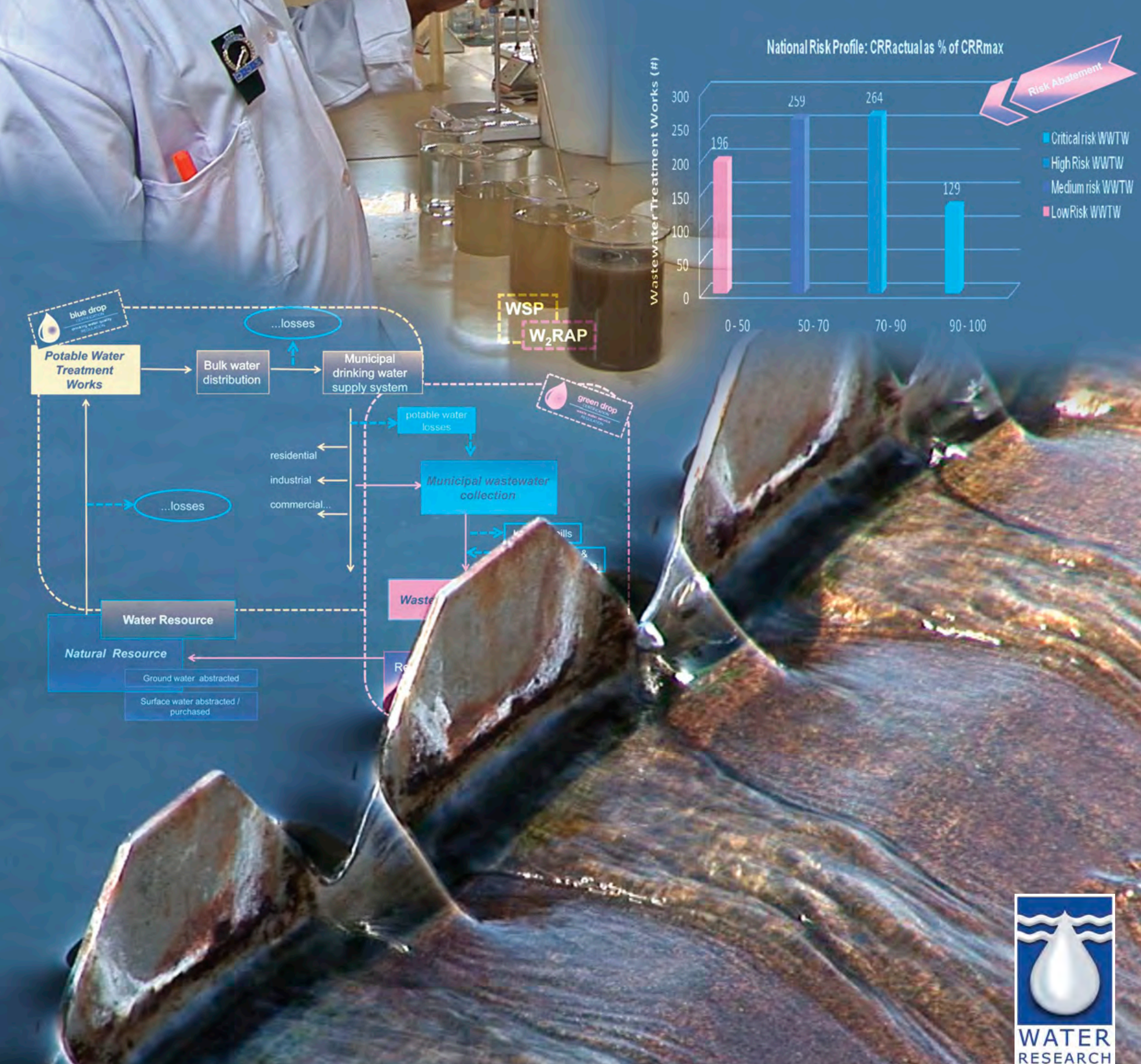
Wastewater Risk Abatement Plan

A W_2RAP GUIDELINE

To plan and manage towards safe and complying municipal wastewater collection and treatment in South Africa

Marlene van der Merwe-Botha & Leonardo Manus



water affairs
Department: Water Affairs
REPUBLIC OF SOUTH AFRICA

green drop
CERTIFICATION
waste water service
REGULATION

WATER RESEARCH COMMISSION

TT 489/11

Wastewater Risk Abatement Plan

A W_2RAP GUIDELINE

To plan and manage towards safe and complying municipal wastewater collection and treatment in South Africa

Marlene van der Merwe-Botha[+] & Leonardo Manus*

Report to the
Water Research Commission

by

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***Department of Water Affairs**

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The publication of this report emanates from a project entitled *"Development of a wastewater risk abatement plan – a guideline to water services institutions to plan and manage towards safe and compliant wastewater treatment in South Africa* (WRC Report No. K8/953/3).

Complementing this report are four WRC Special Publications which can be downloaded from the WRC web site, viz. –
SP 21/11 South African guidelines, manuals and literature on wastewater treatment 1985-2010;
SP 22/11 Wastewater risk abatement plan of City of Cape Town
SP 23/11 Wastewater risk abatement plan of Nelson Mandela Bay Municipality, and
SP 24/11 Wastewater risk abatement plan of Steve Tshwete Local Municipality

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EXECUTIVE SUMMARY

Wastewater collection and treatment systems operate 24 hours, 7 days, 365 days of the year. There is limited control over the quantity and quality of the raw wastewater. The environment in which these municipal assets operate is aggressive, corrosive and subject to aging infrastructure. If any part of this system fails, the consequence to public health and the environment is severe.

To mitigate potential risks, a Wastewater Risk Abatement Plan (W_2RAP) becomes a valuable primary risk management tool to enhance municipal wastewater service delivery. The W_2RAP encompasses all steps in the wastewater value chain, from production to discharge or reuse in a particular catchment.

WRC and DWA recognise that the approach is not new. It draws on many of the principles and concepts from other risk management approaches, in particular the Water Safety Planning Process, Hazard and Operability Study (HAZOP) and Hazard Analysis and Critical Control Points (HACCP).

The W_2RAP is however, amongst the first world-wide initiatives that put in place a guideline to plan for, and apply a risk-based approach to improve and sustain wastewater service performance. The W_2RAP is underpinned by the legislative environment, as well as municipal business requirements such as the IDP, WSDP, Quality Management Systems, Infrastructure Asset Management Plans and Levels of Service. The W_2RAP builds on existing Best Practical Environment Option and outlines a methodical and organised approach to ensure consistent compliance and best practice in rendering wastewater services.

The W_2RAP focuses on public health and natural resource protection and addresses the most eminent hazards, risks and controls that may apply along the value chain. Emphasis is on wastewater planning and management, not on testing, with documentation and communication being a key component of the process.

The development of the W_2RAP in South Africa was undertaken collectively by the Department of Water Affairs and the Water Research Commission, and the prototype testing has been undertaken by the City of Cape Town, eThekwini Municipality, Nelson Mandela Bay Municipality and Steve Tshwete Local Municipality.

The 'prototype testing' approach was taken to ensure that the Guideline conform to the practical realities and operational circumstances that influence the municipal wastewater business on a day to day basis. The W_2RAP shows the synergies between the W_2RAP and Water Safety Planning Process (WSPP) as municipal planning tools, as well as the link to the Blue- and Green Drop regulatory programmes in South Africa.

Different approaches in W_2RAP development and implementation were found when testing the W_2RAP Guideline within the different municipalities. Approaches varied from comprehensive plans for individual systems in high capacity municipalities; to strategic risk-based W_2RAPs in metropolitan municipalities; to CRR risk abatement planning in smaller municipalities that focus on swift turnaround in the most critical risk areas.

Whichever the approach taken, an inclusive and methodical process is outlined to ensure that the municipal user arrives at a practical and living W_2RAP, in order to plan and manage towards safe and compliant municipal wastewater services in South Africa.

The following schematic will direct the user through the Guideline document:

The W_2RAP Guideline is published with 2 complimentary products:

- a **CD** with the prototype W_2RAPs, risk matrix templates, schematics, protocols and other associated material as developed by the 4 test case municipalities
- A **Literature Booklet** containing the most relevant wastewater manuals, literature and reports from 1985-2010, for convenient reference to all municipal users.

"This is a remarkable document. It's huge in conception, objective and scope, yet easy to read. The step-by-step approach takes the reader/practitioner through a logical process that covers enormous ground, without being overwhelming, with frequent reassurance that a range of municipalities already have been able to do this and make it work for them."

- Kathy Eales, specialist peer reviewer

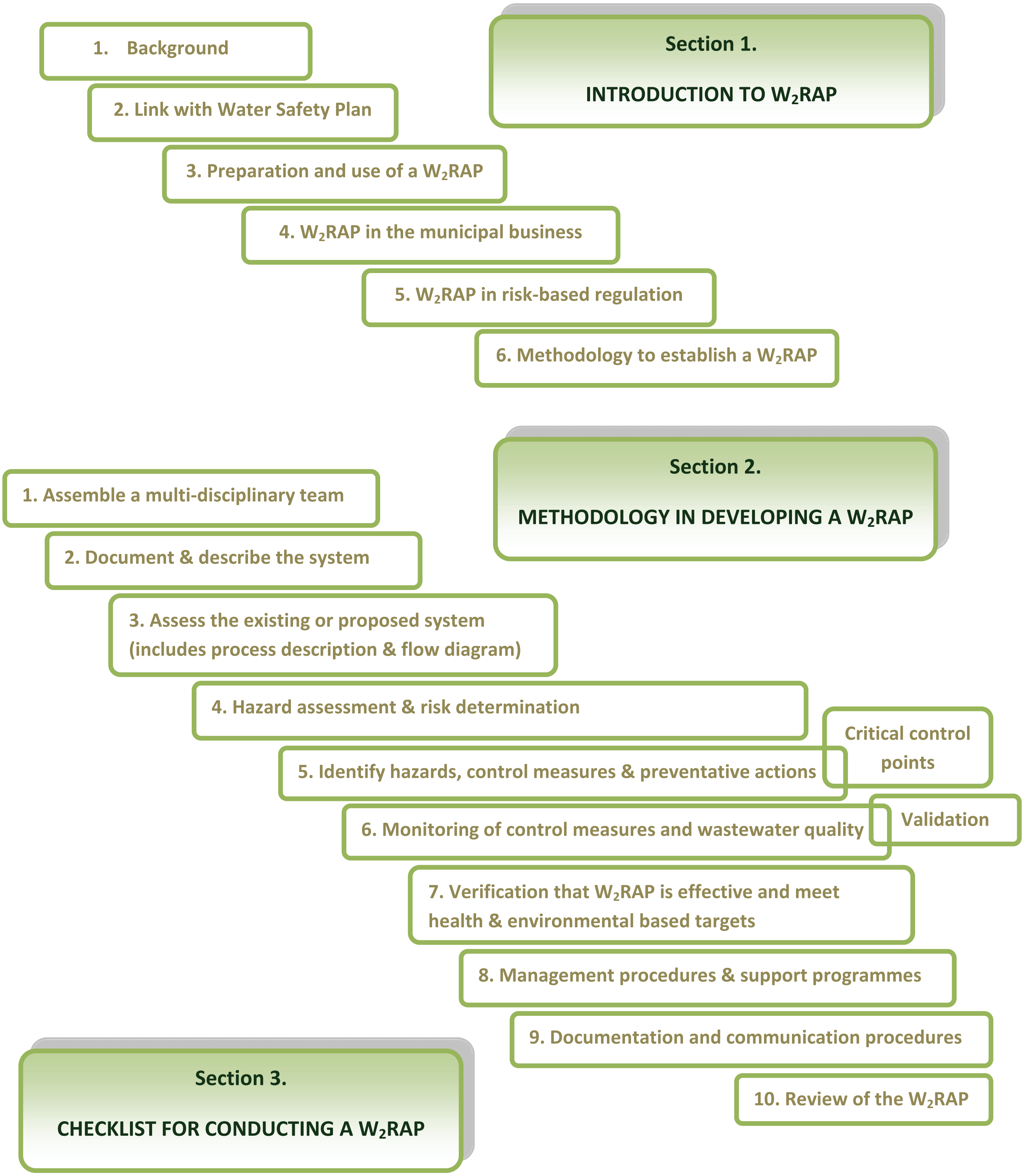

Figure 1: General layout of the W$_2$RAP Guideline

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The Department of Water Affairs and Water Research Commission acknowledge the contributions by the following institutions and individuals

- The *City of Cape Town* for applying the W_2RAP Guideline in practice and making meaningful recommendations to enhance the value of the guide. The City is also thanked for sharing their W_2RAP document with the South African municipal fraternity.
- The *eThekwini Municipality* Water & Sanitation Unit for testing the risk matrix in practice and making recommendations to enhance the value of the W_2RAP Guideline.
- The *Nelson Mandela Bay Municipality* for sharing their W_2RAP with the municipal fraternity and providing inserts to the W_2RAP Guideline to demonstrate application of the guide.
- The *Steve Tshwete Local Municipality* for sharing their W_2RAP with the municipal fraternity and demonstrating the use of the W_2RAP as planning tool within a non-metropolitan municipal environment.
- *Johannesburg Water* for contributing Operational Targets used as management tool for inclusion in the complimentary CD.

The five municipalities are thanked for sharing their W_2RAP documents, data, risk matrix spreadsheets and other relevant information with the water sector, as part of the ***COMPLIMENTARY CD*** attached to this Guideline, for convenient reference to municipal users across South Africa.

The WRC is thankful to the *Development Bank of Southern Africa* for compiling a reference list of applicable literature in the South African Wastewater Industry dating from 1985 to 2010, as a ***COMPLIMENTARY BOOKLET*** to this Guideline

Research and peer review of the W_2RAP Guideline by the following individuals

- *Water Research Commission*: Dr Valerie Naidoo
- *Department of Water Affairs*: Leonardo Manus
- *Research*: Dr Marlene van der Merwe-Botha, Gary Quilling
- *Specialist peer review panel:* Dr Machiel C. Steynberg, Chris Swartz, Kevin Samson, Shaun Deacon, Kathy Eales, Mohammed Dildar, Julie Clarke and Ayesha Laher.

