysis and must know where to deliver the samples once collected. |
| 11 | Is the supervisor receiving the results from the laboratory and does the supervisor know how to interpret them? | | The supervisor must interpret the results and based on this interpretation give the process controller instructions on what action to take. |
| **MAINTENANCE** | | | |
| 12 | Is there good housekeeping in the chlorination room? | Disinfection is generally the last process before distribution of the water to consumers. In this respect it is important that it is done accurately and that all the equipment is maintained in working order. | The process controller must ensure that the chlorine dosing room is kept clean and that correct PPE is available and in working order. |
| 13 | Are the chlorine cylinders correctly stored? | Chlorine gas is hazardous and hence it is important to ensure that the gas bottles are correctly stored to ensure that no gas leaks occur. | The process controller must ensure that the gas bottles are correctly stored and must check for gas leaks on a regular basis or as required. The process controller must report any leaks to the supervisor. |

| | | Notes | Possible Actions |
|---|---|---|---|
| 14 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns.<br><br>The process controller must report and record the dates on which the malfunction was recorded and attended to. |
| 15 | Are all malfunctions recorded and reported? | | |
| **ENVIRONMENTAL and SAFETY ISSUES** | | | |
| 16 | Is correct PPE worn? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required | Ensure that PPE is available on site and is correctly worn. |
| 17 | Is correct safety signage visible and clear? | Safety signage must be visible on the outside of the chlorine room. A cabinet with a gas mask should be fitted to the outside of the room. | The process controller must report the lack of or damaged signage or safety equipment to the supervisor and the supervisor must ensure that it is replaced. A record should b kept of when it is reported and attended to. |
| 18 | Is correct safety equipment easily accessible? | | |
| **3.4.7 SLUDGE TREATMENT** | | | |
| **SLUDGE DRYING BEDS** | | | |
| 1 | Are drying beds in working order? | The splash slab must be kept in place to ensure that the filter medium is not disturbed.<br><br>The sludge should be wasted to the drying beds to a depth of 300 mm. Once the sludge has dried out it must be removed to make space for more sludge. If the dried sludge gets wet again there may be no more space to waste to. | The process controller must monitor the drying beds to ensure that:<br>the splash slab remains in place<br>they are not filled to the brim.<br><br>The process controller must monitor the sludge to ensure that dried sludge is removed timeously. |
| 2 | Is the sludge level in drying beds maintained at a suitable depth? | | |
| 3 | Are the underdrains free of debris? | The underdrains need to be kept free of debris and if the drying beds are working well the underflow will be clear. | The process controller must monitor the underdrains and tunderflow on a daily basis. Should the flow be coloured or should there be no flow, the process controller needs to report the problem to the supervisor. |
| 4 | Is the flow from the underdrains clear? | | |
| **SLUDGE LAGOONS** | | | |
| 5 | Is the sludge level in the lagoons maintained at a suitable depth? | The sludge lagoons must not be overfilled. As one lagoon is filled it must be taken out of operation until the sludge has dried and can be removed for disposal. | The process controller must monitor the depth of the sludge as sludge is wasted and report to the supervisor if the lagoon becomes too full. |
| 6 | Are the clear water return valves in working order? | The sludge must be allowed settle and then the clear water on the top can be decanted and returned to the process. The clear water return valves must therefore be in working order. | The process controller must monitor the settling of the sludge in the lagoons and open the valves as required to decant clear water. |
| 7 | Is the sludge allowed adequate time to settle before decanting the supernatant? | | |

| | | Notes | Possible Actions |
|---|---|---|---|
| 8 | Is the supernatant clear? | | |
| **MAINTENANCE** | | | |
| 9 | Is there good housekeeping around the beds/lagoons? | For health, safety and aesthetic reasons sludge and any other debris/litter must not be allowed to collect on the outsides of the drying beds or lagoons.<br><br>A wheelbarrow and spade should be on hand to remove any dried sludge. | The process controller must maintain the area around the sludge drying beds/lagoons and dispose of any dried sludge responsibly.<br><br>The process controller must request a wheelbarrow and spade should they not be available. |
| 10 | Are a spade and wheelbarrow on hand to remove dried sludge? | | |
| 11 | Are suitably qualified mechanics and artisans available if maintenance is required? | Suitably qualified mechanics and artisans should always be available – they do not have to be on site but should be available to report to the WTW within a reasonable timeframe. | Ensure that a maintenance person is on hand within a reasonable timeframe to deal with any breakdowns.<br><br>The process controller must report and record the dates on which the malfunction was recorded and attended to. |
| 12 | Are all malfunctions recorded and reported? | | |
| **ENVIRONMENTAL and SAFETY ISSUES** | | | |
| 13 | Is correct PPE worn? | To comply with the OHSA PPE: overalls, safety shoes, hard hat, gloves should be worn as required.<br><br>Relevant safety signage should be clearly displayed. | The supervisor must ensure that PPE is available on site and is correctly worn. The supervisor must also ensure that relevant safety signage is procured and put up. |
| 14 | Is correct safety signage visible? | | |
| 15 | Is dried sludge correctly disposed of? | Dried sludge must be collected and responsibly disposed of or re-used. | The process controller must monitor the sludge disposal and report any concerns to the supervisor. |

# Guidelines for the Sustainable Operation and Maintenance of Small Water Treatment Plants

## SECTION 4: APPENDICES

## CONTENTS OF SECTION 4

## 4.1 UNITS OF MEASUREMENT

### 4.1.1 Introduction

Only the SI units of importance to a water treatment plant operator are dealt with in this section. It is important that the SI units are used correctly. One of the aims of introducing the SI is to achieve the goal that all fields of activity should use the same units for the same physical quantity. To achieve this ideal of introducing the universal language of measurement requires a certain amount of sacrifice in some specialised fields. We will sometimes have to give up a unit that has proved itself through years of application, and to replace it with a new unit that may be unfamiliar at first. In the long run, the sacrifice is, however, worthwhile. It is of the utmost importance that only one system be used in order to standardise and thus avoid misunderstandings.

### 4.1.2 The SI system (Systeme International d'Units)

**a. Building blocks of the SI**

For each physical quantity there is one and only one SI unit. These are given in Table 20.

**Table 20:** The most important base SI units

| Quantity | Name | Symbol |
|---|---|---|
| Length | Metre | m |
| Mass | Kilogram | kg |
| Time | Second | s |
| Electric current | Ampere | A |
| Thermodynamic temperature | Kelvin | K |

Note that these are called, base units, and not basic units – they are base units in that the whole structure of the SI is built from them.

**b. Derived SI units**

Derived units consist mainly of the following:

- Derived SI units formed by multiplying and dividing SI units in accordance with the definitions of the quantities, expressed in terms of SI base units and supplementary units.
- SI units with special names

**c. SI: Derived in terms of SI base units and supplementary units**

Examples of these units are given in Table 21.

**Table 21:** Derived SI units

| Quantity | Name | Symbol |
|---|---|---|
| Area | Square metre | $m^2$ |
| Volume | Cubic metre | $m^3$ |
| Speed, velocity | Metre per second | m/s |
| Density | Kilogram per cubic metre | $kg/m^2$ |

## d. Derived SI units with special names

**Table 22:** Derived SI units with special names

| Quantity | Name | Symbol |
|---|---|---|
| Force, weight | Newton | N |
| Energy, work | Joule | J |
| Quantity of heat | Joule | J |
| Pressure, stress | Pascal | Pa |
| Power | Watt | W |
| Electrical potential | Volt | V |
| Electromotive force | Volt | V |
| Electrical conductance | Siemens | S |

## e. Preferred SI prefixes

In the same way as making use of a symbol for SI units, symbols are also used for international prefixes. Examples are given in Table 23.

**Table 23:** Preferred SI prefixes

| Prefix Meaning | Name | Symbol |
|---|---|---|
| Mega – million | $10^{6}$ | M |
| Kilo – thousand | $10^{3}$ | k |
| Milli – thousandth | $10^{-3}$ | m |
| Micro – millionth | $10^{-6}$ | µ |

## f. Other units

There are also certain other units, which are not SI units, but which are accepted (Table 24).

**Table 24:** Other acceptable units

| Quantity | Name | Symbol |
|---|---|---|
| Time | minute | min |
| Time | hour | h |
| Time | day | d |
| Mass | metric ton | t |
| Volume | litre | ℓ |
| Speed | kilometre per hour | km/h |
| Area | hectare | ha |
| Temperature | degrees Celsius | ºC |
| Rotation frequency | revolution per minute | r/min |

## 4.2 BASIC CALCULATIONS

### 4.2.1 Importance of calculators

Any operator working at a sewage – or water purification – plant must be able to make basic calculations. They must be able to multiply, divide, subtract and add. This ability is essential in an operator’s normal duties, for example:

a. Keeping records of flow.
b. Determining the amount of flocculant to be added to water to be treated.
c. Cost calculations.
d. Water loss calculations.

### 4.2.2 General tips in calculating

Make use of the following steps:

a. write down what is given (if necessary, draw a simple sketch)

b. write down what is asked

c. write down the correct formula, and substitute the given values in the formula (using the same units)

d. do a rough calculation

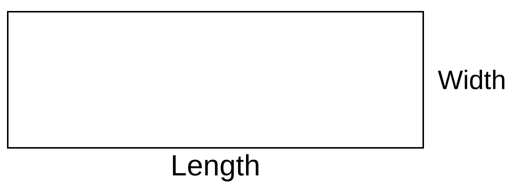
e. do the actual calculation

f. compare the answer in (e) with (d)

g. if the answers differ much, check the calculation for errors

### 4.2.3 Calculation of an area

**a. Rectangle**



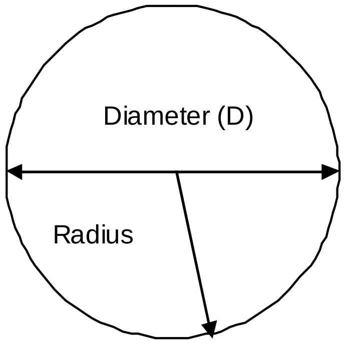

Area (A) = length $\times$ width

<u>Example</u>: A rectangular tank has a length of 2.0 m and is 1 800 mm wide. Calculate the surface area of the tank. (Make use of the general tips.)