ABBREVIATIONS:

AS	Activated Sludge
BOD	Biological Oxygen Demand
CCP	Critical Control Points
COD	Chemical Oxygen Demand
CPS	Cleaner Production Systems
CRR	Cumulative Risk Ratio
DBP	Disinfection Byproducts
DLD	Dedicated Land Disposal
DMP	Disaster Management Plans
DO	Dissolved Oxygen
DSVI	Diluted Sludge Volume Index
DWA	Department of Water Affairs
DWE	Department of Environmental Affairs
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
GLV	General Limit Values
HACCP	Hazard Analysis and Critical Control Points
HAZOP	Hazard and Operability Study
HTH	High test hypochlorite
IHAS	Invertebrate Habitat Assessment System
MLSS	Mixed Liquid Suspended Solids
MSDS	Material Safety Data Sheet
N	Nitrogen
OSHA	Occupational Safety and Health Act
P	Phosphorus
PPE	Personal Protection Equipment
RAS	Return Activated Sludge
RPMS	Regulatory Performance Management System
SABS	South African Bureau of Standards
SANAS	South African National Accreditation System *(for laboratories)*
SANS	South African National Standards
SASS	South African Scoring System
SCADA	Supervisory Control and Data Acquisition
SCFA	Short Chain Fatty Acids
SOP	Standard Operating Procedures
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
VIP	Ventilated Pit Latrine
WAS	Waste Activated Sludge
WHO	World Health Organisation
WRC	Water Research Commission
WSPP	Water Safety Planning Process
WWTP	Wastewater Treatment Plant
W_2RAP	Wastewater Risk Abatement Plan

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SECTION 1

1. BACKGROUND

Communities across the world have one thing in common – they produce wastewater. Wastewater is the water-carried waste that is removed from formal and informal residences, institutions, commercial and industrial establishments, together with the groundwater, surface water, stormwater and potable water as may be present. The primary objective of collection and wastewater treatment is to ensure that the effluent discharged to the environment does not pose unacceptable risks to the human health and natural resources.

Wastewater collection & treatment is the FIRST barrier in a multi-barrier system of ensuring public- and environmental health

In South Africa, the majority of wastewater treatment plants and transport infrastructure are either on-line or under construction. Significant challenges are experienced with regard to wastewater management. Among these are:

- aging infrastructure
- historical low base budget allocation for repairs, operations and maintenance
- 'catch-up' mode to ensure optimal operation and maintenance planning with regard to the installation of new infrastructure and tecnologies
- under investment in sewer collection and sludge handling infrastructure
- low skills base to manage, operate and maintain the specialised nature of wastewater services
- meeting the demand of rapidly increasing housing developments
- inadequate design or technology decisions for the specific municipal environment.

Incidents such as power outages, theft and vandalism, sludge lagoon walls rupturing, overtopping of ponds, mechanical/electrical/process control breakdown and discharge of substandard or untreated sewage to the environment have highlighted that managing risk is an integral part of the overall management of the municipal wastewater business.

Given that it is possible to produce treated wastewater of almost any quality, managing the associated risks is essential for good governance and long-term

BUSINESSDAY

South Africa: Sewage Treatment 'Unacceptable'

Jocelyn Newmarch — 28 April 2010

Recommend — Be the first of your friends to recommend this.

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Johannesburg — INADEQUATE sewage treatment is putting ecosystems at risk, causing headaches for farmers, and may be damaging the health of poor rural communities, a government report says.

The Department of Water Affairs' Green Drop report, which surveys the state of SA's sewage treatment works, is scheduled for release today, but an executive summary obtained by Business Day shows that the treatment of waste water is in dire straits.

Municipal waste water services are considered "far from acceptable" when compared to required national standards and international best practice, the report says. Compliance with the Water Act "must be addressed as a matter of urgency", it says.

Quite separate from the issue of control over SA's drinking water, the country's waste water treatment sector comprises about 850 municipal treatment plants, with extensive pipe networks and pump stations transporting and treating 7600 megalitres of water daily.

The sector has an estimated capital replacement value of R23bn and an estimated operational expenditure of R3,5bn a year, according to the report.

Failure to correctly treat waste water affects the country in three different ways – by poisoning river ecosystems, harming agriculture, and by potentially putting at risk rural communities who rely on rivers for drinking water.

sustainability of the country's water resources. The need is even greater in developing regions that experience water shortages and where high levels of treatment are not economically feasible. Wastewater services are closely linked to aspects of economic growth, water and food security and energy efficiency in the country, and cannot be compromised in any way.

When health effects occur as the result of environmental action, **risk analysis** is used as a valuable tool to **identify, quantify and manage** the corresponding risks according to the potential- and probable impact on a receiving resource. This involves the development of:

- Guidelines;
- Standards; and
- Management strategies.

The use of a comprehensive risk assessment and risk management approach, that includes the various steps and aspects of wastewater collection and treatment, is considered an effective means to **consistently, responsibly** and **sustainably** ensure that wastewater is safely and cost effectively collected, treated and discharged or reused.

> Simply stated risk management address the question" "What (the event/incident) could go wrong (the Risk) the probability (the likelihood) that will it occur, what are the results (the consequences) of the incident, what do we have in place to prevent 'the incident' from occurring (contingency measures or risk control strategy), and if the event/incident does happen, how do we deal with it (emergency procedures)'

EXAMPLE
City of Cape Town W_2RAP

This approach and "planning mechanism" is referred to as a **Wastewater Risk Abatement Plan** (**W_2RAP**). The process equips water management professionals to define control points and risk management procedures for the operation and maintenance of wastewater treatment plants. It aims to organise and coordinate effort of the responsible municipal units to achieve an impact on the ground (i.e. a clear turnaround in effluent quality) versus mere good intentions and plans.

Guidelines for the development of these plans are based on the principles of the WHO's Water Safety Plans, as contained within "*Guidelines for Drinking Water Quality: Third Edition: Incorporating the First and Second Addenda: Volume 1: Recommendations: Geneva 2008*".

2. LINKAGE TO THE WATER SAFETY PLAN

One aspect of the Water Safety Planning Process (WSPP) is to describe how risks associated with poorly managed wastewater treatment can be abated. There is therefore a strong link between the **WSPP and W_2RAP**.For example, impact events can be through direct contamination of the water and ground water resource through discharge of poorly treated effluent and wastewater by-products or through contamination due to spillages / breakages in the sewerage reticulation network. Thus, although a **W_2RAP** is a comprehensive process in itself, the control measures and outcomes of it **will inform the WSPP** risk abatement procedures and control methodologies and identify linkages and complimentary areas. To further entrench this, a strong similarity with the WSPP Guideline was maintained in the development of the W_2RAP Guideline.

This Guideline focuses on the principles of W_2RAP and should not be viewed as a comprehensive guide to the application of water services management practices. It is expected that most elements of a W_2RAP will be applicable in terms of wastewater practitioner's standard practice or as part of benchmarked good practice without consolidation into a comprehensive W_2RAP. This may include quality management systems, such as the ISO 14001 and ISO 9001. Existing good management practices can be considered a suitable platform for integrating W_2RAP principles. It should be noted that this however, does not imply that such practices necessarily have, as initial focus to the system management, structured hazard identification and risk assessment.

The complexity of W_2RAP will be dependent on the actual circumstances relevant to each wastewater treatment works (WWTW). In many cases, they may be fairly simple, focusing only on the key hazards identified for the specific system. The range of examples of control measures given in the following text does not imply that all of these are appropriate in all cases. W_2RAPs are powerful tools for the wastewater manager to manage the treatment and effluent disposal safely and a valuable monitoring tool for public health and environmental conservation authorities.

It is vital to remember that "*risk management starts with the on-site operational staff*" (City of Cape Town quote).

THE W_2RAP APPROACH

The W_2RAP approach organizes and systematizes management practices applied to wastewater collection and treatment and ensures the applicability of these practices to the management of treated effluent quality.

Key aspects of the approach

- Allows for a differentiation & management of risks at less advanced treatment works (financially constrained operations)
- Increases the control of excreta related infections where reclaimed water is reused
- Dependent on actual circumstances relevant to the specific wastewater treatment plant, within a specific catchment or drainage area
- Powerful tool to safely manage treatment and effluent disposal.
- Development (validity of **W_2RAP)** dependent on reliable technical and accurate scientific information.

3. PREPARATON AND USE OF THE W_2RAP

Who should prepare the W_2RAP?

Are there different types of W_2RAPs?

TIP

W_2RAP development can be a gradual and systematic process – and need not be 'perfect' at the 1st go… Each of the W_2RAP test municipalities opted for a different approach!

W_2RAPs should, by preference, be developed by the authority that is responsible for planning and management aspects of the service. Different types of W_2RAPs can also be developed, depending on the complexity of the system and the capacity of the municipality. In testing the W_2RAP Guideline by various municipalities across South Africa, the following different approaches were identified:

- ✓ Comprehensive W_2RAP development for individual wastewater treatment plants and their contributing reticulation systems within its applicable catchments or drainage district (e.g. Nelson Mandela Bay)
- ✓ Development of a high level core-W_2RAP that assess and rate the primary risks involved in the day to day operation of the municipal wastewater business. This W_2RAP might include a Plan for

the gradual and phased development of W_2RAPs for individual systems, where the core-W_2RAP serve to identify and prioritise the higher risk systems to be developed (e.g. City of Cape Town)

- ✓ A spreadsheet based W_2RAP, based on a comprehensive matrix equipped with weighting suited to the specific municipal environment that would provide key answers and risk-based priorities for planning and budgeting purposes (e.g. eThekwini). Again, a complimentary Plan for gradual and phased development of individual system W_2RAPs can compliment such approach, where the highest risk systems will be prioritised in terms of their development
- ✓ For smaller systems, either 'specified technology' W_2RAPs or 'model' W_2RAPs with guides for their development can be prepared
- ✓ For municipalities that have identified the wastewater treatment component as the key risk area within their business, a W_2RAP approach can be developed based on the national Cumulative Risk Ratings. This national baseline is reviewed every 1-2 years in South Africa by the national Water Services Regulator (DWA) to inform critical risk plants and areas. Municipalities can identify key risks areas and formulate action plans to mitigate and abate the specified risks accordingly (e.g. Steve Tshwete municipality, Berg River municipalities)
- ✓ Ideally, the last option (CRR-based W_2RAPs) must be included as a section in any type of W_2RAP approach
- ✓ Lastly, the Regulator may be prescriptive regarding a specific W_2RAP process or type to address catchment based issues (e.g. Hartbeespoort catchment) or a national improvement initiative (e.g. Green Drop Certification).

For household wastewater or sanitation systems (e.g. VIPs, septic tanks, on-site packaged plant applications), the W_2RAP is likely to be developed by a statutory body or accredited third party organisation. In these settings, guidance on the sanitation technology, wastewater storage, handling and effluent use may also be required. Plans dealing with household sanitation systems should be linked to a hygiene education programme.

The W_2RAPs should normally be reviewed and agreed upon with the authorities responsible for protection of public health in terms of water resource protection and the environment, to ensure that wastewater will be treated to a quality consistent with the health-based and environment targets. In the South African context, this will be the Department of Water and Department of Environmental Affairs which collate the sister Departments of Water Affairs (DWA) and of Environmental Affairs (DEA).

Where a service provider experiences difficulties to develop a W_2RAP, the competent national or regional authority should act as a source of information and guidance on risk management of wastewater collection and treatment systems. This will include defining requirements for operational monitoring and management. Approaches to verification in these circumstances will depend on the capacity of local authorities and communities and should be defined in national policy.

Benefits of using the W_2RAP

A W_2RAP has three key components which are guided by health-based targets and overseen through surveillance of effluent released by wastewater treatment works. These are:

- ***System assessment*** to determine whether the wastewater treatment as a whole can deliver effluent of a quality that meets health-based and environmental targets. This also includes the assessment of design criteria of new systems;
- Identifying ***control measures*** in a wastewater treatment system that will collectively control identified risks and ensure that the health-based and environmental targets are met. For each control measure identified, an appropriate means of ***operational monitoring*** should be defined

that will ensure that any deviation from required performance is rapidly detected in a timely manner; and

- ***Management*** plans describing actions to be taken during normal operation or incident conditions and documenting the system assessment (including upgrade and improvement), monitoring and communication plans and supporting programmes.

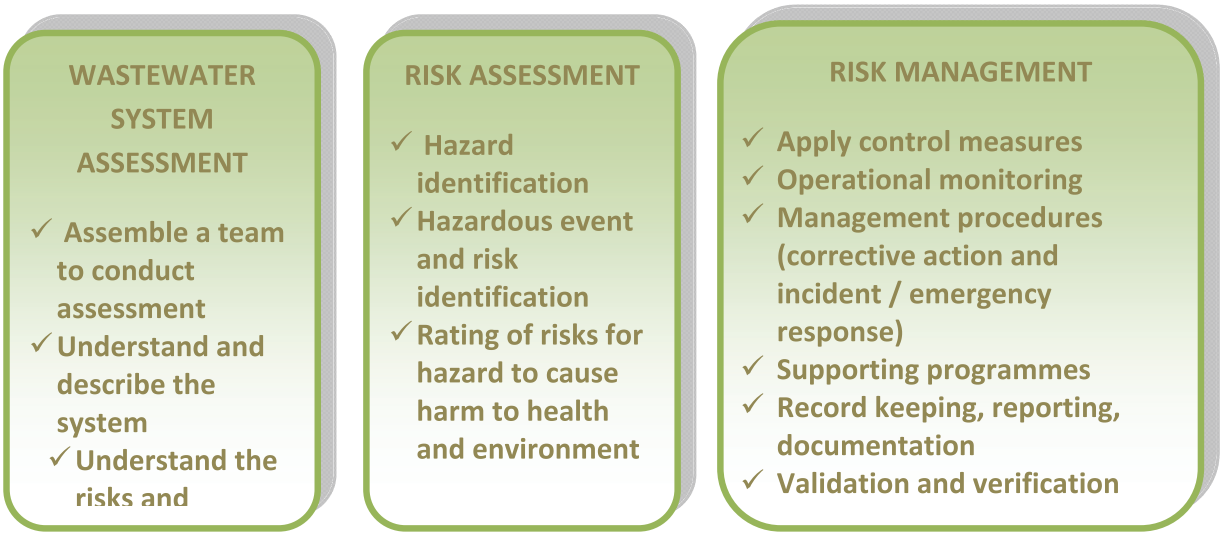

Figure 2: Three essential components of a W$_2$RAP

The primary objectives of a W$_2$RAP are:

- To prevent contamination during transport of wastewater, storage and disposal of sludge;
- To reduce or remove contamination through the treatment processes; and

To minimise contamination of the resource to which the treated effluent is returned to. The intended consequences of these objectives have direct bearing on safeguarding public health and protecting the ecosystem. The objectives are equally applicable to large sophisticated wastewater treatment plants, as well as smaller less-complex treatment systems, and are achieved through:

- development of an understanding of the specific system and its capability to treat wastewater and release treated effluent that meets health-based and environmental targets;
- identification of potential sources of contamination and how they can be controlled;
- validation of control measures employed to control hazards;
- implementation of a system for monitoring the control measures within the wastewater treatment system;
- timely corrective actions to ensure that returned effluent is to standard and sludge have been disposed of safely; and
- verification of effluent quality to ensure that the W$_2$RAP is being implemented correctly and is achieving the performance required to meet relevant national, regional and local waste quality standards or objectives.

EXAMPLE
Nelson Mandela Bay

The Nelson Mandela Bay Municipality (NMBM) wastewater risk abatement plans provide a practical approach to manage the entire wastewater system from catchment through treatment to the receiving environment and end users in order to provide an effective means of consistently, responsibly and sustainably ensuring the safety of wastewater treatment and its by-products. The wastewater risk abatement plans are implemented through practical risk management based on scientific best practices and supported by appropriate monitoring, management and good communication. This involves and encourages everyone in the wastewater cycle to take responsibility for safe wastewater and public- and environmental health.

WASTEWATER QUALITY POLICY STATEMENT

Nelson Mandela Bay Municipality will at all times, when reasonably possible, treat wastewater and its by-products to a safe and acceptable standard. Wastewater final effluent should not contain chemical, microbial or any other substantial amounts of substances that is deleterious to health or the environment. The aim is that wastewater produced will comply for at least 99% of the time with the wastewater quality standards as specified by the Department of Water Affairs for the specific wastewater treatment facility.

Figure 3: Wastewater Quality Policy statement as a prominent feature in the Nelson Mandela Bay municipal W_2RAP

4. W_2RAP IN THE MUNICIPAL BUSINESS

The business of wastewater collection and treatment operates in a highly regulated environment. In this regard, the following Acts have particular reference: Occupational Health and Safety Act (OSHA), especially the machinery regulations, Basic Conditions of Employment Act (BCEA), Labour Relations Act (LRA), National Water Act (NWA), Skills Development, National Environmental Management Act (NEMA), as well as a host of municipal- and financial management legislature.

Whilst municipalities and their service providers need to comply with these Acts, synergies between a risk abatement approach and the day-to-day municipal planning and operations need to be established. Some of the established municipal practices and systems include:

- Integrated Development Plan (IDP) is the strategic development plan for a municipal area containing short, medium and long-term objectives and strategies. It serves as the principal decision-making and management instrument for municipalities linking developments with the multi-year municipal budget. It is legislated by the Municipal Systems Act 2000 (MSA) and supersedes all other plans that guide development at a local level. The purpose of IDP is to foster integrated and appropriate service delivery by providing the framework for economic and social development within the municipality.

- Informing the IDP are the respective sector plans where the Water Services Development Plan (WSDP) is the tool used for comprehensive water services planning and management. Water Services Authorities are obliged to prepare and adopt the WSDP for their areas of jurisdiction as required by the Water Services Act, 1997 (No. 108 of 1997).
- Supply Chain Management Regulation is the imperative to ensure compliance with the Municipal Finance Management Act and specifically, the SCM regulations. These procedures do tend to be cumbersome and delays the effective and efficient response to wastewater collection and treatment's operational and maintenance needs. The stringent regulations are unlikely to change as these are legislative requirements. However, the W_2RAP and O&M Plan need to take this into account and put plans and mitigation measures in place for emergencies, breakdowns, reactive repairs and associated costs.
- A Quality Management System (QMS), such as ISO 9001, is an important guide for O&M Plan's successful implementation and risk management. The QMS would include Standard Operating Procedures, data capturing, training, equipment malfunction reporting, preventative and mitigation and verification of input data. Such system thereby becomes one of the appropriate measures to be taken against certain risk and hazards identified.

Observation by the eThekwini Municipality:

"...we have seen a definite link between the W_2RAP and our Asset Management Plan in terms of the Level of Service (LOS) risk assessment. This, together with all other risk assessment initiatives will be explored further during 2011 for cross-linkages underpinning the Municipal IDP. We also see the parallel with the Water Safety Plan quite clearly...."

Observation by Steve Tshwete Municipality:

"...we view the W_2RAP as a guide to overall risk management at all our treatment plants. The risk assessment process that will begin in 2011 will assist us to identify specific actions to be taken at different levels of our municipal business, namely: Environmental, Financial, Operational and Institutional..."

The following schematic illustration demonstrates the linkages between the most essential municipal business processes and the **W_2RAP** as a primary risk management tool to enhance the wastewater business within the municipal environment.

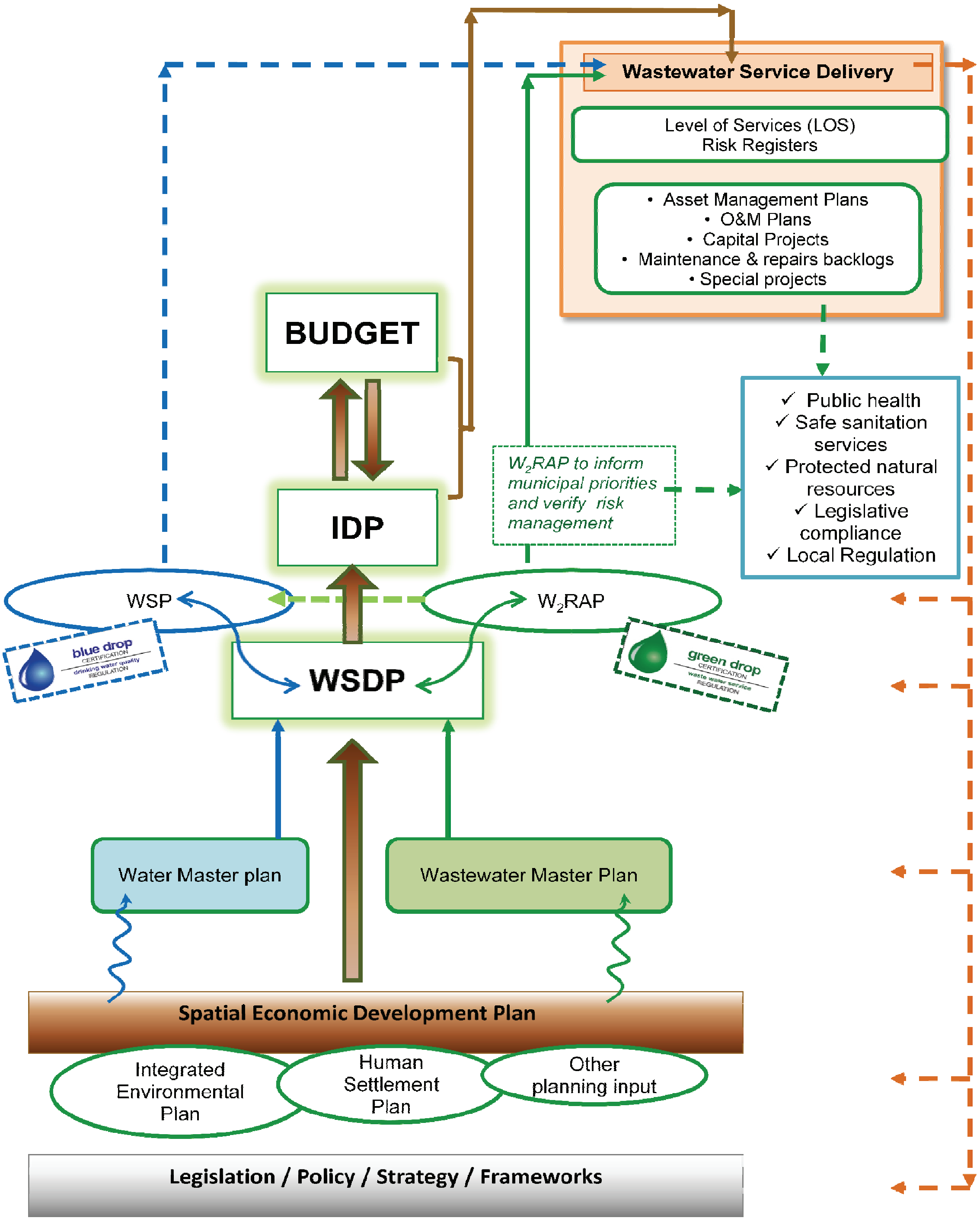

Figure 4: Linkages between the most essential municipal business processes and the W_2RAP

5. W_2RAP IN RISK-BASED REGULATION

Regulation is important to ensure effective and efficient delivery of sustainable wastewater services, by way of clarifying the requirements and obligations placed on water service institutions and thereby protecting consumers from a potential unsustainable and unsafe service.

Two particular forms of regulation bear direct relevance to the W_2RAP approach:

- ***Incentive-based regulation*** (Green Drop Certification) which identify and develop the core competencies required for the sector by way of facilitating a gradual and sustainable improvement in wastewater management performance in South Africa. The Green Drop process measure and compare the results of the performance of Water Service Authorities and their Providers, and subsequently rewards (or penalises) the municipality upon evidence of their excellence (or failures) according to the minimum standards or requirements that has been defined. One requirement that is assessed via the Green Drop process is the use of a risk abatement approach / W_2RAP.
- ***Risk-based regulation*** focuses on the wastewater treatment function specifically. This allows the Regulator to have insight into the treatment component within the business, which is one of the high risk components within the production chain. Risk analysis is used by the Regulator to identify, quantify and manage the corresponding risks according to their potential impact on the water resource and to ensure a prioritised and targeted regulation of high risk municipalities.

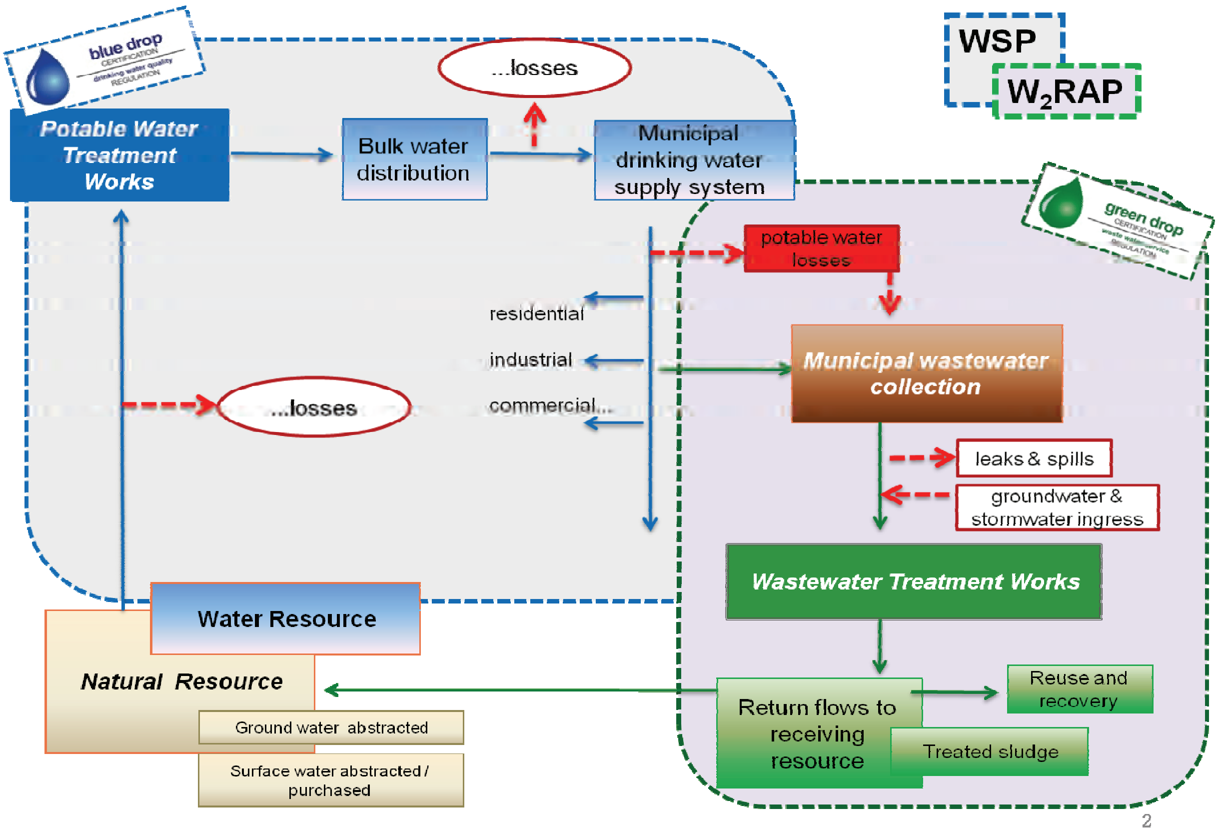

Figure 5: Schematic representation of the Water Cycle indicating the regulatory focus in terms of Green Drop regulation and the W_2RAP process

In the national risk-based regulatory approach, a CRR value is calculated and published every 2 years for each municipal wastewater treatment facility in South Africa.

Cumulative Risk Rating (CRR) = A x B + C + D

where:
A = Design Capacity of plant which also represent the hydraulic loading onto the receiving water body
B = Operational flow exceeding-, on- and below capacity
C = Number of non-compliance trends in terms of effluent quality as discharged to receiving water body
D = Compliance or non-compliance in terms of technical skills

EXAMPLE
Steve Tshwete

Steve Tshwete Local Municipality has used the CRR methodology to compile and implement a W$_2$RAP for enhancement of their wastewater treatment plants performance:

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Name of WWTP	CRR Criteria	As per 1st order CRR score	Revised CRR score	Target CRR score	Reason for score
Kwazamokhule	(A) Design Capacity	1	1	1	Design Capacity = 3.8 Ml/day
	(B) Flow exceeding capacity	5	2	3	Flow data for 2010 indicate that the average flow is 1.5 Ml/day = 40% of design capacity. Therefore CRR score is changed
	(C) Effluent Failures	5	3	0	Kwaza WWTW does not comply with 3 parameters. Results are discussed in 3.2.2
	(D) Technical Skills	1	1	1	Technical skills are adequate. Qualified supervisor available on plant. External service provider responsible for maintenance has qualified artisans. List of operators and relevant qualifications 3.2.3
	Total CRR score	11	6	4	CRR score is decreased from 11 to 6

Figure 6: Extract from the Steve Tshwete W$_2$RAP showing the use of CRR values to plan targeted risk abatement against the most critical risk elements

In applying a CRR-based approach, a municipality can enquire its risk profile and the individual risk factors and values that cumulate into a total CRR value from DWA. Using this as the baseline risk position, the different plans and measurements can be put in place to reduce the respective risk contributors to effect a reduction in the overall CRR value (=risk abatement).