Length = 2.0 m
Width = 1 800 mm = 1.8 m

Area = $L \times W = 2.0\ m \times 1.8\ m = 2\ m \times$ about $2\ m =$ about $4\ m^2$ (rough)
Area = $2.0\ m \times 1.8\ m = 3.60\ m^2$

**b. Circle**




In the calculation of the area of a circle, one of the two formulae may be used:

$$\text{Area} = \pi r^2 \text{ or } \pi \frac{D^2}{4}$$

r = radius
D = diameter

$$\pi = \frac{\text{circumference}}{\text{diameter}} = \frac{22}{7} = 3.14$$

Example: calculate the area of a circle with a diameter of 8.4 m

$$\text{Area} = \pi r^2 = \frac{22}{7} \times 4.2\text{ m } 4.2\text{ m} = 55.44\text{ m}^2$$

or

$$\text{Area} = \pi \frac{D^2}{4} = \frac{22}{7} \times \frac{8.4\text{ m x } 8.4\text{ m}}{4} = 55.44\text{ m}^2$$

**4.2.4 Calculation of volume**

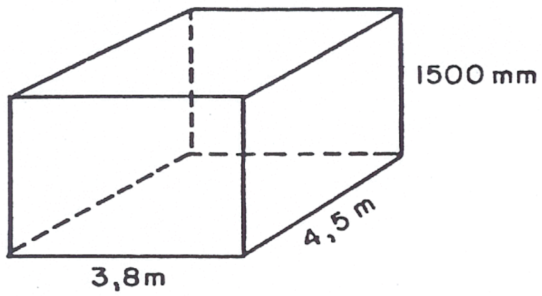
The volume of any container is equal to the area multiplied by the depth or height.

Volume = area x× depth (height)
= A x H

**a. Rectangular tank**

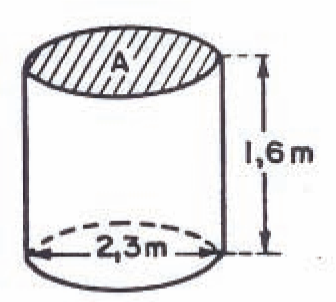
Example: calculate the volume of the following rectangular tank:

Length = 4.5 m
Width = 3.8 m width and
Height (or depth) = 1 500 mm depth




Area (A) = L × W = 4.5 m × 3.8 m = 17.1 m²
Volume (V) = A × H = 17.1 m² × 1.5 m = 25.65 m³

**b. Cylinder**




Example: calculate the volume of a cylindrical tank with a diameter of 2.3 m and a depth of 1.6 m

Area of base (A) = $\pi r^2$ or $\pi \frac{D^2}{4}$

= $3.14 \times 1.15 \times 1.15$ or $3.14 \times \frac{2.3 \times 2.3}{4}$

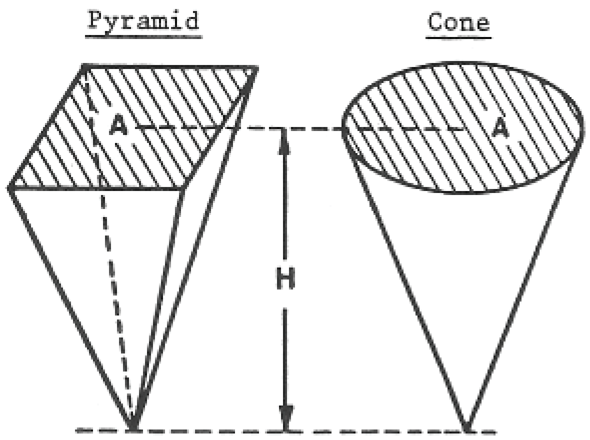
= $4.153\ m^2$

Volume (V) = $A \times H$

= $4.153\ m^2 \times 1.6\ m$

= $6.645\ m^3$

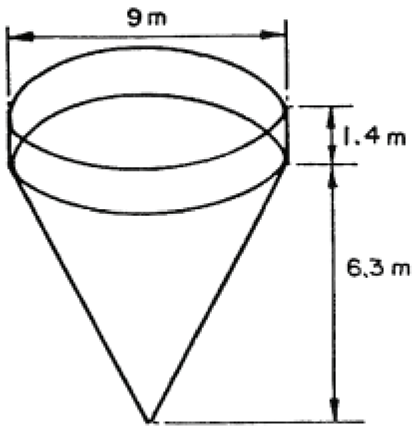
**c. Pyramids and cones**




Volume (V) = 1/3 Area of base A × Vertical height H

**d. Dortmund sedimentation tank**

Example: what is the volume of the following Dortmund sedimentation tank?




From the schematic drawing it may be seen that the tank consists of the following components:

(a) A cylinder 1.4 m high and with a diameter of 9 m, standing on a cone

(b) A cone with the same base area as the cylinder, and a depth of height of 6.3 m

Total volume = volume (a) + volume (b)

$$= \left(3.14 \times \frac{9x9}{4} \times 1.4\right) m^3 + \left(3.14 \times \frac{9x9}{4} \times \frac{6.3}{3}\right) m^3$$

$= 89.1\ m^3 + 133.65\ m^3$

$= 222.75\ m^3$

= approximately 223 $m^3$

### 4.2.5 Different units of volume measurement

According to the SI units, the base unit of length is the metre. The correct volume is thus m x m x m = $m^3$ (cubic meter). In certain instances a cubic metre may be too large to serve as volumetric measure, while in other cases it may be too small.

**a. Small volumes**

For most small volumes, a measurement of 1 $mm^3$ is too small, but 1$cm^3$ (1 ml), 1 $dm^3$ (1l) are all accepted.

**b. Large volumes**

1 000 L = 1 kl = 1 $m^3$
1 000 000 L = 1 mL
*or* 1 000 $m^3$ = 1 mL

The flow velocity of a river is measured in cumec ($m^3$/s)

### 4.2.6 Graphs

The use of graphs is of great value in water and sewage treatment and you should be able to plot and interpret graphs. Two different sets of figures or data are required to draw a graph.

***Example: Flow recorder***

A certain volume of water is treated at a water or sewage purification works. The volume may differ from year to year, month to month, day to day, hour to hour, etc. Most of the flow meters supplied at a works are of the recording type, with graphs which may last a week or a month. It is important when changing the graph paper of a flow meter to:

(a) set the graph according to the correct time and write in the date,
(b) clean the pen and fill the pen regularly with the correct ink

A graph has two axes. One is vertical and the other horizontal. The vertical axis will represent flow ($m^3$ or L/s) and the horizontal axis, time (minutes, hours and days). Ordinary graph paper is used in Figure 13 to illustrate water consumption from information as given in Table 25.

**Table 25:** Daily flow: 01-09-2005 to 10-09-2005

| **Date** | **Total flow (m³)** |
|---|---|
| 01-09-2005 | 2100 |
| 03-09-2005 | 3800 |
| 05-09-2005 | 2800 |
| 07-09-2005 | 4200 |
| 09-09-2005 | 1000 |
| 02-09-2005 | 3500 |
| 04-09-2005 | 4600 |
| 06-09-2005 | 1500 |
| 08-09-2005 | 3600 |
| 10-09-2005 | 3300 |

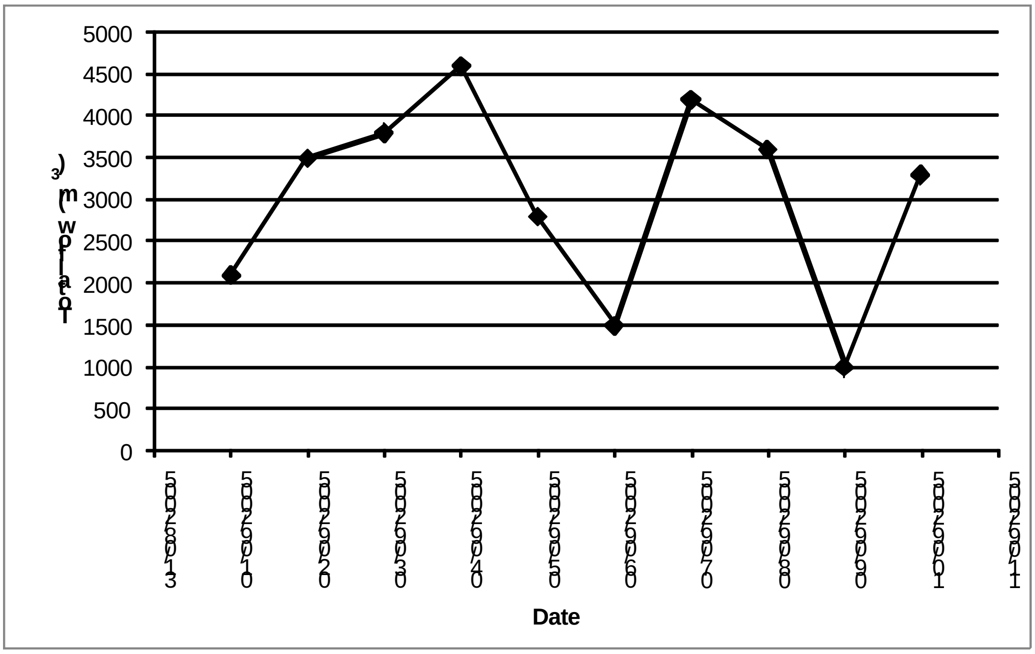



**Figure 13:** Water consumption data shown in Table 25 plotted as a graph.

Once one understands how to interpret a graph, he may use this principle to illustrate a variety of important information, e.g. monthly and yearly consumption, variations of quality of water, etc. More guidance is however needed from the lecturer.