TIP

Municipalities can consult the Department of Water Affairs to obtain their plant specific risk assessments and CRR values!

The aforementioned regulatory strategies are driven from the office of the Minister of Water Affairs, as is highlighted in the April 2011 Budget Vote Speech.

Budget Vote speech delivered by the Honourable Minister of Water and Environmental Affairs, Minister Edna Molewa, Parliament National Assembly

...the continuous consultative audits conducted as part of the Green Drop Certification programme ensured that local authorities are capacitated on the strategic elements required for effective wastewater management....

...the introduction of the targeted Risk-based Regulation also ensures that all municipalities are informed on the site-specific risks posed to their wastewater operations with tangible targets set for improved planning...

...this Risk-based Regulation was augmented by a global first innovation to develop a Wastewater Risk Abatement Planning (W_2RAP) process which is currently being peer reviewed by the Water Research Commission and will be rolled out as soon as the peer review is completed. This will create a new pre emptive paradigm for waste water service management....

... in another important development, the Cities of Cape Town and eThekwini adopted this process voluntarily since they saw the enormous benefit that such an approach will bring to their wastewater management approach...

6. METHODOLOGY IN ESTABLISHING A W_2RAP

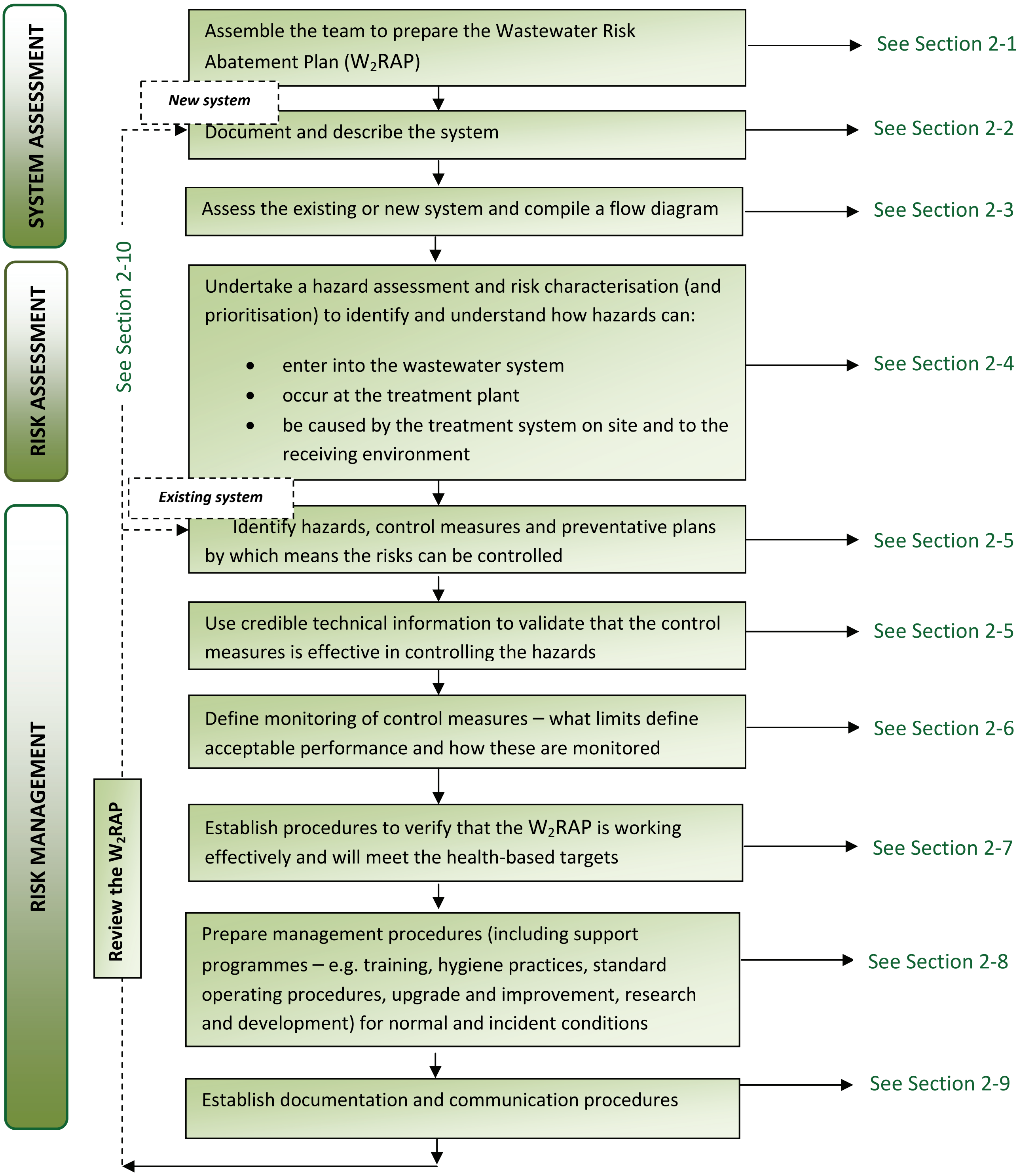


Figure 7: Overview of the key steps involved in developing a Wastewater Risk Abatement Plan (W_2RAP)

SECTION 2

1. ASSEMBLE A TEAM TO DEVELOP THE W_2RAP

The selected multi-disciplinary team of experts developing the W_2RAP must have a thorough understanding of the wastewater treatment system and its receiving environment. Typically, this would include individuals involved in each stage of the wastewater services value chain and may include:

- engineers,
- catchment and water services managers,
- water quality specialists,
- environmental, public health or hygienist professionals,
- operational staff,
- consumer representatives, where DWA could act as representative,
- water services councilor / local government, and
- external specialist.

In most settings, the team will include members from several institutions (business, public, civil society) and there should be some independent members, such as from professional organisations or universities.

A senior member of the team, with the necessary authority, organisation skills and interpersonal skills, is appointed to guide and direct the team through the preparation of the W_2RAP. The team's responsibility is to define the scope of the W_2RAP, the critical points and the hazards categories to be addressed.

The size of the team will vary and sub-teams may take responsibility for certain activities. Operational staff involvement is essential, as they have good knowledge about problems on the ground. Should the required skills not be available or limited, the project leader should seek external support.

2. DOCUMENT AND DESCRIBE THE SYSTEM

Effective management of the wastewater treatment system requires a comprehensive understanding of the system, the range and magnitude of hazards that may be present and the ability of existing processes and infrastructure to manage actual or potential risks. It also requires an assessment of capabilities and resources to meet targets. When a new system or an upgrade of an existing system is being planned, the first step in developing a W_2RAP is the collection and evaluation of all available relevant information and consideration of what risks may arise during the collection, treatment and disposal of wastewater.

Factors for consideration during the documentation and description of the system include:

- Catchment/ drainage area
  - ❖ Average Dry Weather Flow and Peak Wet Weather Flow to treatment plant
  - ❖ Maps and catchment layout plans

    - ❖ Water quality objectives of the receiving water resource
    - ❖ Restrictions on effluent quality limits within the catchment
- Collection and reticulation
    - ❖ Gravity and pump systems
    - ❖ Age, capacity and condition of main collectors an pumping mains
    - ❖ Industrial / domestic sources
- Treatment facility
    - ❖ Capacity and plant classification
    - ❖ Age, upgrade history
    - ❖ Technology, process units
    - ❖ Sludge management
    - ❖ Authorisation and legal requirements
    - ❖ Plans to upgrade – short to long term
    - ❖ Facilities to become redundant
    - ❖ Buildings, structures and landscaping
- Influent quantity and quality
    - ❖ Typical inflow
    - ❖ Typical outflow
- Receiving environment and end users
    - ❖ Discharge to water body
    - ❖ Reuse of reclamation (including irrigation).

TIP

A number of manuals and reports have been developed by WRC and DWA pertaining to the various wastewater subject fields. Pictorial reference is made throughout the W_2RAP Guide. Refer to the attached DBSA Booklet for detailed reference!

The intended use of the effluent and sludge then need to be defined, i.e. will the effluent be discharged to a water course, agricultural or industrial use. It is also possible to use the sludge in agricultural applications, mine dump rehabilitation or soil conditioning. This exercise will identify the vulnerable and down-stream groups that may be at particular risk.

3. ASSESS THE EXISTING OR PROPOSED SYSTEM

Assessment of the wastewater system involves subsequent steps in the W_2RAP in which effective strategies for control of hazards are formulated and implemented. To ensure the accuracy of the assessment, it is essential that all elements of the wastewater system (transporting of wastewater, treatment and disposal of effluent and sludge, utilisation/flaring of biogas) are considered concurrently and that interactions and influences between each element and their overall effect are taken into consideration. The assessment and evaluation of a wastewater treatment system are enhanced through the development of a flow diagram.

Assessing the system – Use of a Flow Diagram

Diagrams provide an overview description of the wastewater treatment system. This includes characterisation of the type (quality) and volume of wastewater:

- Reticulated
- Received
- Treated (unit processes)
- Stored

Discharged☑ **Important:** It is essential that the representation of the wastewater treatment system is conceptually accurate. If the flow diagram is inaccurate, it is possible to overlook potential hazards that may be significant. To ensure accuracy, the flow diagram should be validated by visually checking the diagram against features observed on the ground.

EXAMPLE

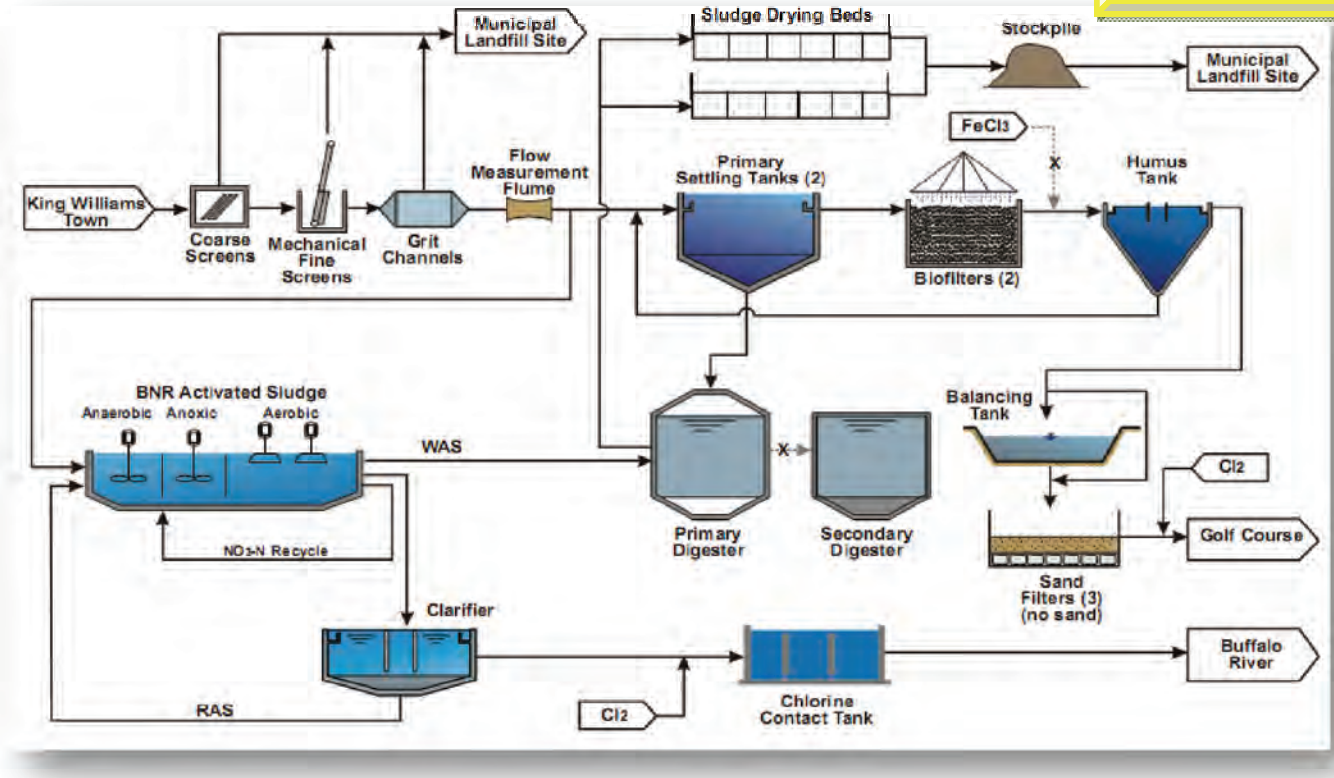


Figure 8: Schematic diagram of a typical wastewater treatment process flow (combination of biofilter and activated sludge process)

EXAMPLE

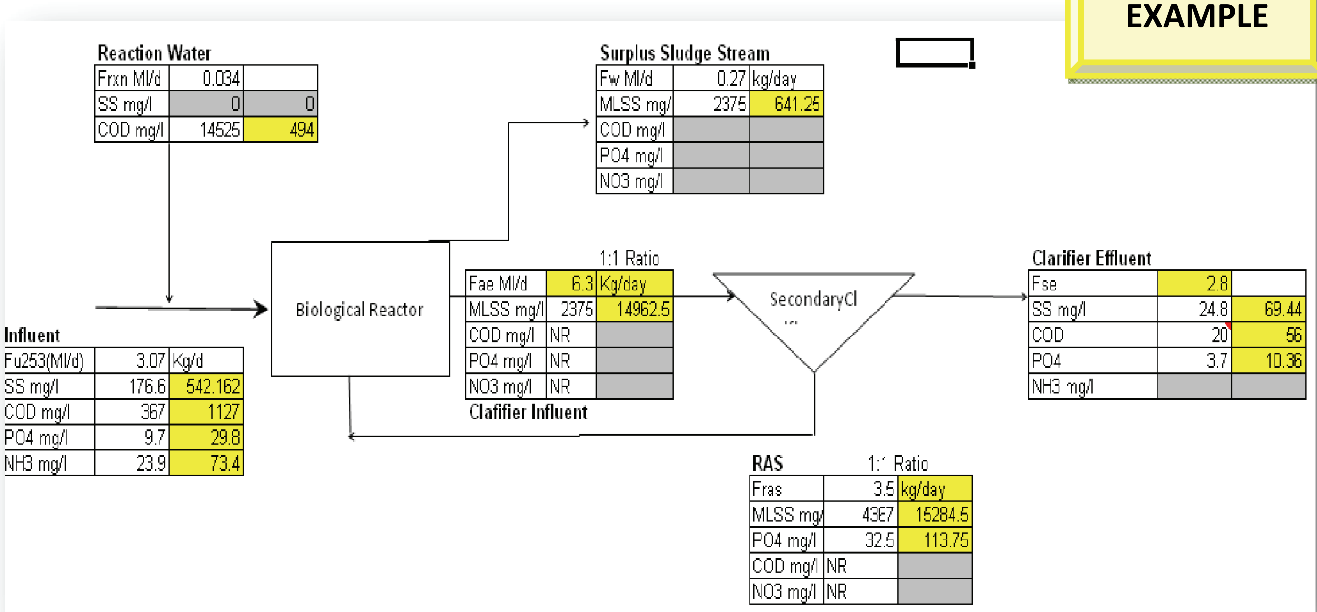


Figure 9: Typical use of a flow diagram to indicate associated 'flows' and 'effluent quality' during the treatment process – also known as a 'mass balance'

When assessing a wastewater system (existing or to be developed), the following should be considered.

- Undertaking a range of analyses to establish overall sensitivity of the receiving environment and to determine potential critical impacts of contamination of the receiving environment would be a prudent approach. This would normally involve water resource sensitivity analysis, environmental analysis, geological assessment and land use inventories to determine potential impact of further potential contaminants.
- Treatment plants should be designed to take account of variations known or expected to occur with significant frequency rather than for just for average occurrence. Lack of planning for these variations causes short-term overloading resulting in critical failure events.
- When designing new systems, all receiving effluent quality factors and final treated effluent quality factors should be taken into account in selecting appropriate technologies for treatment and disposal of wastewater. Variations in the parameters of the received untreated wastewater (quantity and quality) can be significant, due to influences of the waste generating sources and allowance must be made for this.

TIP

Ask other municipalities what they are doing..... solutions differ for coastal vs. inland systems, urban vs. rural based systems, different technologies used, etc

☑ **<u>Important factors to consider in selecting the most appropriate technology:</u>**

- Sensitivity of receiving water body or land
- Legal requirements in terms of water use licensing
- Capacity of the local authority to operate and maintain the system
- Availability of funding to construct the facility
- Running cost recovery and consumer's ability to pay for the ongoing operation and maintenance of the system (life cycle costs)
- Availability of reasonably priced land
- Projected population growth
- Opportunities for re-use of the treated effluent of value added returns and byproducts form the system
- Proximity of the community to the infrastructure
- Availability of fresh water for domestic use
- Acceptance by community
- Future economic growth
- Potential for ingress of stormwater, potable water or groundwater

It is often more efficient to invest in preventive and corrective measures than to invest in major infrastructure to manage a hazard.

Factors for consideration during the assessment of the system include:

i) Influent quantity and quality

- ❖ Analysis of historical data (quality): sampling, frequency, determinants
  - ▪ operational monitoring
  - ▪ compliance monitoring
  - ▪ catchment monitoring
  - ▪ industrial monitoring
- ❖ Compliance measured against legal limits
- ❖ Analysis of flow data
  - ▪ Dry weather and wet weather conditions

    - Nightflows as part of 24 hour trend flows
- Analysis of raw inflow composition and organic load to plant
    - Under dry and wet conditions

ii) Assessment of facility

- Infrastructure
- Biological processes
- Chemical processes
- Hydraulic capacity assessment
- Air quality assessment
- Health and safety assessment

iii) Receiving environment and end users

iv) Skills levels for the specific technology.

Collecting and evaluating available data

Table 1 gives examples of areas that should normally be taken into consideration as part of the assessment of the wastewater treatment system. In most cases, consultation with the Water Resource Protection authority, environmental and public health authorities, including land and water users and all bodies that regulate activities in the catchment, will be required for the analysis of catchments. A structured approach is important to ensure that significant issues are not overlooked and that areas of greatest risk are identified.

The overall assessment of the wastewater treatment system should take into consideration any historical water quality data that assist in understanding the receiving wastewater characteristics and wastewater treatment system performance both over time and following specific events (e.g. heavy rainfall events, holiday season, etc.).

4. HAZARD ASSESSMENT AND RISK CHARACTERISATION

Identifying hazards

At each step of the hazard identification, it is important to ensure that adequate protection measures can be applied and to identify treatment requirements. Each step will thus be determined by the events that could lead to failure in the treatment process and failure in effluent quality compliance, and the associated control measures for each hazard. Sources of hazards can be found in each step of the wastewater collection and treatment system (Table 1). The impact of the hazard can be characterised by assessing the severity of the likely health and environmental outcome and probability of occurrence.

Table 1: Examples of information useful for assessing a wastewater collection and treatment system

Component of wastewater system	Information to consider in assessing component of wastewater treatment system
Catchment	Geology (presence of dykes, sill & faults), topography and soil conditions
	Meteorology and weather patterns (regional climate, rainfall data, temperature data, wind data, evaporation and extreme weather)
	General catchment and river health
	Wildlife & natural vegetation
	Competing water uses
	Nature and intensity of development and land use and zoning, flood lines
	Other activities in the catchment that potentially release contaminants into source water (settlements without sanitation, religious ceremonies, mining)
	Planned future activities
	Sensitive landscapes and site of archaeological interest
	Industrial activity (types of industries, type of waste purification and by whom)
Surface water (inland and coastal)	Description of water body type (e.g. river, reservoir, dam, deep/shallow sea)
	Flow and reliability of source water
	Water constituents (physical, chemical, microbial)
	Presence of wetlands and other protection
	Surface water use (domestic, industrial, agricultural, recreational or natural environment)
	Water authorities and water users
Groundwater	Confined or unconfined aquifer
	Aquifer hydrogeology
	Presence and position of boreholes within a 1000 m radius of system
	Yield of boreholes
	Groundwater use
	Groundwater quality (pH, conductivity & nitrate)
Collector systems	% of area unsewered
	Manner of service (pit latrines, bucket system, conservancy tanks, septic tanks and French drains)

Treatment	% of area severed or to be sewered
	Type of network in place or to be installed (standard or small bore systems)
	Location of sewers (midblock or standard)
	Protection (e.g. covers, enclosures, access)
	Nature of sewerage
	Domestic component (existing and projected)
	Industrial component (daily volumes / expected volume to be treated, type of industrial waste[mainly organic, organic / inorganic, heavy metals, mixture], potential problem constituent received from industries)
	Stormwater, ground water and/or potable water ingress or influx
	Hydraulic & organic loading
	Seasonal variations
	Peak dry and wet weather flow factors
	A history of equipment malfunctions
	Maintenance schedules and frequency
	List of suppliers for critical equipment and parts
	Treatment processes (including optional processes)
	Method of disposal of screenings, sludge, supernatant liquid, methane gas, etc.
	Wastewater treatment chemicals used
	Treatment efficiencies (chemical, physical, microbiological)
	Disinfection of pathogens
	Disinfectant residual / contact time
	Disinfection other – details of use, period of application and intensity
	Equipment design
	Monitoring equipment and automation
	Availability of standby / spare equipment (mechanical, electrical)
	Final effluent and sludge disposal (methodology, quantities, norms and standards applicable)
	Water Balance

Other factors	Availability of scientific and analytical services
	Turnaround time to receive operational and compliance analysis
	Organisational context, i.e. capacity, structure, skills levels
	Ringfenced budget and expenditure cost centers
	Cost-reflective tariffs
	Route for emergency repairs in supply chain procedure
	Turnaround time to procure services and goods
	Political objectives – service delivery
	Social and reputational issues – manage perceptions, communication

Prioritising hazards for control

Once potential hazards and their sources have been identified, the risk associated with each hazard or hazardous event should be compared so that priorities for risk management can be established and documented. Although there are numerous hazards that can compromise wastewater reticulation and treatment systems, not every hazard will require the same degree of attention.

The risk associated with each hazard or hazardous event may be described by identifying the likelihood of occurrence (e.g. certain, possible, rare) and evaluating the severity of consequences if the hazard occurred (e.g. insignificant, major, catastrophic). The aim should be to distinguish between important and less important hazards or hazardous events. The approach used typically involves a semi-quantitative matrix.

Simple scoring matrices typically apply technical information from guidelines, scientific literature and industry practice with well informed "expert" judgment supported by peer review or benchmarking. Scoring is specific for each wastewater treatment system, since each system is unique. Where generic W$_2$RAPs are developed for technologies used by small wastewater treatment systems, the scoring will be specific to the technology rather than the wastewater treatment system.

Effective risk management requires the identification of potential hazards, their sources and potential hazardous events and an assessment of the level of risk presented by each. In this context:

- a hazard is a biological, chemical, physical or radiological agent that has the potential to cause harm;
- a hazardous event is an incident or situation that can lead to the presence of a hazard (what can happen and how); and
- risk is the likelihood of identified hazards causing harm in exposed populations in a specified time frame, including the magnitude of that harm and/or the consequences.

By using a semi-quantitative scoring, control measures can be ranked in relation to the most significant hazards. A variety of approaches to ranking risk can be applied. An example of an approach developed (WHO), is given in Table 2, where darker variations of orange represent higher likelihood of occurring and more severe consequences. Application of this matrix relies to a significant extent on expert opinion to make judgment on the health risk posed by hazards or hazardous events.

Table 2: Example of a simplified risk scoring matrix for ranking risks

Likelihood	**Severity of consequences**				
	Insignificant	Minor	Moderate	Major	Catastrophic
Almost certain					
Likely					
Moderately likely					
Unlikely					
Rare					

An example of descriptors that can be used to rate the likelihood of occurrence and severity of consequences is given in Table 3. A "cut-off" point must be determined above which all hazards will require immediate attention. There is little value in expending large amounts of effort and resources to consider very small risks.

Table 3: Examples of definitions of likelihood and severity categories that can be used in risk scoring

HAZARD ASSESMENT MATRIX

LIKELIHOOD	RATING	CONSEQUENCE	RATING
Almost certain (once a day or permanent feature)	5	Catastrophic (Death expected from exposure)	5
Likely (once per week)	4	Major (Population exposed to significant illness)	4
Moderately likely (once per month)	3	Moderate (moderate impact to large population)	3
Unlikely (once per year)	2	Minor (minor impact to large population)	2
Rare (1 in 5 years)	1	Insignificant (No impact)	1

Likelihood is determined by "how often' or "how likely" a hazard or a hazardous event occurs. It should take into account hazards that have occurred in the past and their likelihood of re-occurrence and should also predict the likelihood of hazards and events that have not occurred to date.

Consequence looks at the severity of the results of the hazard/hazardous event and the seriousness or intensity of the impact of the hazard. When dealing with impact we are concerned with human health and environmental integrity.

RISK RATING = LIKELIHOOD X CONSEQUENCE

Multiplying the derived likelihood ratings with derived consequence ratings from the above table is a simple way of producing a risk rating.

Example: a likelihood rating of 2 multiplied by a consequence rating of 4 would give a risk rating of 2 x 4 = 8, which would be ranked higher than an event with a likelihood of 1 and a consequence of 5 and a risk rating of 1 x 5 = 5.

A higher score implies that a bigger risk of a hazardous event occurring exists and should therefore be prioritised. A risk profile is given below:

Score		Risk Profile
0-10	LOW	These are systems that operate with minor deficiency and usually meet the effluent quality specifications set by the Department of Water Affairs. It is unlikely that this level of risk is harmful to the health of people and the environment. Aesthetically and/or physical non-compliance can be expected for short periods.
11-20	MODERATE	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health. These systems would not generally require immediate action but the deficiencies should be rectified to avoid future problems and associated cost to rectify once in HIGH risk. Aesthetically and/or physically non-compliance can be expected over a medium term. Medium term impact on infrastructure and partial failure of the wastewater treatment plant and disinfection process is likely.
21-25	HIGH	These are systems with deficiencies which individually or combined pose a high risk to the quality of the receiving environment and health, and may lead to potential health, safety and environmental concerns. Once a systems (or part of a system) are classified under this category, immediate corrective action is required to arrest or eliminate the deficiency. High impact on the health of people and the environment and/or significant damage to infrastructure can be expected. Total failure of the collector, treatment and disinfection facility are likely.

The risk matrix can be used in different variations and applications, depending on the priorities and approach taken by the municipality. The most important step is that risks are ***properly identified***, so that it can be assessed for its likelihood and consequences. Risks in the collector system, such as pumpstation overflows and sewer blockages, are very real risks. Risk identification is therefore not a management prerogative; it must involve the operational and maintenance staff who is closely involved in the day to day processes.

Note: It is acceptable to use synonyms or variations of the terminology used in the example above, as long as the definition is clear and the objective is achieved. For example:

- Likelihood = Probability = Possibility = Chance = Odds
- Consequence = Impact of the result = Effect

} = RISK RATING

TIP

"Risk Categories" can assist to organise and group different risks and hazards. The following are 2 examples often used by municipalities:

Operational risk categories:

- Design
- Operation
- Maintenance
- Scientific

Infrastructure Risk Categories:

- Collection system
- Treatment system
- Catchment system
- Administrative system

Risks are often not directly related to the infrastructure itself, and may be administrative issues such as missing drawings or O&M manuals or institutional issues such as a long lead time to order chemicals, extensive red tape to obtain a signatures, etc.

In testing of the W_2RAP by the City of Cape Town, the Impact on public, environment, employees and the costs were assessed against the likelihood and consequences. The rating is based on the 5-point system, and showed mechanical/electrical/process control systems malfunction, odour problems and Toxic influent to be the highest risks. Having recognised these as high risk areas, action plans have been implemented to mitigate and reduce these risks.