Examples of flow sheets are shown in Figures 25 and 26.

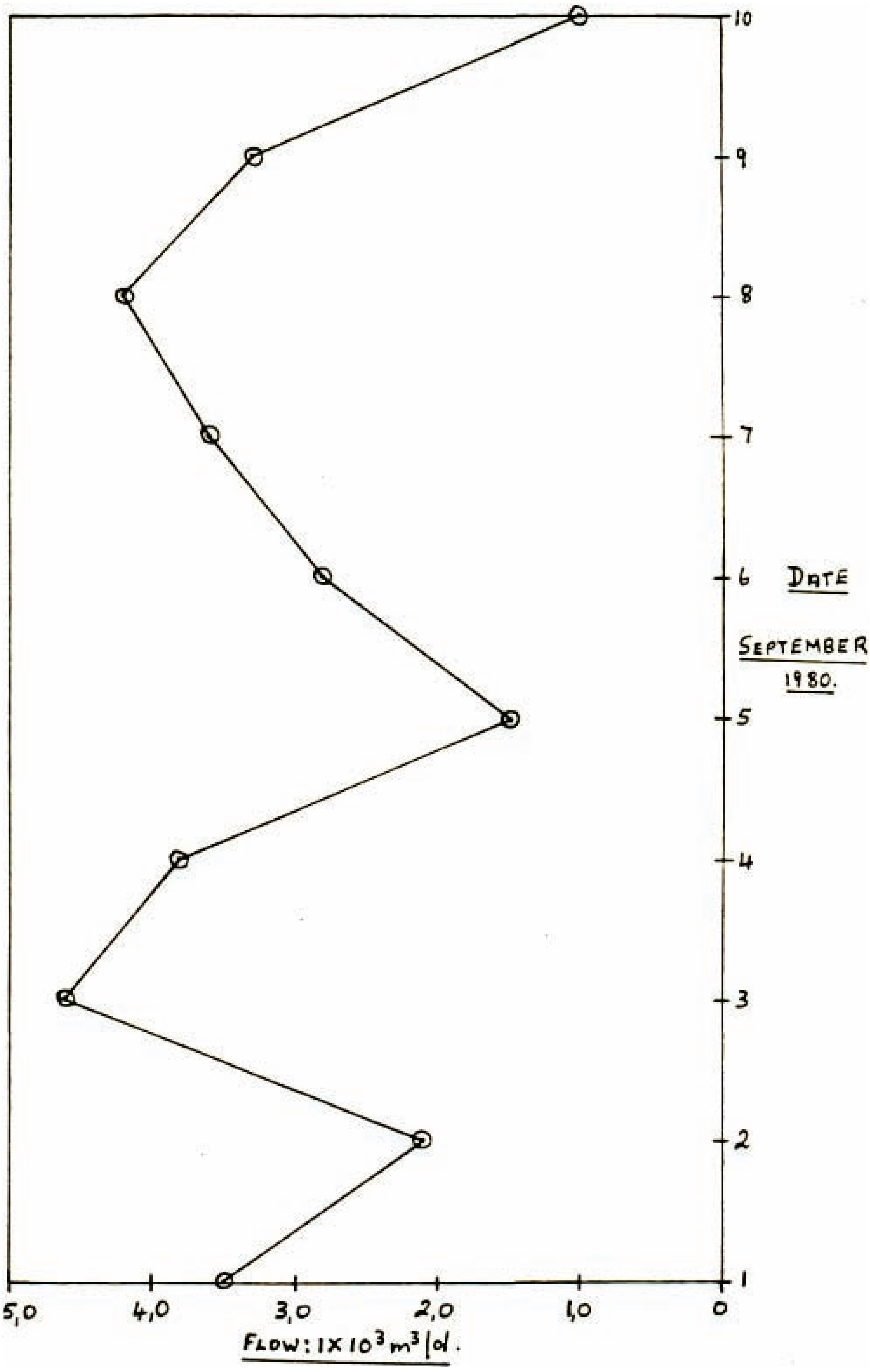



**Figure 14:** Daily water consumption flow sheet

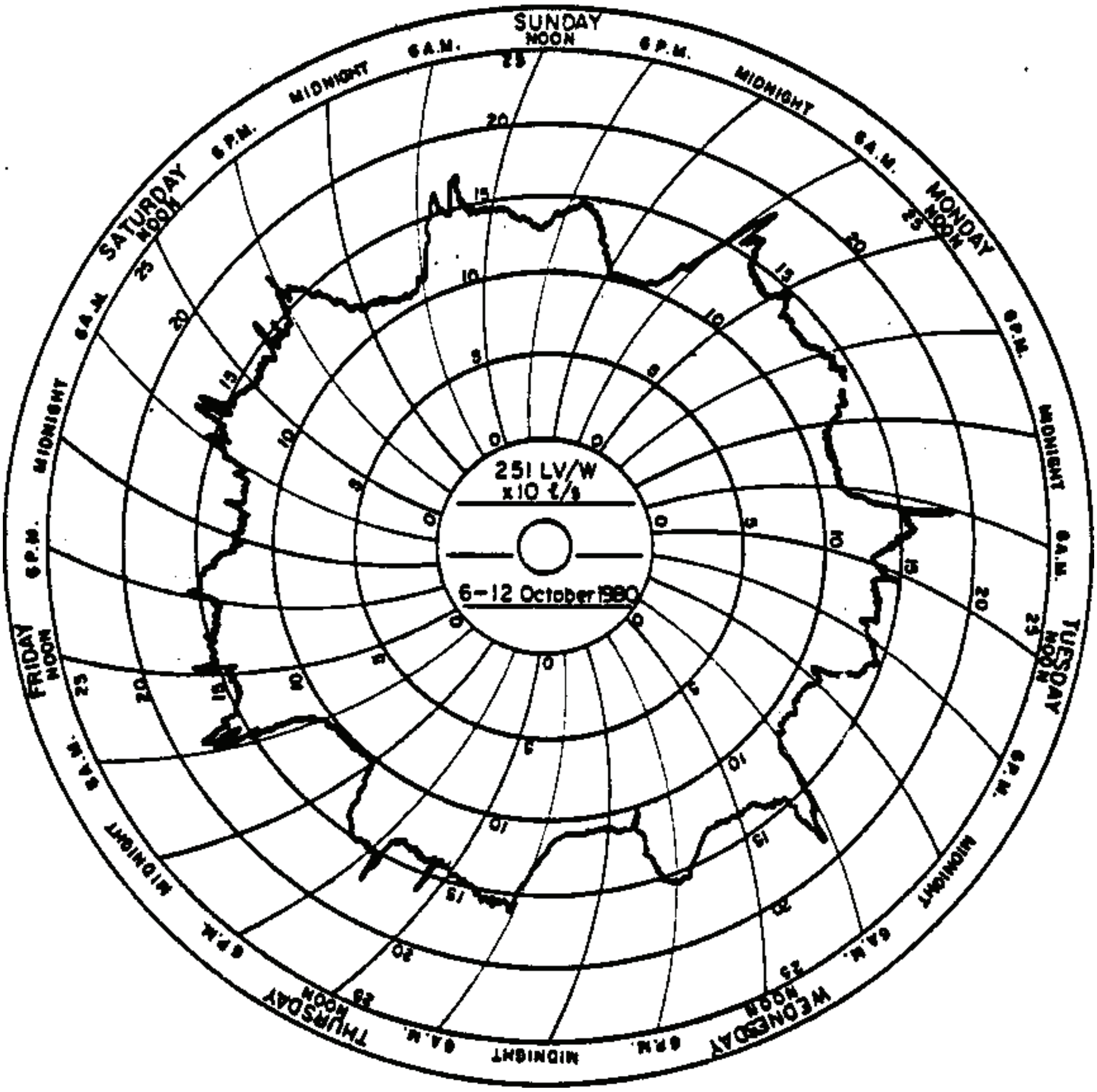



**Figure 15:** Disc flow sheet

### 4.2.7 Concentrations of solutions

In the treatment of water, concentrations of solutions are usually expressed in mg/L, the same as milligrams per cubic decimetre ($mg/dm^3$).

#### a. Percentage

Concentrations in % merely mean "parts per hundred". It must, however, be borne in mind that percentage can be expressed as mass per volume (m/v), mass per mass (m/m) or volume per volume (v/v), e.g. 5 g aluminium sulphate dissolved in water and diluted to 100 ml is a 5% (m/v) solution; 20 g lime mixed with 80 g sand is a 20% (m/m) mixture of lime; 15 ml alcohol diluted to 100 ml is a 15% (v/v) solution.

When the relative density of the solution is very near to 1.0 then it is permissible to take the % (m/v) as equivalent to the % (m/m) and when the relative density of both the substance and the solvent are very near to 1.0 the % expressed as m/v, m/m or v/v can all be taken as equivalent. To convert the % m/v to m/m, the relative density of the solution must be taken into account.

Example: A commercial ferric chloride solution has a relative density of 1.45 and the concentration is 43% (m/m). This means that 43 g of the solid is contained in

$\frac{100}{1.45}$ mL solution, therefore the % (m/v) is

$43 \times 1.45 = 62.4\%$

If a solution of 5% ferric chloride (m/v) is to be prepared from the commercial solution, one of the following methods can be used:

(a) The commercial solution contains :

62.4 g ferric chloride in 100 mL

i.e. 5 g ferric chloride in $100 \times 5 / 62.4$ mL = 8.0 mL

Therefore 8.0 mL is to be measured out and diluted to 100 mL with water.

(b) The commercial solution contains:

43 g ferric chloride in 100 g solution

i.e. 5 g ferric chloride in 100x5 / 43 g solutions = 11.6 g

Therefore 11.6 g of the commercial solution is to be weighed out and diluted to 100 mL. As the ferric chloride solution is very corrosive, it can damage the balance when weighed and should rather be measured by volume.

Therefore 11.6 / 1.45 mL (=8.0 mL) is to be measured out and diluted to 100 mL.