Table 4: Example of the risk index that the City of Cape Town employs for risk identification, risk assessment and risk rating

Emergency procedure in place for each item

EXAMPLE
City of Cape Town

EMERGENCY NUMBER	DESCRIPTION	RISK Rating	IMPACT RATING	PROBABILITY RATING	IMPACT PUBLIC	ENVIRONMENT	STAFF	COST
WW/EMER/1	Elect/mech/PCS failure		13	5	3	4	1	5
WW/EMER/3	Odour problem		12	5	5	1	3	3
WW/EMER/6	Toxic Influent		14	4	3	5	1	5
WW/EMER/16	Chlorinator failure	40	20	2	5	5	5	5
WW/EMER/20	Storm/flood/etc. impact on the WWTP	39	13	3	2	4	3	4
WW/EMER/12	Vehicle hi-jacking	36	12	3	1	1	5	5
WW/EMER/15	Power failure	33	11	3	1	4	1	5
WW/EMER/4	Sabotage	32	16	2	3	4	4	5
WW/EMER/5	Personnel injury	30	10	3	1	1	4	4
WW/EMER/7	Motor vehicle accident	30	6	5	1	1	1	3
WW/EMER/11	Broken sewer	28	14	2	4	4	2	4
WW/EMER/14	Broken air main	26	13	2	2	5	1	5

WW/EMER/2	Blocked sewer	24	12	2	3	4	2	3
WW/EMER/17	Fire	22	11	2	2	3	2	4
WW/EMER/10	Explosion (gas or other)	20	20	1	5	5	5	5
WW/EMER/8	Sludge lagoon failure	18	18	1	5	5	3	5
WW/EMER/9	Maturation pond failure	18	18	1	5	5	3	5
WW/EMER/13	Riot/strike/civil unrest	14	7	2	1	2	1	3
WW/EMER/18	Civil structural failure	14	14	1	1	4	4	5
WW/EMER/21	Public injury	12	12	1	5	1	1	5
WW/EMER/19	Drowning/near drowning	11	11	1	3	1	3	4
WW/EMER/22	Bomb threat	8	8	1	1	1	1	5
		100	**20**	**5**	**5**	**5**	**5**	**5**

RISK RATING	
VERY HIGH (catastrophic impact)	5
HIGH (major implications)	4
MEDIUM (moderate impact)	3
LOW (minor impact)	2
VERY LOW (insignificant)	1

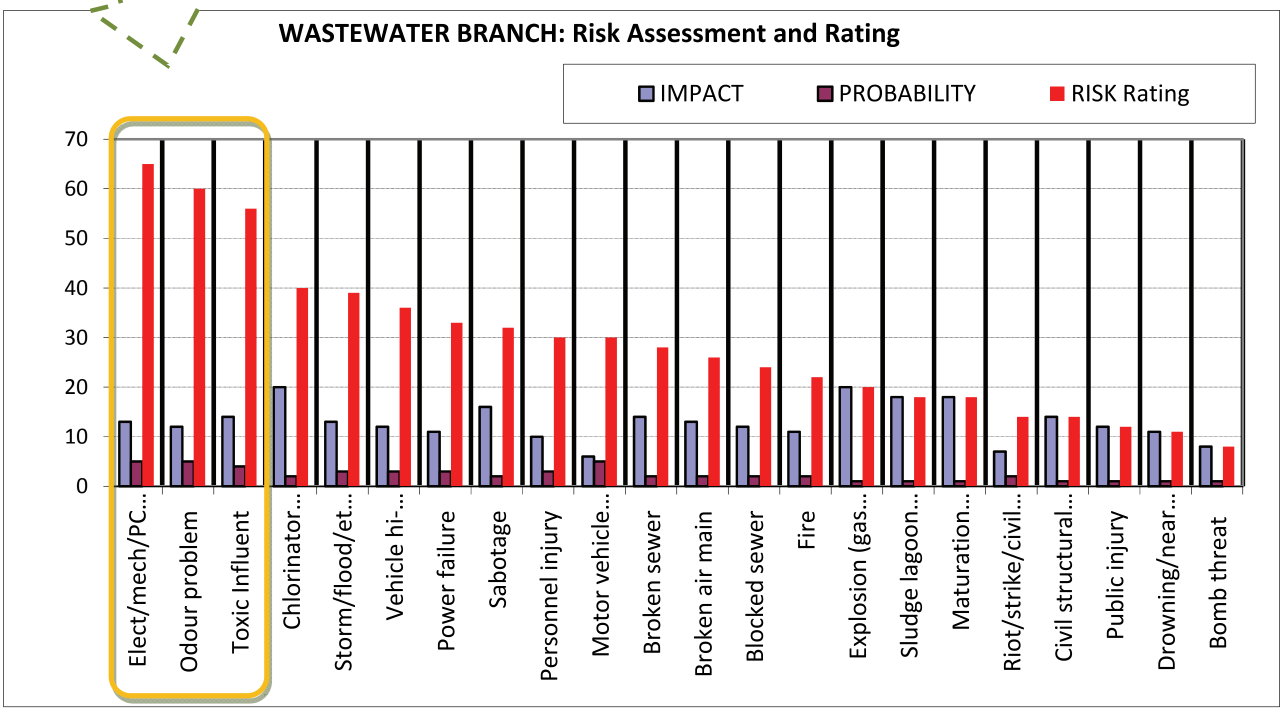


Figure 10: Use of a bar chart to demonstrate the areas that carry highest (to lowest) risk in the City of Cape Town

In the W_2RAP development of eThekwini Municipality, it was opted to change the risk matrix to skew is more in the direction of ***severity***, whilst adding a control effectiveness scale to measure effectively of control measures against the identified hazards. In addition, eThekwini prefers to use a weighted suite of severity components in addition to Public Health, such as environmental river health, social, reputational, and political (service delivery).

An example of the risk matrix is given below, and could be used to trigger specific considerations by municipalities to define an approach towards risk abatement.

EXAMPLE
eThekwini Municipality

Table 5a: Example of the eThekwini municipal risk matrix

Min Risk	2	7	8	13	14	19	20	24	25	26	30	**Max Risk**
	Low Risk 2 to 13				Medium Risk 14 to 25				High Risk 25 to 30			

Probability Score	
1	Rare (1 in 5 years)
2	Unlikely (once per annum)
3	Moderately Likely (once per month)
4	Likely (once per week)
5	Almost Certain (Once a day or permanent feature)

Severity Score	
2	Insignificant (No Impact)
3	Minor (Minor Impact to a large population)
4	Moderate (Moderate Impact to a large population)
5	Major (Population exposed to significant illness)
6	Catastrophic (Death expected from exposure)

Risk Matrix		Severity				
		2	3	4	5	6
Probability	1	2	3	4	5	6
	2	4	6	8	10	12
	3	6	9	12	15	18
	4	8	12	16	20	24
	5	10	15	20	25	30

Risk Matrix		Severity				
		2	3	4	5	6
Probability	1	2	3	4	5	6
	2	4	6	8	10	12
	3	6	9	12	15	18
	4	8	12	16	20	24
	5	10	15	20	25	30

Table 5b: Typical application of the risk tool to identify risk areas and mitigation measures at eThekwini wastewater treatment facilities

Area	Location	System	Hazard/Risk Description	Could this issue result in a risk?	Likelihood	Consequence	Inherent Risk Score (before consideration of any controls)	Inherent Risk Characterization	Existing controls	Control ref	Control Effectiveness	Residual Risk Score	Residual Risk Characterization	Recommended mitigation/ improvement plan	Responsible	Deadline	Budget	Signature
Inland Area	Dassenhoek	Inflow Metering	Removal and delay in replacing/repairing non functional flow metering equipment	Y	4	4	16	Medium	reactive maint	A3	0	16	Medium	M&E require additional staff	AC	x/x/2011	R	
Central Coastal Area	Central	Human resources	Lack of maintenance staff	Y	4	5	20	Medium	None	A66	0	20	Medium	Maintenance contract	VM	y/y/2011	R	
Southern Coastal Area	Isipingo	Primary Settling	Inefficient or inadequate maintenance	Y	3	5	15	Medium	6 PSTs, Bearings part of critical spares item, Routine oiling and /or greasing or all moving equipement, Checks on	B10	0	15	Medium	Preventative maintenance roster	KM	z/z/2011	R	
Northern Coastal Area	Gennazano			Y	3	5	15	Medium	Manual screen	C02	0	15	Medium	Preventative maintenance roster	KM	b/b/2011	R	

EXAMPLE

eThekwini Municipality

In the eThekwini Inland Area, for the plant Dassenhoek, the area of risk (system) has been identified to be the Activated sludge process…

The hazard/risk description is given as "Inefficient or inadequate process control (wasting/return/internal recycles not to design spec)...

This risk is carrying a likelihood of '4' and consequence of '5', which rates is to carry a '20' inherent risk score, which is characterised as a '**MEDIUM**' risk.

The existing controls comprise of a logsheet, operational tests, monitoring, visual checks and inspections. The control measure is provided with a reference number.

After implementation of these control measures, the residual risk score remaining is '8', which is characterised as a '**LOW'** risk.

'Jay' is assigned as the responsible person for risk control and continued monitoring of this risk event. A timeframe (deadline) and budget is allocated against this risk control measure to ensure the implementation of the control.

5. IDENTIFY HAZARDS, CONTROL MEASURES & PREVENTATIAVE ACTIONS / validation

Identifying control measures

Control measures are activities and systems to prevent, minimise, reduce and mitigate against the identified risks (consequence and likelihood). For each hazardous event and risk, a control measure is defined with associated critical limits that indicate compliance or whether control is being lost.

Control measures are defined barriers in the wastewater collection and treatment system that directly affect final treated effluent quality and ensure that the effluent consistently meets effluent quality targets.

Suggested control measures are marked "RISK CONTROLS" throughout the document, as these are important risk abatement measures.

Any set of control measures should always include the availability of:

- ✓ **Standard Operating Procedures (SOPs),**
- ✓ **Contingency measures,**
- ✓ **Training,**
- ✓ **Emergency procedures.**

Operational Risk Categories:

- Design
- Operation
- Maintenance
- Scientific

Infrastructure Risk Categories:

- Collection system
- Treatment system
- Catchment system
- Administrative system

Control measures can be applied within the "Risk Categories" previously described (or any variation thereof that is a best fit to the municipal terminology or systems).

Annexure A contains a list of possible Control Measures or Corrective Action Plans that would apply to wastewater system related risk situations.

National limits or site-specific authorisation (license) limits are determined by DWA and used to set limits and all control measures are validated using these limits and accepted best practices. *A control measure is triggered whenever monitoring or reporting indicates that critical limits have been exceeded at any point along the wastewater services value chain.*

The level of control applied to a hazard should be proportional to the associated ranking. Assessment of control measures involves:

- identifying existing control measures for each significant hazard or hazardous event from consumer (initial point of waste collection) to catchment (final point of effluent discharge);
- evaluating whether the control measures, when considered together, are effective in controlling risk to acceptable levels; and
- if improvement is required, evaluating alternative and additional control measures that could be applied.

☑ **The strength of a multi-barrier approach is that…** a failure of one barrier may be compensated by effective operation of the remaining barriers, thus minimizing the likelihood of contaminants passing through the entire system and being present in sufficient amounts to cause harm to the receiving environment.

Critical control points are established once the hazard identification and risk assessments have been completed. Critical control points (CCPs) are defined as points along the wastewater collection and treatment chain where monitoring and/or interventions can have a significant impact on the quality of wastewater. CCPs should be positioned to act as a multi-barrier protection process. This provides the ability to locate, isolate and mitigate and arrest a specific problem before it escalates to higher risk scenarios, or before it is fatal to health and environment.

The strength of this approach is that a failure of one barrier may be compensated by effective operation of the remaining barriers, thus minimising the likelihood of contaminants passing through the entire system and being present in sufficient amounts to cause harm to the receiving environment. Many control measures may contribute to control more than one hazard, while some hazards may require more than one control measure for effective control. Examples of control measures are provided in the following sections.

All control points and control measures are important and should be afforded ongoing attention. They should be subject to operational monitoring and control, with the means of monitoring and frequency of data collection based on the nature of the control measure and the rapidity with which change may occur.

☑ **Typical CCPs**

- industrial discharge/connection points
- pumpstations
- screening chambers
- inlet screens
- penstocks
- activated sludge transfer point
- stormwater tank overflow / discharge
- chlorine contact tank
- pond overflow
- sludge pumpstations
- sludge stabilisation and dewatering
- security entry point

If the existing controls and contingency measures are not adequate, it is necessary to develop the appropriate control measures to reduce the risk. After an (risk) event or incident took place, it is necessary to re-assess the risks and the control measures.

TIP

Indicate the Critical Control Points on the Flow Diagram

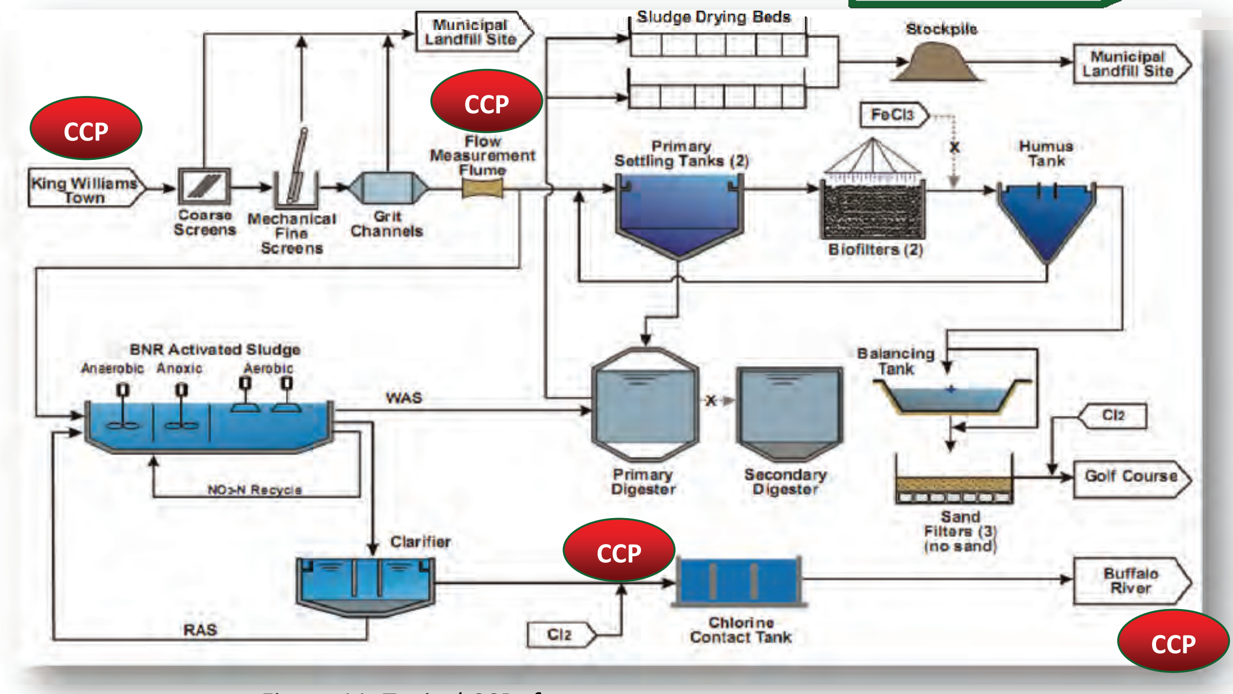
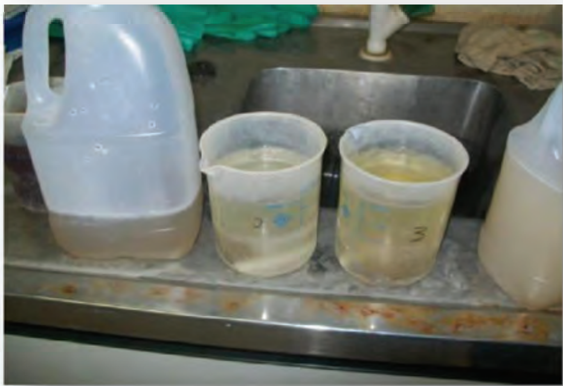


Figure 11: Typical CCPs for a wastewater treatment system

When conducting a risk assessment, it is possible that a municipality may conclude that the risk control measures may not be affordable, possible, the likelihood is rare or too costly to mitigate. Then the following risk control strategies should be considered:

- Reduce the level of risk, i.e. either the likelihood or the consequence
- Accept the risk, no action is required
- Transfer the risk
- Avoid the risk
- A combination of the above.

5.1 Hazards and Control Measures in the Collection and Reticulation of Wastewater Services



Effective management of the wastewater collection has a number of benefits. By decreasing the potential for contamination by leakage / spillage / overflow from the reticulation system, health and environmental hazards can be reduced and consumer confidence can be upheld. Similarly through effective control and understanding of the nature and quantity of the wastewater, the amount of treatment required could be reduced or methodology of treatment simplified. This may minimise operational costs.

Hazard identification

Understanding the nature of the wastewater quality is important, as it will influence the requirements for treatment, treatment efficiency and the resulting health risk associated with the treated effluent.

The nature of the wastewater is influenced by two main components:

- Domestic Component – requires an understanding of the current and future projected volumes and strength of domestic wastewater
- Industrial Component – requires an understanding of the daily volumes, expected volumes to be treated, times of discharge (e.g. at night) and the type (composition) of industrial waste:
  - mainly organic
  - organic / inorganic
  - heavy metals
  - combination of above, and
  - potential problematic constituent/s received from industries.
- Stormwater, potable water, ground water ingress – requires an understanding of the design capacity to allow for ingress, and the measure to be taken when excessive ingress occur.

It is important that the characteristics of the collection and reticulation of wastewater services are understood and that the scenarios that could lead to pollution or hazard events are identified and managed. The extent to which potentially polluting activities can be reduced may appear to be limited by pressure for increased development. However, introducing good practice in containment of hazards is often possible without substantially restricting activities and collaboration between stakeholders may be a meaningful tool to reduce pollution without reducing beneficial development.

> Effective management of the collection and reticulation of wastewater provide the **first barrier** in prevention of health and environmental hazards…

Where the management of the collection and reticulation of wastewater is beyond the jurisdiction of the wastewater treatment service provider, the planning and implementation of control measures will require coordination with other agencies. These may include planning authorities, environmental and water resource regulators, municipal authorities and industrial and other commercial entities whose activities have an impact on the final effluent quality generated. This will contribute to a sense of ownership and joint responsibility for wastewater management and environmental and water resources protection through multi-stakeholder bodies that assess pollution risks and develop plans for improving management practices for reducing these risks.

Hazards and hazardous events that can have an impact on the wastewater collector systems and that should be taken into consideration as part of a hazard assessment include:

- wastewater discharges due to
  leakages in the sewer reticulation system due to lack of maintenance or replacement of deteriorated infrastructure;
  damaging of the sewer reticulation system due to construction activity;
  human interference, in regards to abuse of materials discarded into sewers causing blockages, vandalism, etc.;
  design error or choice.
- industrial discharges
  uncontrolled and unknown discharge of chemicals into sewer system, for which the treatment plant may not be equipped or which can damage the reticulation system leading to leakages and blockages;
  chemical pollution into environment through leakages in the sewer reticulation system due to lack of maintenance.
- ingress of extraneous water sources
  stormwater
  losses from potable water system
  ground water
- through human error
  resulting in the unintentional cross-connection of wastewater or stormwater pipes to the distribution system or through illegal or unauthorised connections.

Further hazards and hazardous situations that can have an impact on wastewater pumpstations and that should be taken into consideration as part of a hazard assessment include:

- mechanical failure of duty and standby pumpsets
- electrical failure within the pumpstation
- power outages
- screen blockages
- human access / absence of exclusion areas;
- human error

  inadequate health and safety precaution taken by staff at the treatment works
    - safety clothing
    - effective and adequate sanitary behavior, i.e. washing of hands, drinking from secure and sanitary facilities
- failure of alarms and monitoring equipment
- uncontrolled discharge from tankers along the reticulation system
- design deficiencies.

Control measures

Effective management of the collection and reticulation of wastewater includes the following elements:

- development and implementation of preventative maintenance plans for major assets;
- developing and implementing an operations and maintenance plan, that includes infrastructure replacement, regular inspections and monitoring of the infrastructure;
- ensuring that planning regulations include ensuring that geographical and updated knowledge base of the location of sewer system is maintained and readily available to prevent damages to services;
- ensuring that data and information management systems are current, accurate and have appropriate functionality;
- ensuring that there is effective monitoring of industrial activities which have wastewater implications and adherence to their permitted activities / discharge quality;
- promoting awareness in the community of the impact of human activity on wastewater system and potential hazard implications.

Examples of control measures for effective management of the collection and reticulation of wastewater include:

- registration of chemicals use and potential discharge
- designated and limited use of certain chemicals;
- specific protective requirements (e.g. pre-treatment by removal of certain chemicals or dilution of wastewater generated by certain types of industries);
- control of human activities to prevent access to or vandalism of reticulation system and to reduce abuse of system
- community awareness programmes identifying action and potentially resultant health & environmental reaction/hazard;

- land use planning procedures, use of planning and environmental regulations to regulate potential polluting developments and reduce damages to services by construction activity through prior knowledge of where the services are located;
- undertaking effective operations and maintenance activities, timeous replacement of old or aging infrastructure, regular inspection and monitoring of the conditions of and flow within the reticulation, i.e. blockages, leak detection, regulator inspection of pipe conditions, i.e. CCTV;
- diversion of local stormwater flows;
- runoff interception;
- security to prevent tampering;
- implementing cross-connection devices;
- implementation of municipal bylaws and control systems to discourage abuse of sewer systems; and
- integrated development planning, including spatial development plans, stormwater management plans, water demand management plans, etc.

Similarly, control measures for effective protection sewer pumpstations include:

- rapid response to alarm conditions;
- ensuring working alarm and failure monitoring equipment, ready access to spares and back systems (i.e. power supply, spare pumps) ;
- routine checks and monitoring;
- assess power outages and identify outage areas/blocks using electricity sub-station footprints relative to the critical installations;
- mobile or fixed generating plants;
- overflow retention dam;
- built-in time for reaction before overflow occurs
  i.e. surcharge capacities of sewer feeding the pump stations and holding pond capacity)
- security from access by animals;
- security to prevent unauthorised access and tampering; and
- bioaugmentation when overflow occurs (remediation).

Table 6: Typical application of the risk tool to manage and track risk control measures in Nelson Mandela

EXAMPLE
Nelson Mandela Bay

WASTEWATER RISK ABATEMENT PLAN
LIST OF HAZARD EVENTS - COLLECTION & RETICULATION

Section	No	Hazard event	Risk assessed	Control measure in place	Last updated
Collection & Reticulation to Fishwater Flats	2.1	Sewage leakages in sewer reticulation system due to lack of maintenance	Yes	Yes	Nov-10
	2.2	Sewage leakages in sewer reticulation system due to deteriorated/old infrastructure	Yes	Yes	Nov-10
	2.3	Sewage leakages due to damage to reticulation system due to construction activities	Yes	Yes	Nov-10
	2.4	Sewage discharge due to blockages in sewers and/or sewer manholes	Yes	Yes	Nov-10
	2.5	Sewage leakages due to human interferance or vandalism of sewers	Yes	Yes	Nov-10
	2.6	Industrial discharges due to uncontrolled discharge of chemicals into sewer system	Yes	Yes	Nov-10
	2.7	Chemical pollution into the environment from industrial sewers due to lack of maintenance or old infrastructure	Yes	Yes	Nov-10
	2.8	Ingress of storm water into sewer system	Yes	Yes	Nov-10
	2.9	Unauthorized or unintentional connections to sewers	Yes	Yes	Nov-10
	2.10	Security	Yes	Yes	Nov-10
	2.1	Pump equipment failure due to lack of maintenance	Yes	Yes	Nov-10
Pumping stations to		Pump equipment failure due to deteriorated/old frastructure	Yes	Yes	Dec-10
		arge foreign objects that cause damage to pump npellers.	Yes	Yes	Jan-11
		ailure of screening at pumping station	Yes	Yes	Feb-11
		ower failures	Yes	Yes	Mar-11
		ailure of alarms and monitoring equipment	Yes	Yes	Apr-11
	2.7	Overflow or flooding of pumping station during flood event	Yes	Yes	May-11
	2.8	Security	Yes	Yes	Jun-11

The pumping station that transfers sewage to the Fishwater Flats WWTP is prone to flood events during rain events when stormwater ingress takes, and is therefore identified as a one of the 'hazards/risks' ….

The critical limit (trigger) is defined as 'visual leakage / flooding'…

The 'probability'= medium, 'severity'= high and the risk rating = **HIGH**. ..

The preventative action set in place is "develop and implement an O&M reticulation plan that includes infrastructure replacement and backlog maintenance". The control measure is "replace pipelines and provide adequate protection where problem persists"…

The validation of the control measures is the Standard Operating Procedure (SOP) and W_2RAP…

The CCP is 'sewer manholes' and the risk rating after corrective action was taken is '**LOW'**.

5.2 Hazards and Control Measures in Wastewater Treatment

> After protection of the collection and reticulation of wastewater, the next barriers to contamination of the environment are those of wastewater treatment processes!

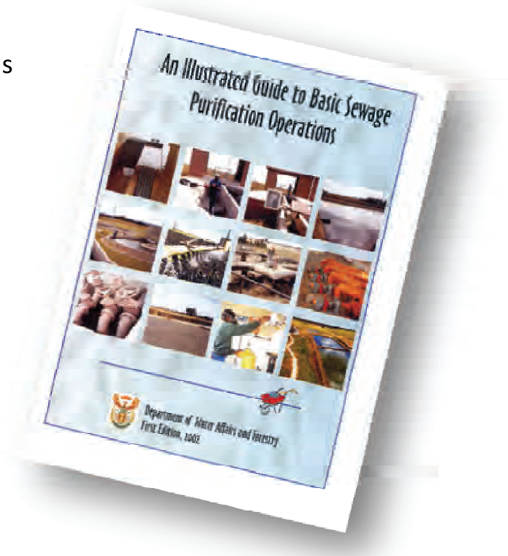
The focus of this section is more in relation to hazards relating to the treatment process which can lead to failure or ineffectual treatment and thereby create hazardous events / environmental impacts. Those hazards relating to worker and facility safety are dealt with under Section 5.6.

Hazard identification

Hazards may be introduced during treatment, or hazardous circumstances may allow contaminants to pass through treatment in significant concentrations, which is then released into the receiving environment as treated effluent. Hazard identification involves gathering and weighing the available evidence to determine whether a substance or constituent exhibits a particular adverse health hazard towards humans or the environment.

Examples of potential hazards and hazardous events that can have an impact on the performance of wastewater treatment include the following:

- flow and load variations that exceed their design limits;
- ineffectual / unsafe disposal of screenings and grit;
- inappropriate or insufficient treatment processes, including disinfection;
- insufficient or inadequate maintenance, i.e. lack of periodical desludging of settling tanks, fall railings, basic housekeeping, lack of regular condition inspection of equipment, motors, electrical units and infrastructure, etc.;
- inadequate backup or support resources (infrastructure, financial, human resources) and lack of contingencies plans;
- process control failure and malfunction or poor reliability of equipment;
- use of unapproved or contaminated water treatment chemicals and materials;
- chemical dosing failures;
- inadequate mixing;
- failure of alarms and monitoring equipment;
- power failures or extended interruptions;
- accidental and deliberate pollution; and
- natural disasters.



Control measures

Examples of generic treatment control measures include:

- reduce or divert excessive extraneous flows to the plant with disinfection;
- use of approved water treatment chemicals and materials;
- control of wastewater treatment chemicals;

- process controls at each process unit;
- ensure plant operate within design capacity;
- availability of backup systems and contingency plans;
- wastewater treatment process optimisation, including
    - chemical dosing
    - flow rate
- security to prevent unauthorised access and tampering.

Most of the control measures are in relation to ensuring the effective operation of the treatment system and can be identified for the various components which form the treatment system as indicated as follows:

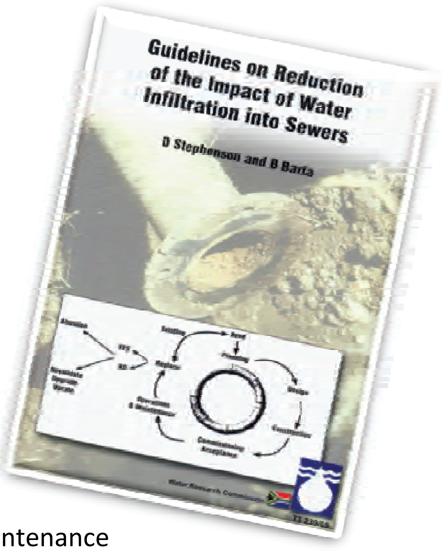
Wastewater collection and preliminary treatment

This component comprises of the safe transport of wastewater to a treatment facility, where removal of rags, sticks, floatables, grit and grease takes place that is likely to case maintenance or operational problems with the treatment operations, processes and ancillary systems.