**b. Milligrams per litre**

Lower concentrations are conveniently expressed in mg/L, which is the same as ppm or g/kL or g/m³ and kg/mL. A 1% (m/v) solution is equivalent to 10 g/L or 10 000 mg/L.

## 4.3 ELEMENTARY HYDRAULICS

### 4.3.1 Properties of water

The main properties of water with respect to hydraulics are as follows:

(a) It cannot be compressed.

(c) Water has a low coefficient of expansion.

(d) The density of water is greatest at about 4 °C.
Density = 1 000 kg/m³ = 1.0 kg/£ (4 °C)
Relative Density = 1.0

**a. Flow velocity (v)**

Flow velocity of water is the distance covered during a given time.

| | | | | |
|---|---|---|---|---|
| Velocity | = | distance | = | m = m/s (also written as m.s-1) |
| | | time | = | s |

The velocity of flow from a free falling column of water can also be given:

$V = \sqrt{2gH}$ m/s

g = gravitational force
H = static head of the water column

**b. Flow rate (Q)**

The flow rate of water is the volume of water which flows per unit time.

SI units: Volume = m³

Time = s

$$Q = \frac{\text{Volume}}{\text{time}}$$

$= m^3/s$

Velocity is given in m/s. To calculate the volume, this must be multiplied by the cross sectional area (A)

Thus $Q = A \sqrt{2gH}\ m^3/s$

This formula is of importance because most measurements of water flow are based on this formula. Friction in pipelines or channels will however influence the velocity of flow and must therefore be taken into account. Friction losses are indicated by the factor “C”, and the formula becomes:

$$Q = C A \sqrt{2gH}\ m^3/s$$

Friction losses (C) will vary and depend on the type of pipe, obstructions, nature of internal surface of the pipe, etc. These factors can be obtained from tables given by the suppliers of pipes.

<u>Example</u>: A sludge draw off pipe with a diameter of 200 mm is drawing sludge from the bottom of a 4 m deep sedimentation tank by means of a valve. Calculate the volume of sludge which can be removed per second from the tank, given that the friction loss factor due to the valve and pipe is 0.6.

| | | |
|---|---|---|
| Q | = | $C A \sqrt{2gH}$ |
| C | = | 0.6 |
| A | = | area of the pipe |
| | = | $\pi D^2/4$ |
| | = | $\frac{3.14 \times 0.2 \times 0.2\ m^2}{4}$ |
| | = | $0.031\ m^2$ |
| g | = | 10 m/s |
| H | = | 4 m |
| Q | = | $0.6 \times 0.031 \times \sqrt{(2x10x4)} m^3/s$ |
| | = | $0.0186 \times \sqrt{80}\ m^3/s$ |
| | = | $0.0186 \times 8.95\ m^3/s$ |
| | = | $0.166\ m^3/s$ |
| | = | 166 l/s |

c. **Hydrostatic Pressure**

The pressure exercised by a liquid is determined by the height and mass of liquid above a certain point.

(a) Water with a depth of height of 1 m will exercise a pressure of about 10 kPa at the bottom.

(b) Water with a depth or height of 2 m will exercise a pressure of about 20 kPa at the bottom.

(c) The shape of the container or dam does not play any role on the pressure exercised at the bottom as shown in Figure 16. The pressure exercised in each case is about 20 kPa at the bottom of the vessel.

(d) The pressure (kPa) exercised at the bottom of any container, dam, sedimentation tank, sand filter, or a reservoir connected to a pipe line (as shown in Figure 4.9), is called the hydrostatic pressure.

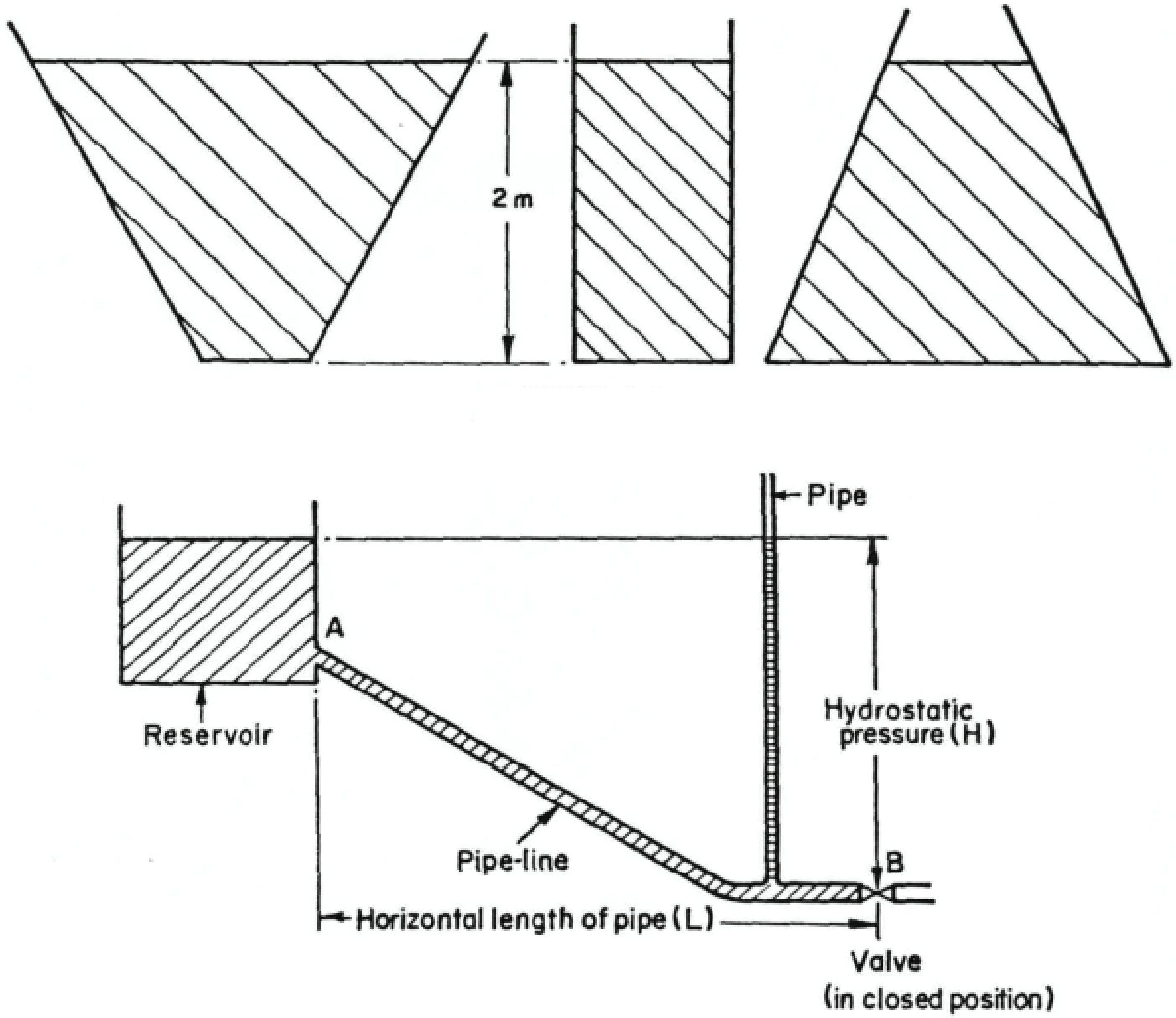



**Figure 16:** Hydrostatic Pressure

### 4.3.2 Flow in pipes

When the valve is opened at the end of a pipe line (Figure 4.9), the volume of water obtained at this point will depend on the following factors:

(a) the hydraulic gradient

(b) the hydraulic radius of water in the pipe

(c) other factors such as the roughness of the pip, bends, valves and other obstructions.

#### a. Hydraulic gradient

The hydraulic gradient is the ratio between the available head (hydrostatic pressure) and the horizontal length of the pipeline as shown in Figure 4.9.

Hydraulic gradient = available head (in m)
length of pipe line (in m)

In a sewage pipe line, to create the "self cleansing velocity" in the pipeline and to ensure a velocity of about 1 m/s, a hydraulic gradient of 1:40 or 2.5% is needed. This means that a head of 1 m is needed for every 40 m length of pipeline.

If water is to be pumped from a lower to a higher level, against a big hydrostatic head from point B to A (Figure 4.9), the pressure at point B will be highest and gradually decrease to point A. The pipe used near point B should therefore be resistant to a high pressure, near the middle to a lower pressure and near the end of the line to the lowest pressure.

When a burst in such a pipeline occurs, it must be ascertained that the replacement pipe is of the correct class.

#### b. Hydraulic radius

The hydraulic radius of the pipe is the "wetted area" in the pipeline i.e., dependant on whether the pipe is flowing full or only partially full.

#### c. Other factors

Other factors such as the roughness of the inner surface of the pipe, bends, valves and other obstructions also influence the flow of water in pipes. The roughness of the inner surface of a new pipeline will gradually deteriorate with time and therefore the volume of water delivered will also gradually decrease.

#### d. Siphon

Water can be siphoned out of a container by means of a pipe as shown in Figure 4.10.

When suction is applied at point A of the pipe, the pressure that is due to the atmosphere, called atmospheric pressure, forces the water up the pipe. The maximum height which can be reached is equivalent to the atmospheric pressure. At sea level it is about 10 m. Inland it will decrease due to the lower atmospheric pressure which is about 1 m less for each 1 000 m above sea level.

1 Atmosphere = 1 bar = 100 kPa = 10 m water pressure.

Centrifugal pumps lift water by generating a partial vacuum, which permits the atmospheric pressure to force the water up the suction pipe. The theoretical suction lift is therefore equal to the atmospheric pressure head – about 10 m at sea level. This theoretical maximum lift cannot be obtained in practice because the pumps cannot produce a perfect vacuum and because of friction losses (roughness of sides of pipeline, bends, valves, etc.) and the temperature of the water. At 100 °C (boiling point of water), the vapour pressure is equal to atmospheric pressure and a suction lift is impossible.

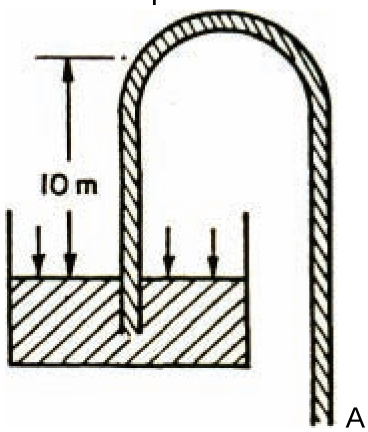



**Figure 17:** Siphon

## e. Flow Measurement

There are various means to measure the flow rate of water. The principles involved are given under 3 and 4. It is, however, very important to know and record the flow rate at any sewage or water purification works. The proper maintenance and care of any flow meter or recorder is therefore of great importance and an operator should know how to maintain such an instrument (cleaning, replacing ink, etc.).

## 4.4 INFORMATION ON NATIONAL TRAINING COURSES

| | |
|---|---|
| **Centre for Environmental Management (NWU)** | CEM-01.1: Introduction to Sustainable Environmental Management – An Overview of Principles, Tools and Issues<br>CEM-02.1: Environmental Law for Environmental Managers<br>CEM-02.4: Environmental Law Update<br>CEM-02.5: Legal Framework for Managing Water in South Africa<br>CEM-02.6: Legal Framework for Integrated Waste Management in South Africa<br>CEM-03.1: Implementing Environmental Management Systems (SANS/ISO 14001) SAATCA Registered<br>CEM-04.1.1: Environmental Management System SANS/ISO 14001:2004 Audit: A Lead Auditor Course based on SANS/ISO 19011:2002 *Prerequisite: Env. Law (CEM-02.1) & EMS (CEM-03.1) (SANS/ISO 14001) Courses* SAATCA Registered<br>CEM-03.6: Transition Workshop ISO 14001:1996 to ISO 14001:2004 Environmental Management Systems<br>CEM-04.2.1: Occupational Health and Safety Management System OHSAS 18001:1999 Audit: A Lead Auditor Course based on SANS/ISO 19011:2003 SAATCA Registered<br>CEM-05.1: Environmental Impact Assessment: The NEMA Regulations: A Practical Approach<br>CEM-05.2: Environmental Risk Assessment and Management<br>CEM-05.3: Social and Heritage Impact Assessment<br>CEM-06.1.1: Handling, Storage and Transportation of Dangerous Goods<br>CEM-06.2.1: Introduction to Integrated Waste Management for Environmental Managers<br>CEM-06.4.1: Introduction to Integrated Water Resource Management for Environmental Managers<br>CEM-06.4.2: Geohydrological Principles and Tools for Environmental Managers<br>CEM-06.4.3: Water Quality Monitoring: Principles, Approaches and Techniques<br>CEM-06.5.1: Sustainable Remediation and Mine Closure<br>CEM-07.1: Implementing Integrated Management Systems: ISO 9001, ISO 14001 and OHSAS 18001<br>CEM-08.1.1: Occupational Health and Safety Law for Managers<br>CEM-08.2.1: Implementing Occupational Health and Safety Management Systems Based on OHSAS 18001 SAATCA Registered |
| **Rhodes University** | Introduction to Managing Environmental Water Quality<br>Management Development Programme<br>Certificate Course in Strategic Management<br>Certificate Course in Human Resources Management |
| **University of Pretoria** | Environmental Management<br>Waste Management<br>Air Quality Management<br>Environmental Management<br>Industrial Waste Management<br>Membrane processes<br>WQM and effluent treatment<br>Operation of water and wastewater treatment plants |

| | |
|---|---|
| **Tshwane University of Technology** | Basic Chemical Analysis Of Water<br>Chemical Analysis Of Potable Water<br>Chemical Analysis Of Wastewater And Industrial Effluents<br>Water Quality Management In The New Millennium – Quo Vadis<br>Optimisation Of Potable Water Purification Plants<br>Operation Of Activated Sludge Plants<br>ND Water Care<br>BTech Water Care<br>MTech Water Care<br>DTech Water Care |
| **Water Academy** | The Theory and Operation of the Activated Sludge Process (Based on Unit Standard WW11)<br>Basic Numeracy in the Water Industry<br>Measure, estimate and calculate physical quantities and explore, describe and represent geometrical relationships in 2-dimensions in different life or workplace contexts (MathLith4003)<br>The Basic Theory and Operation of Mechanical and Electrical Systems (Based on Unit Standard WW30)<br>An Introduction to the Principles of Hydraulics in the Water Industry<br>Supervise Personal Safety Practices on a Waste Water Treatment<br>Supervise Work Unit to Achieve Work Unit Objectives (individuals and teams) (HRMP AD4/002)<br>National Certificate in Waste Water Process Operator or Related Skills Programmes (Learnerships)<br>National Certificate in Water Process Operator or Related Skills Programmes (Learnerships)<br>National Certificate in Waste Water Reticulation or Related Skills Programmes (Learnerships)<br>Demonstrate an Understanding of the Principles of Quality Awareness, Management and how to set up a Quality Management System<br>Demonstrate an understanding of the Principles of Environmental Management and how to set up an Environmental Management System<br>Demonstrate an understanding of the methodology of evaluating data including Laboratory, Sampling, Water Loss<br>The Q-MAP System – An Integrated Quality, Performance, Knowledge and Process Management System, Audited by ISO 9001/2000. This system has been developed specifically for the Water Industry and will enable water, sanitation and related services to provide cost effective, sustainable and quality services.<br>Environment Management System<br>Laboratory Management System<br>Water Demand and Water Loss Management<br><br>“The Work" is a revolutionary process based on the methods of international trainer and authoress Byron Katie. Doing "The Work" leads to profound changes in the workplace and deals with issues such as blame, "why should I" etc.<br>Manage and Enhance Performance – Thinking Skills, Lateral Thinking, Participative Management, Project Management, Quality Management, Performance Management, Personal and Team Motivation |

| | |
|---|---|
| | Advanced management development program for the water and waste water sector<br>Awareness creation of the implications of water and sanitation on community health<br>BSc degree in community water services and sanitation<br>Building capacity for mainstreaming gender in water supply and sanitation in South Africa (GEMSA)<br>Capacity Building and Training Programme for North West, Free State, Northern Cape and Mpumalanga District Municipalities<br>Danida: Pilot project for competency based training of water and wastewater operators in the North West Province<br>Gender awareness raising in South Africa<br>Increasing the level of competency within Bushbuckridge water board<br>Increasing the level of competency within the local councils within the area of jurisdiction of the Eastvaal district council: bulk water and sanitation<br>Intensive in-service training program for sustainability in water and sanitation in the Northern Province Phase 1 Extension<br>Intensive in-service training program for sustainability in water and sanitation in the Northern Province Phase 2 and field support programme<br>Management of water supply and wastewater systems<br>Short term training course in sanitation for the Northwest Provincial Sanitation Coordinating Committee |
| **ESETA service providers** | Further Education and Training Certificate: Sanitation Project Facilitation<br><br>Further Education and Training Certificate: Supervision of Wastewater Reticulation Operations<br><br>Further Education and Training Certificate: Water Purification Processes<br><br>General Education and Training Certificate: Water Services<br><br>National Certificate: Community Water, Health and Sanitation Promotion<br><br>National Certificate: Community Water, Sanitation and Health Facilitation<br><br>National Certificate: Sanitation Project Co-ordination<br><br>National Certificate: Supervision of Water Reticulation Operations<br><br>National Certificate: Wastewater Process Control<br><br>National Certificate: Wastewater Process Operations<br><br>National Certificate: Wastewater Reticulation Services<br><br>National Certificate: Wastewater Reticulation Services<br><br>National Certificate: Water Reticulation Services |

## 4.5 EXCERPTS FROM RELEVANT LEGISLATION

### 4.5.1 Draft Regulations for the Registration of Waterworks and Process Controllers

The Minister of Water Affairs and Forestry under section 26(c), (e) and (f) of the National Water Act, 1998 (Act No. 36 of 1998), intends to make the regulations in the Schedule.

Interested parties are invited to submit written comments on the proposed regulations to the Director-General of Water Affairs and Forestry, Private Bag X 313, Pretoria 0001; Fax: (012) 323 0321; email: boydla@dwaf.gov.za (for the attention of Ms L Boyd) 60 days after the gazetted date.

**SCHEDULE**

***Definitions***

In these regulations any word or expression to which a meaning has been assigned in the Act, shall have the meaning so assigned and, unless the context indicates otherwise-

“National Qualifications Framework” means a flexible and integrated education and training system, which promotes a process of life-long learning through planned career paths;

“process controller” means a natural person employed at a waterworks, which has achieved relevant competencies to effectively operate a unit process at the work or a person authorised to design, construct, install, operate or maintain any waterworks;

“the Act” means the National Water Act, 1998 (Act No. 36 of 1998)

***Application for registration***

The owner of a waterworks in operation at the date of commencement of these regulations must apply within 30 days of such date for registration of -

(a) the waterworks; and
(b) every process controller on that waterworks.

The owner of a waterworks to be put into operation after the date of commencement of these regulations must apply for registration of the waterworks as prescribed by sub-regulation (3), before it is commissioned.

Application forms for registration for purposes of these regulations are obtainable from the Department and must be directed to the responsible authority with information-

(a) in respect of the waterworks concerned, the particulars referred to in Schedule I or II, as the case may be; and
(b) in respect of each process controller employed or to be employed for the operation of the waterworks, the particulars referred to in Schedule III.

***Registration***

Upon receipt of the particulars contemplated in regulation 2, the responsible authority must-

(a) classify every waterworks in accordance with Schedule I or II, as the case may be; and
(b) classify each process controller employed or to be employed for the operation of the waterworks in accordance with Schedule III.
(c) issue a certificate of registration in respect of such waterworks and process controller.

The responsible authority must keep a register of particulars of every waterworks, including its location, in respect of which registration has been issued and every process controller registered in terms of these regulations; and

**Display a copy of the registration certificate for both the waterworks and process controller(s)**

The owner of a waterworks must display in a prominent place on that waterworks a copy of the registration certificate(s) issued under regulation 3.

**Employment of supervisory persons and process controllers**

The owner of a waterworks must, from the date of commencement of its registration under regulation 3, employ for the operation and control of a waterworks-

(a) a supervisory process controller;
(b) process controllers; and
as set out in Schedule IV.

An updated register of the required personnel for these functions must be kept by an owner of a waterworks and be available for inspection by the responsible authority at all times.

**Repeal of regulation**

The regulations published under Government Notice R. 2834 of 27 December 1985, are hereby repealed.

In terms of contravention or failure to comply with a regulation is an offence and any person found guilty of the offence is liable to a fine or to imprisonment for a period not exceeding 5 years.

## SCHEDULE I: REGISTRATION OF A WATERWORK USED FOR THE TAKING, TREATMENT AND STORAGE OF WATER AND DISPOSAL OF WASTE

## Rating

| **Class of works**<br>**Range of points** | **E**<br>**<30** | **D**<br>**30-49** | **C**<br>**50-69** | **B**<br>**70-90** | **A**<br>**>90** |
|---|---|---|---|---|---|

| Points to be awarded at the discretion of the Director-General in accordance with the following criteria: | | | Max |
|---|---|---|---|
| Population supplied | | Up to 5 000<br>5 001 to 50 000<br>50 001 to 250 000<br>> 250 000 | 1<br>2<br>3<br>4 |
| Infrastructure | Design Capacity in kilolitres per day (kℓ/d) | 0 to 500<br>501 to 2 500<br>2 501 to 7 500<br>7 501 to 25 000<br>>25 000<br>Actual volume:_____________kℓ/d | 2<br>4<br>6<br>8<br>10 |
| | Versus peak day | Design more than peak day use<br>Design = peak day use<br>Design < peak day use | 0<br>1<br>3 |
| | Final water storage capacity | >60 hours during peak<br>30-60 hours during peak<br><36 hours during peak | 0<br>1<br>2 |
| | Installed power (kilowatts of installed power to operate) | 0-5 kW<br>5-100 kW<br>101-1000 kW<br>>1000 kW | 1<br>3<br>5<br>10 |
| Operating Procedures | Raw water flow rate | No variation<br>Little variation (<5%)<br>Controlled variation with automatic adjustments<br>Uncontrolled variation with automatic adjustments<br>Controlled variation with manual adjustments.<br>Uncontrolled variation with manual adjustments | 0<br>1<br>2<br>3<br>4<br>5 |
| | Raw water quality | No adjustments needed in operating procedures<br>Seasonal adjustments needed in procedures<br>Monthly adjustments needed in procedures<br>Weekly adjustments needed in procedures<br>Daily adjustments needed in procedures<br>Hourly adjustments needed in procedures | 0<br>1<br>2<br>3<br>4<br>5 |
| | Chemical dosing | No chemicals added<br>Disinfection chemical<br>+1 flocculation chemical without pH control<br>+2 flocculation chemicals without pH control<br>+1 flocculation chemical with pH control<br>+2 flocculation chemicals with pH control | 0<br>2<br>4<br>6<br>8<br>10 |

| Class of works<br>Range of points | E<br><30 | D<br>30-49 | C<br>50-69 | B<br>70-90 | A<br>>90 |
|---|---|---|---|---|---|

| Points to be awarded at the discretion of the Director-General in accordance with the following criteria: | | | Max |
|---|---|---|---|
| Operating Processes | Desludging | Automatic desludging | 1 |
| | | Manual desludging | 2 |
| | | Automatic fixed schedule of desludging | 3 |
| | | Manual fixed schedule of desludging | 4 |
| | | Optimised desludging | 5 |
| | Filter Backwash | Automatic controlled by timer | 1 |
| | | Automatic controlled by pressure | 2 |
| | | Manual with fixed time schedule | 3 |
| | | Manual with fixed pressure schedule | 4 |
| | | Optimised filter backwash | 5 |
| | Settling Process | Uncontrolled process | 2 |
| | | Controlled process (sludge blanket | 5 |
| | Stabilisation | pH correction with automatic dosing | 1 |
| | | pH correction with manual dosing | 2 |
| | | pH correction according to Langelier/Razner index | 3 |
| | | pH correction according to Stasoft programme | 4 |
| | | Complete stabilisation with $CO_2$ | 5 |
| | | Uncontrolled with tablets | 1 |
| | Disinfection | Dosing with liquids or powder | 2 |
| | | Dosing with chlorine gas or ozone | 3 |
| | | Optimum chlorine gas or ozone dosing | 4 |
| | | Combination chlorine and ozone | 5 |
| | | Without any adjustments in procedure | 1 |
| | Recirculation | With automatic adjustments in procedure | 2 |
| | | With separate settling tanks | 3 |
| | | Controlled recirculation with adjustments | 4 |
| | | Uncontrolled recirculation with adjustments | 5 |
| | Sludge handling | Sludge lagoons | 3 |
| Control Processes | Water Losses | On works only | 2 |
| | Water Management | Different reservoirs | 2 |
| | | Different pressure zones | 4 |
| | Pumping | Gravitation only | 2 |
| | | Gravitation and pumping | 4 |
| | | Raw or final pumping | 4 |
| | | Raw, final and other pumping | 6 |
| | Level | Indicators | 2 |
| | | Telemetric | 4 |
| | Maintenance | None by operators | 0 |
| | | Basic maintenance by operators | 1 |
| | | Specialised maintenance by operators | 2 |
| | Lab services | Reading with instrumentation by operators | 2 |
| | | Full lab service on site but not done by operators, although still a management function.. | 3 |
| | | Chemical analyses done by operators | 4 |
| | | Jar tests to maintain optimum dosing by operators (more than 2x daily | 5 |
| | Administration | Record readings | 1 |
| | | Calculate daily flow and stock taking | 2 |
| | | Calculate dosing and generate reports | 4 |
| | | Work on computer (not just check screen | 5 |

| Class of works<br>Range of points | E<br><30 | D<br>30-49 | C<br>50-69 | B<br>70-90 | A<br>>90 |
|---|---|---|---|---|---|

| Points to be awarded at the discretion of the Director-General in accordance with the following criteria: | | | Max |
|---|---|---|---|
| Special Processes | Demineralisation<br>Fluoridation<br>Reverse Osmosis<br>Activated carbon<br>Softening | Mechanical – Air<br>Chemical | 2<br>1 –<br>5*<br>5<br>5<br>5<br>5 |

* need to motivate number of points claimed, e.g. combination of chemicals.

| EDUCATIONAL REQUIREMENTS | Years appropriate experience | | | | | | |
|---|---|---|---|---|---|---|---|
| | CLASS | | | | | | |
| **Existing qualifications prior to the NQF** | **Trainee** | **I** | **II** | **III** | **IV** | **V** | **VI** |
| ▪ Std. 6 | 0 | - | - | - | - | - | - |
| ▪ Std. 6 plus Maintenance Workers Certificate | 0 | 4 | - | - | - | - | - |
| ▪ Std. 7 plus Maintenance Workers Certificate | 0 | 3 | - | - | - | - | - |
| ▪ Std. 8 (or NTC I) plus Maintenance Workers Certificate<br>▪ Std. 8 (or NTC I) plus Water and Wastewater Treatment practice NI | 0 | 2 | 5 | - | - | - | - |
| ▪ NTC I in Water and Wastewater Treatment practice | 0 | 1.5 | 4 | - | - | - | - |
| ▪ Std. 8 (or NTC I) plus Operators certificate | 0 | 1 | 3 | 9 | - | - | - |
| ▪ Std. 9 (or NTC II) plus Operators certificate<br>▪ NTC II in Water and Wastewater Treatment practice | 0 | 0.5 | 2 | 7 | 15 | - | - |
| ▪ Matric (or NTC III) plus Operators certificate<br>▪ Matric (or NTC III) plus Water Treatment practice N3<br>▪ Matric (or NTC III) plus wastewater Treatment practice N3<br>▪ NTC III in Water Treatment practice<br>▪ NTC III in wastewater Treatment practice | | 0 | 0.5 | 3 | 8 | 15 | - |
| ▪ National Diploma or National Technical Diploma or NTC VI or 3 year BSc (all in appropriate field) | | | | 0 | 2 | 6 | - |
| ▪ Higher National Diploma or 4 year BSc (both in appropriate field) | | | | | 0 | 4 | 15 |
| ▪ Professional Engineer (Act 81 of 1968) in appropriate field; Natural Scientist (Act 55 of 1982) in appropriate field; Corporate member of IWPC (now WISA) | | | | | 0 | 3 | 12 |
| **National Qualifications Framework (NQF) qualifications** | | | | | | | |
| ▪ Unit standard on the water cycle from Certificate in Wastewater or Water Process Operations (NQF2) | 0 | - | - | - | - | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ▪ ****Skills programme equivalent to a value of at least 30 credits taken from: Certificate in Wastewater Process Operations (NQF2) Or**<br>▪ **National certificate in Water Purification Process Operations (NQF2) Or**<br>▪ **National certificate in Industrial Water Treatment Support Operations (NQF 2)**<br>▪ **General Education and Training Certificate in Water Services (NQF1) plus all core unit standards from the Certificate in Wastewater or Water Process Operations (NQF2) or industrial water treatment support operations (NQF2)**<br>▪ Grade 10 certificate with maths and science plus all core unit standards from the Certificate in Wastewater or Water Process Operations (NQF2) or industrial water treatment support operations (NQF2) | | 0 | 2 | - | - | - | - |
| ▪ **All fundamental and core subjects from:**<br>▪ **Certificate in Wastewater Process Operations (NQF2) or**<br>▪ **National Certificate in Water Purification Process Operations (NQF 2) or**<br>▪ **National Certificate in Industrial Water Treatment Support Operations (NQF 2)**<br>▪ Matric certificate with maths and science plus all core unit standards from Certificate in Wastewater Process Operations (NQF2) or National certificate in Water Purification Process Operations (NQF2) or National Certificate in Industrial Water Treatment Support Operations | | | 0 | 5 | - | - | - |
| ▪ **Certificate in Wastewater Process Operations (NQF2)**<br>▪ **National Certificate in Water Purification Process Operations (NQF2)**<br>▪ **National Certificate in Industrial Water Treatment Support Operations (NQF2) or all core subjects from National Certificate in Industrial Water Treatment Plant Operations (NQF3)**<br>▪ Matric certificate with science and maths plus all core and elective unit standards<br>▪ Certificate in Wastewater Process Operations (NQF2) or National Certificate in Water Purification Process Operations (NQF2) or National Certificate in Industrial Water Treatment Support Operations (NQF2) *or* all core subjects from National Certificate in Industrial Water Treatment Plant Operations (NQF3) | | | | 0 | 5 | - | - |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ▪ ****The full core unit standards from:**<br>**Certificate in Wastewater Process Control (NQF4) *<u>or</u>* Certificate in Water Purification Process Control (NQF4*) <u>or</u>* National Certificate in Industrial Water Treatment plant Operations (NQF4)**<br>▪ **Certificate in Wastewater Process Control (NQF4)**<br>▪ **Certificate in Water Purification Process Control (NQF4)**<br>▪ **National Certificate in Industrial Water Treatment Control Operations (NQF4)**<br>▪ **Matric with science and maths *<u>plus</u>* all core subjects from:**<br>Certificate in Wastewater Process Control (NQF4) *<u>or</u>* Certificate in Water Purification Process Control (NQF4) *<u>or</u>* National Certificate in Industrial Water Treatment Control Operations (NQF4) | | | | | 0 | 10 | 15 |
| ▪ *****All fundamental and core unit standards from:**<br>**Certificate in Wastewater Process Control (NQF4) *<u>or</u>* Certificate in Water Purification Process Control (NQF4) *<u>or</u>* National Certificate in Industrial Water Treatment Control Operations (NQF4)**<br>▪ **Certificate in Wastewater Process Control (NQF4) plus relevant management unit standards at NQF level 5 to a credit value of 50.**<br>▪ **Certificate in Water Purification Process Control (NQF4) plus relevant management unit standards at NQF5 to a credit value of 50.**<br>▪ **National Certificate in Industrial Water Treatment Control Operations (NQF4) plus relevant management unit standards at NQF5 to a credit value of 50.**<br>▪ **National Diploma or National Technical Diploma or NTC VI or 3 year BSc (all in appropriate field) plus all core unit standards from:**<br>▪ **Certificate in Wastewater Process Control (NQF4) or Certificate in Water Purification Process Control (NQF4) or National Certificate in Industrial Water Treatment Control Operations (NQF4) plus relevant management unit standards at NQF5 to a credit value of 50.**<br>▪ **NQF5 water/wastewater management qualification or industrial water treatment management.**<br>▪ **Higher National Diploma or 4 year BSc (both in appropriate field), plus all core unit standards from:**<br>Certificate in Wastewater Process Control (NQF4) *<u>or</u>* Certificate in Water Purification Process Control (NQF4) *<u>or</u>* National Certificate in Industrial Water Treatment Control Operations (NQF4). | | | | | | 0 | 10 |
| ▪ **NQF 6 water or wastewater management qualification or industrial water treatment management qualification**<br>▪ **Class V requirements *<u>plus</u>* a full NQF 6 generic management qualification.** | | | | | | | 0 |

## SCHEDULE III: WATERWORK PROCESS CONTROLLER REGISTRATION

This Schedule must be read in conjunction with the Qualifications registered with the South African Qualifications Authority on the National Qualifications Framework. The qualifications include Water and Wastewater Process operations and control and industrial water treatment support and control operations.

## NOTES ON SCHEDULE III

**NOTE: this will apply only to those who have been working at a registered Waterworks for longer than 10 years with no classification or a Class 0 classification under Government Notice No. R. 2834 of 27 December 1985 and who have now achieved the relevant unit standards by recognised prior learning assessment. The non-prescriptive criteria allow for the older process controller who could not be classified under the old regulation to select unit standards relevant to their experience/training on which they can be assessed. A motivation for being registered in this category must accompany the application.

***NOTE: this will apply only to those who have been working at a Registered Waterworks for longer than 10 years in a *supervisory capacity* with no classification under Government Notice No. R. 2834 of 27 December 1985 and who have now achieved the relevant unit standards by recognised prior learning assessment. A motivation stating reasons for being registered in this category must accompany the application

Re-evaluation of present operator classification in terms of Government Notice No. R. 2834 of 27 December 1985 may be requested. Process Controller registration in terms of Schedule III is only an indication of the persons' level of competency and in no way obliges the employer to amend a salary or create a new position for such persons.

## SCHEDULE IV: MINIMUM CLASS OF PROCESS CONTROLLER REQUIRED PER SHIFT, AND SUPERVISION, OPERATIONS AND MAINTENANCE SUPPORT SERVICES REQUIREMENTS AT A WATERWORK

| WORKS CLASS | CLASS OF OPERATOR PER SHIFT | SUPERVISION* | OPERATIONS AND MAINTENANCE SUPPORT SERVICES REQUIREMENTS* |
|---|---|---|---|
| E | Class I | Class V* | THESE PERSONNEL MUST BE AVAILABLE AT ALL TIMES BUT MAY BE IN-HOUSE OR OUTSOURCED<br>- electrician<br>- fitter<br>- instrumentation technician |
| D | Class II | Class V* | |
| C | Class III | Class V* | |
| B | Class IV | Class V | |
| A | Class IV | Class V | |

NB. Fluoridation – for any class works, minimum operator classification should be class III

### NOTES FOR SCHEDULES IV

*does not have to be at the works at all times but must be available at all times. If the owner of a waterwork has no person of this class employed on that work, a contractor/consultant with the required qualifications as prescribed in Schedule III in respect of that particular class of persons shall be appointed to visit the work weekly.

## 4.6 LINKS AND RESOURCE LISTS

| | | |
|---|---|---|
| WRC | : | www.wrc/org.za |
| DWAF | : | www.dwaf.gov.za |
| WISA | : | www.wisa.org.za |
| DBSA | : | www.dbsa.org |

## 4.7 GLOSSARY OF TERMS (water terms; water abbreviations)

**Capacity:** The quantity that can be contained exactly or the exact rate of flow.

**Carbonate alkalinity:** Alkalinity caused by carbonate ions.

**Carbonate hardness:** Hardness caused by the presence of carbonate and bicarbonates of calcium and magnesium.

**Catchment:** The area tributary to a stream or lake.

**Clarity:** Clearness of liquid as measured by a variety of methods.

**Clay:** A natural occurring material, usually being activated and used as an adsorbent.

**Coagulant:** A substance added to destabilise colloids in a stable suspension.

**Coagulation:** Aggregation of microparticles into microfloc by charge neutralisation.

**Colloid:** Finely divided solids, less than 0.001 mm in size, intermediate between a suspension and a true solution.

**Cycle:** Filtration interval, length of time filter operates before cleaning.

**Dam:** A barrier constructed across a water-course for the purpose of creating a reservoir.

**Demand:** Used in conjunction with modifying terms, e.g. biochemical oxygen, chlorine, oxygen, water.

**Depth filtration:** The use of a deep bed of medium to remove particulate matter by filtration.

**Discharge:** The rate of flow of water in a stream or conduit at a given place and within a given period of time.

**Disinfection:** Killing or inactivation of the larger portion of micro organisms, with probability that all pathogenic bacteria can be killed by the agent used.

**Earth dam:** A dam, the main section of which is composed principally of earth, gravel, sand, silt and clay.

**Ecology:** The branch of biology dealing with the relationships between organisms and their environment.

**Effective storage:** The volume of water available for a designated purpose.

**Effluent:** Liquid or waste water flowing out of a reservoir, a sewer or a purification works.

**Erosion:** Wearing away of land by running water and by wave action.

**Feed:** The mixture of particles and fluid that is deposited on a septum in a diatomaceous earth filter.

**Filter aid:** A chemical added to improve the effectiveness of filtration.

**Filter medium:** The permeable material that separates particles from a fluid passing through it.

**Filter:** A filtration device or a structure consisting of supported filter medium and equipment for the subsequent removal of the deposited solids.

**Filtration:** To filter, i.e. the operation of passing a liquid through a porous or open textured medium in order to remove suspended particles by leaving them behind in the pores of the filtering medium or at the surface of the filter.

**Flocculant:** Substances added to a destabilised suspension to accelerate flocculation, densify or strengthen flocs.

**Flocculation:** Aggregation of micoflocs into flocs by collisions due to hydro-dynamic operation.

**Flood:** A relatively high flow as measured by either gauge height or discharge quantity.

**Flow rate:** The unit rate at which a product is passed through a system.

**Fuller's earth:** Clay, i.e. hydrous aluminum silicate.

**Geohydrology:** The branch of hydrology relating to subsurface or subterranean waters.

**Geology:** The science that deals with the origin, history and structure of the earth, as recorded in the rocks, together with the forces and processes now operating to modify rocks.

**Groundwater:** Subsurface water occupying the saturation zone from which wells and springs are fed.

**Hardness:** A characteristic of water imparted by salts of calcium, magnesium and iron such as carbonates, bicarbonates, sulphates, chlorides and notates, that causes, e.g. curdling of soap and deposition of scale in boilers.

**Head:** The height of the free surface of fluid above any point in a hydraulic system; a measure of the pressure or force exerted by the fluid.

**Hydraulics:** The branch of engineering science which deals with water or other fluid in motion.

**Hydrogeology:** The branch of hydrology that deals with groundwater, its occurrence and movements, its replenishment and depletion, the properties of rocks that control groundwater movement and storage, including for the investigation and use of groundwater.

**Hydrologic cycle:** The circuit of water movement from the atmosphere to the earth and return to the atmosphere through various stages or processes such as precipitation, interception, runoff, infiltration, percolation storage, evaporation and transpiration.

**Hydrology:** The engineering science concerned with the waters of the earth in all their states, including the physical, chemical and physiological reactions of water with the rest of earth and its relation to the life of the earth.

**Hydrostatic pressure:** The total force, or force per unit area, exerted by a body of water at rest.

**Impermeable:** Not allowing, or allowing with only great difficulty, the movement of water, impervious.

**Impounding reservoir:** A reservoir wherein surface water is retained for a considerable period of time but is released for use at a time when the ordinary flow of the stream is insufficient to satisfy requirements.

**Infiltration:** The absorption, flow or movement of water into or through the interstices of soil or porous medium.

**Inorganic:** Substances which are not of basically carbon structures.

**Ion:** A charged atom, molecule, or radical, the migration of which affects the transport of electricity through an electrolyte or, to some extent through a gas.

**Isostatic:** Subject to equal pressure from every side; being in isostatic equilibrium.

**Jet:** The stream of water under pressure issuing from an orifice, nozzle, or tube.

**Langelier index:** The hydrogen ion concentration that a water should have to be in equilibrium with its content of calcium carbonate.

**Leakage:** The uncontrolled loss of water from artificial structures as a result of hydrostatic pressure.

**Limnology:** Scientific study of fresh water, in lakes, ponds, and streams, with reference to their biological, geographical, physical and other features.

**Liquid:** A substance that flows freely, by movement of the constituent molecules, but without the tendency for the molecules to separate from one another.

**Mean annual runoff:** The average over a period of years of the annual amounts of runoff discharged by a stream; MAR.

**Micro-organism:** Minute organism, either plant or animal, invisible or barely visible to the naked eye.

**Milligrams per litre:** A mass/volume unit of concentration of constituents of water or wastewater.

**Mineral:** Any substance that is neither animal nor vegetable; obtained by mining.

**Organic:** Chemical substances of animal or vegetable origin, basically carbonaceous.

**Oxidation:** The addition of oxygen to a compound or a reaction which results in loss of electrons from an atom.

**Peak:** The maximum quantity that occurs over a short period of time.

**pH:** The reciprocal of the logarithm of the hydrogen ion concentration.

**Purification:** The removal of undesirable or objectionable matter from water by natural or contrived means – an extractive process.

**Recycle:** The return of clarified liquid for another cycle of phase separation.

**Reservoir:** A basin, lake, pond, tank or other space which is used for storage; impoundment.

**River:** A large stream of water that serves as the natural channel for the drainage of a basin of considerable area.

**Saturation:** A condition reached by a material holding another material in an amount such that no more can be held within it in the same state.

**Sediment:** Solids, settled from suspension in a liquid.

**Sedimentation:** The process of deposition of sediment from water.

**Storage:** The impounding of water, either in surface or in underground reservoirs, for future use.

**Stream:** A course of running water, flowing in a definite channel, in a particular direction.

**Supernatant:** Liquid above settled solids.

**Turbidity:** A measure of the scattering and absorption of light rays, caused by the presence of fine suspended matter.

**Turbulence:** The fluid property caused by irregular variation in the speed and direction of movement on individual particles or elements of the flow.

**Unit operation:** In which physical changes take place.

**Unit process:** In which chemical changes take place.

**Water consumption:** The consumptive use of water for any particular purpose.

**Water demand:** A schedule of water requirements for domestic, industrial, irrigation, mining and power generation.

**Water purification:** The removal of undesirable substances from water.

**Water requirement:** The need for water, e.g. for plants, recreation and the environment.

**Water supply:** In general, the sources of water for public or private uses.

**Water treatment:** The addition of substances to water in order to render it more suitable for any particular purpose.

**Water works:** As defined under the Water Act, 54 of 1956.

## REFERENCES


BRISCOE J and DE FERRANTI D (1988) *Water for rural communities: helping people help themselves.* World Bank, Washington, DC, USA,.

DE VOS A (2005). *Small-scale drinking water treatment*. Course notes for SADEC/SAICE short course.

EVANS P (1992). *Paying the piper: an overview of community financing of water and sanitation* (Occasional Paper; no.18). IRC International Water and Sanitation Centre, The Hague, The Netherlands.

GLENNIE C (1994) *Policy/strategy for action: effectiveness* In: Netherlands. Ministry of Housing, Spatial Planning and the Environment (NL). *Ministerial conference on drinking water and environmental sanitation: implementing Agenda 21, March 22nd/March 23rd 1994, Noordwijk: conference report. Vol. 2.* The Hague, The Netherlands, Ministry of Housing, Spatial Planning and the Environment. Paper no.3 (viii, 17p).

HAARHOFF J and VAN VUUREN (1993) *A South African Design Guide for Dissolved Air Flotation*. Research report no. TT 60/93, Water Research Commission, Pretoria, South Africa.

IRC (1989). *Cost-recovery of village water supplies: a training guide for community development assistants.* Draft. The Hague, The Netherlands, IRC International Water and Sanitation Centre.

IRC (1995). *Making your water supply work: Operation and Maintenance of small water supply systems.* Occasional Paper Series 29, The Hague, The Netherlands, IRC International Water and Sanitation Centre.

ITTISSA and BIRRU (1991) Towards a new philosophy on operation and maintenance. In: *Waterlines,* vol.10, no.2, p. 25-28.

KATKO T (1990) Cost recovery in water supply in developing countries. In: *International Journal of Water Resources Development,* vol.6, no.5, p. 86-94.

LOGSDON GS, KOHNE R, ABEL S and LABONDE S (2002) Slow sand filtration for small water systems, J. Environ. Eng. Sci. **1** 339-348

MATJI MP (2003) *Investigation of water supply issues in typical rural communities: case studies from Limpopo Province.* Research Report No. 1271/1/03, Water Research Commission, Pretoria, South Africa.

MCPHERSON HJ (1990) *Proceedings of the Meeting of the Operation and Maintenance Working Group,* Geneva, 19-22 June 1990. Vol.1, Report of the meeting, Vol.2, Case studies on O & M, Geneva, Switzerland, World Health Organisation, Community Water Supply and Sanitation Unit.

NYUMBU IL (1990), *Water supply and sanitation: handbook of financial principles and methods.* Geneva, Switzerland, World Health Organisation, Community Water Supply and Sanitation, EHE/CWS.

PYBUS P, SCHOEMAN G and HART T (2001) *The level of communication between communities and engineers in the provision of engineering services.* Research Report No. TT 133/00, Water Research Commission, Pretoria, South Africa.

RALL M (1998) *Towards more successful rural water supply schemes.* Civil Engineering: Technical Article.

RAVENSCROFT P and CAIN J (1997) *Sustainability of Community Water Supply and Sanitation: a recipe for success.* Workshops proceedings, sustainability of small water systems in Southern Africa, Johannesburg, South Africa, 22-23 August.

ROARK P (1993) *Models of management systems for the operation and maintenance of rural water supply and sanitation facilities.* (WASH Technical Report; no.71). Arlington, VA, USA, Water and Sanitation for Health Project.

SINCLAIR M (2003) *Environmental influences on health: how safe is the water we drink?* Web document: www.waterquality.crc.org.au

SMET J (1993) *Health through sanitation and water: a study from a village perspective, evaluation of the SIDA supported HESAWA programme in the Lake Regions of Tanzania.* (SIDA evaluation report; no.1/93). Stockholm, Sweden, Swedish International Development Authority.

SWARTZ CD (2000) *Guidelines for the upgrading of existing small water treatment plants.* Research Report No. 738/1/00, Water Research Commission, Pretoria, South Africa.

WHO and IRC (1993). *Management of operation and maintenance in rural drinking water supply and sanitation: a resource training package.* The Hague, The Netherlands, IRC International Water and Sanitation Centre.

WOOD M (1997) Partnerships changes in rural water supply. *Proceedings of the 23rd WEDC Conference, Water & Sanitation for all: partnerships and innovations, Durban, South Africa, 1-5 September 1997.* Loughborough, UK: WDEC.

WYATT A (1998) *The maintenance of infrastructure and its financing and cost recovery,* Nairobi, Kenya, UN/HABITAT.

## FURTHER READING

BOUWER JL and HAYLETT J (2005) *An Illustrated Guide to Basic Water Purification Operations*, Research Report No. TT 247/05, Water Research Commission, Pretoria, South Africa.

DWAF and WRC (2003) *Management of water – related microbial diseases*. Research report no. TT175/03, Water Research Commission, Pretoria, South Africa.

DWAF, DoH and WRC (1998) *Quality of Domestic Water Supplies* Volume 1: Assessment Guide, Research report no. TT 101/98

DWAF, DoH and WRC (2000) *Quality of Domestic Water Supplies* Volume 2: Sampling Guide, Research report no. TT 117/00

DWAF, DoH and WRC (2000) *Quality of Domestic Water Supplies* Volume 3: Analysis Guide, Research report no. TT 129/00

DWAF, DoH and WRC (2001) *Quality of Domestic Water Supplies* Volume 5: Management Guide, Research report no. TT 162/01

DWAF, DoH and WRC (2002) *Quality of Domestic Water Supplies* Volume 4: Treatment Guide, Research report no. TT 181/02

SCHUTTE CF (2006) *Handbook for the Operation of Water Treatment Works*, Research Report No. TT 265/06 Water Research Commission, Pretoria, South Africa.

SWARTZ CD (2000) *Guidelines for the upgrading of existing small water treatment plants.* Research Report No. 738/1/00 Water Research Commission, Pretoria, South Africa.