Wastewater conveyance and pumpstations

Common problems reported on sewage pumpstations, which in could lead to hazardous situations, include:

- blockages;
- power failures;
- lack of routine inspections and condition analysis;
- lack of preventative maintenance;
- excess ingress of stormwater;
- inadequate redundancy/standby on pumps;
- pumps that are unsuitable for sewerage – certain types of pumps give chronic problems;
- level switches and controls are out of order;
- baskets and screens are not cleaned; and
- odour problems.



Most of these aspects can be resolved through preventative maintenance (infrastructural, mechanical and electrical) rather than reactive maintenance. Once of the most critical control measure would be to ensure that an adequate and planned maintenance programme is put in place. Including in this aspect would be ensuring that adequate budget is allocated to achieve this.

Other control measures include:

- the age of many of the existing systems and the need to replace them with more appropriate and current materials, i.e. changing from the old clay and concrete piping to uPVC and AC piping. The control measure in this situation would be to ensure that a capital replacement programme is developed AND supported by sufficient funds, either through grant or loan financing with cost recovery through the municipal rate structures;
- ensuring availability of backup power generation (generators, battery operated lights, solar panels, etc.), at the critical components, due to unstable electricity supply;
- ensure contingency plans are in place in cases of unforeseen incidents (e.g. bypass facility and handrake screens);
- implementing stormwater reduction activities, e.g. seal of manholes, replace manholes covers, removal of grit from sewers;
- use of telemetry on pumpstations (especially when station are unmanned);
- having standby equipment (pumps, etc.) available to put into action when breakage of equipment or maintenance breaks prevents the main equipment from being in use; and
- reconsidering the custom “one duty pump / one standby pump” arrangement with lower risk alternatives.

Screenings removal

The removal of screenings is typically achieved through either manual coarse and fine screens or mechanical screens, or a combination of screens. These screenings represent a biohazard and must be disposed in a responsible manner, without risk to the environment or threat to public health.

Control measures to address this aspect are:

- regular inspections to ensure that screenings are being removed reliably and effectively from the influent wastewater, if not, they can impact on the performance of down-stream processes and in the final effluent, which could lead to a hazardous situation;
- ensure that the disposal method of the screenings and grit have been formalised as a procedure, where necessary registered and permitted (i.e. burial, incineration, etc.), are being applied, are appropriate to the specific location and that adequate safety precautions such as restricted access, etc. are put in place; and
- ensure that medical waste and other classified waste is discharged at classified sites suitable for hazardous material intake and processing.

Grit removal

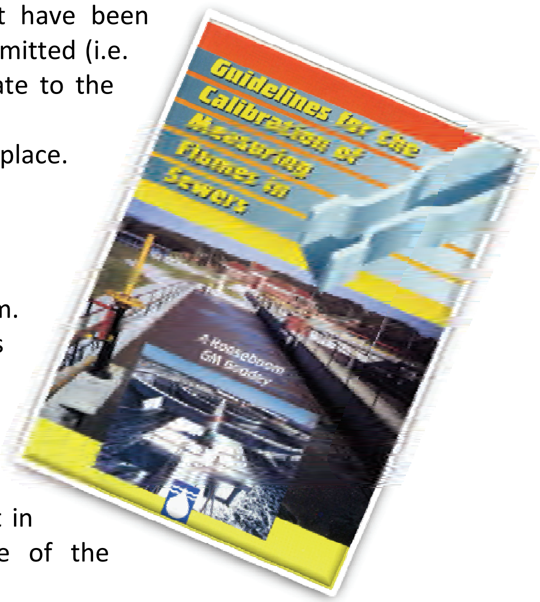
The removal of grit and detritus is achieved either manually using grit channels or using vortex grit tanks with mechanical equipment. Similar to screenings it has a biohazard potential and the grit/detritus must be disposed without risk to the environment or threat to public health.

Ineffectual grit removal can cause operational problems in downstream processes by:

- shortening the life of mechanical equipment such as pumps;
- accumulating in downstream unit processes, decreasing their efficiency.

Similar control measures as identified with screenings are applicable and could assist in reducing hazards and or potential to leading inadequate processing, which could then causes a potentially hazardous situation. These being:

- regular inspections to ensure that grit is being removed reliably and effectively from the influent wastewater, this includes checking that grit removal pumps and associated grit separation equipment are functioning and maintained;
- ensure that the disposal method of the screenings and grit have been formalised as a procedure, where necessary registered and permitted (i.e. burial, incineration, etc.), are being applied and are appropriate to the specific location; and
- adequate safety precautions such as restricted access are put in place.



Flow measurement

Flow measurement forms a critical element of the system. Continuous flow measurement assists in the planning for daily peaks and, in conjunction with the water quality data can be used to calculate the plant load and corresponding discharge loads. Ineffectual or non-existent flow measurements lead to potential hazards as the lack of, or incorrect flow information may lead to ineffectual management of the treatment process. This may result in insufficient treatment or overloading conditions causing failure of the treatment process.

Of particular importance is that flows are measured during dry and wet weather conditions, and that the flows during a normal day-week cycle be monitored to include nightflows. This data provides essential management information and informs proactive plans when excess flows are detected.

Common problems relating to ineffectual flow measurement are due to:

- absence of flow meters or manual measurement devices;
- removal of flow sensors and electronic counters and delays in replacing;
- vandalism;
- lack of calibration of meters and therefore, low credibility in flow data;
- lack of maintenance of flow sensors;
- lack of trained skilled process controllers to execute flow measurements; and
- lack for routine schedules/rosters to inspect and log meter readings.

Typical control measures would include:

- instituting effective stock-on hand and stock control procedures, by ensuring that critical replacement equipment is kept in stock and replaced when taken from stock, rather than obtaining items once they are broken;

- restricted access;
- regular maintenance schedules including the calibration of meters;
- development of sites rosters and flow measurement schedules;
- expand monitoring to include wet/dry and day/night flow measurements at more regulator frequencies; and
- training of process controllers to take and record readings and feed into management systems.

Primary treatment

This component comprises of the removal of a portion of the suspended solids and organic matter, with or without chemical addition or filtration.

Flow equalisation (aka balancing)

Although not necessarily required at all WWTW, wastewater flow balancing can assist in dealing with peak flow/load conditions during rain events or at daily peak flow events, and thereby optimisation of the treatment efficiency. The hazard potential existing in the situation where flow balancing is required but not available, relates to the overloading of the system and thus ineffectual treatment or even severe cases spillage/overflowing, which creates an immediate health hazard. The presence of flow equalisation can also cause hazards, especially odours when located near a residential area.

Typical control measures would include:

- maintaining effective flow measurement and record keeping to determine the extent and need for flow balancing; and
- developing control procedures for dealing with situations of temporary overloading, temporary diversions to secure attenuating holding facilities, i.e. tanks, etc.

Primary settling

Primary settling is the first barrier in ensuring that removal of readily available settleable solids and floating material takes place, thus reducing the solids content. Efficiently designed and operational settling tanks will remove 50-70% of TSS and 25-40% of BOD. Some designs also allow for stormwater retention for overflows from combine or storm sewers.

Most of the potential for hazardous situation and problems with primary settling tanks would relate to:

- the infrastructural condition of the settling tanks;
- primary sludge accumulation;
- short circuiting;

- hydraulic stability; and
- temperature and wind effects.

The control measure relate to:

- instituting effective preventative maintenance programmes;
- operational requirements such as routine desludging and optimal flow division amongst the available structures, based on performance analysis of the system (upflow rates, TSS, BOD, COD removal); and
- Proper design and configuration.

Ponds (Primary ponds)

Some plants make use of a pond system for primary wastewater treatment either followed by an integrated pond treatment system or secondary treatment systems. Poor preliminary treatment (specifically screenings removal), poor operations (no facility to remove sludge) and sometimes poor maintenance are some of the basic problems, which impact the effectiveness of the treatment process.

The same problems and control measures that apply under "integrated Pond Systems" (Section 5.2.3) also apply for primary pond systems.

Typical control measures that apply to primary ponds would include:

- screenings should be removed before the wastewater enters the primary pond;
- instituting sludge removal procedures on a periodical basis, and ensuring that removed sludge is disposed of responsibly and safely (refer to control measures for sludge removal in Section 5.3);
- developing effective maintenance procedures and schedules.

Secondary treatment

This component relates to the removal of biodegradable organic matter, suspended solids and nutrients (nitrogen, phosphorus). Disinfection may also be included in the definition of conventional secondary treatment.

Biofilters (aka Trickling Filters)

Trickling filters are robust biological treatment systems and have been widely used in South Africa. The design allows for a non-submerged fixed film reactor that uses packing material for bacterial attachment and treatment of the wastewater as the liquid flows over the attached biofilm. The problems experience by trickling filters mainly relates to distribution failure (poor flow distribution), equipment failure (poor condition of rotating distribution

arms), blockages, leakages, plugging and short circuiting. Clogging of the filters may also occur under certain conditions, significantly reducing the efficiency of the filters.

Typical control measures would include:

- developing effective maintenance methods which include but are not limited to flushing surface media, removing weeds and debris, cleaning and adjusting distribution arms and turning over of the surface media with hand tools;
- maintain optimal airflow (natural draft) or forced (controlled) ventilation using low-pressure fans;
- developing effective procedures for de-commissioning and re-commissioning, to ensure safe operation, which include work permit and lockout procedures.

Activated Sludge and Biological Nutrient Removal

This unit process employs an activated mass of microorganisms in a controlled environment where stabilising, settling and treatment of wastewater is possible. Recycle streams ensure that the necessary mass of organisms return to the treatment process, whilst waste activated sludge is removed from the system to keep the food:microorganism ratios optimal.

Strict guidelines and conditions control the management and disposal of sludge, as this technology constitute a potential biohazard through the presence of sewerage borne microorganisms (pathogens) and the use of microorganisms as biological treatment means. Ineffectiveness of activated sludge (AS) systems is linked to the following common problems:

- lack in competency of operational staff on the plant;
- mechanical aerators and mixers are not in working order;
- return activated sludge pumps are out of order;
- clarifiers are not operated adequately to achieve solids separation;
- grit and settleable solids carry over as result of the primary settling tanks not functional;
- sludge withdrawal for RAS (return AS) and WAS (waste AS) is not according to schedules;
- reactor mixed liquor solids concentration (Mixed liquor suspended solids – MLSS) is too low or too high;
- oxygen demand are not controlled over the anoxic and aerobic zones, or introduced to the anaerobic zones;
- activated sludge reactors are oversized / undersized;
- process configuration is not correctly applied or executed according to design and wastewater characteristics (food:microorganism ratios);
- excessive foam and scum formation;
- industrial loads, in particular shock loads, impacting on activated sludge performance; and
- insufficient funds to attend to maintenance and repairs, as this are a fairly expensive technology.

Control measures thus geared to the management of the process rather than specific hazard related control measures would include ensuring that all personnel are adequately trained, accredited and competent, in line with the requirements of the legislation.

Sludge management and disposal is discussed in Section 5.3 in more detail.

Integrated Pond Systems (aka lagoons)

Pond systems are shallow earthen basins (2-5 m deep), which operate on a flow through basis or with solids recycle and with/without aeration. When applying solids recycle, the same principles apply as for the activated sludge process.

Common problems associated with integrated ponds systems which lead to ineffective treatment and thus poses a hazard risk are:

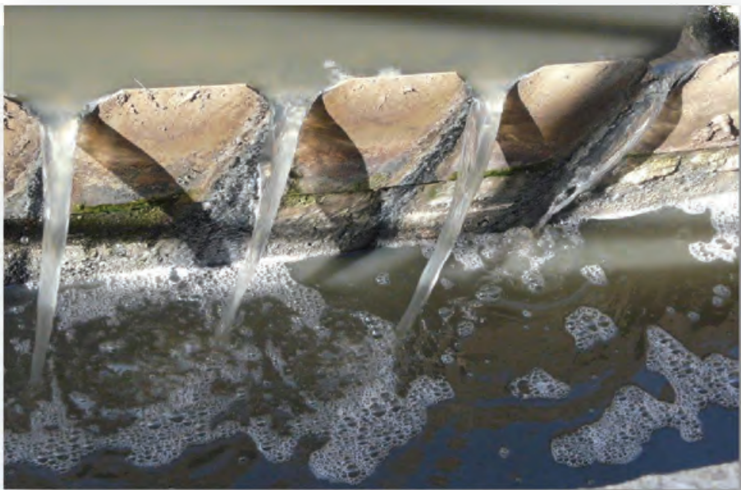
- inadequate screenings removal;
- overloading;
- insufficient primary pond capacity with inconvenient or inadequate sludge removal;
- floating aerators not working, due to age or lack of maintenance;
- leaking ponds and unlined ponds causing seepage into ground water;
- the ponds not maintained (overgrown with reeds, etc.);
- animals and the neighboring community have access to the ponds;
- excessive algal growth, impacting the effluent quality exiting from the pond; and
- ponds are often misperceived not to be 'treatment systems', and therefore not operated as such.

Applicable control measures have already been identified in the previous sections, which would include:

- optimising the input variable;
- developing effective maintenance procedures and schedules and ensure that they are implemented;
- lining of ponds to prevent contamination of groundwater and surface run-off;
- effective and safe sludge removal;
- scheduled harvesting of macro-algae biomass to allow for optimal nitrogen removal;
- basic housekeeping and care for terrain; and
- restricted access.

Secondary Settling / Clarification

Secondary settling is the final step in producing a well clarified, stable effluent low in BOD / COD and TSS. Much of the problems and control measures I primary settling tanks are applicable, however, the presence of large volume of flocculent solids in the mixed liquor requires additional control measures. These solids tend to form a sludge blanket in the bottom that will vary in thickness.



Control measures would include:

- design rectification, where deficiencies in tank type, surface and solids loading rates, depth);
- ensure even flow distribution
- weir maintenance; and
- scum removal.

Tertiary treatment

This component relates to the removal of residual suspended solids (after secondary treatment), usually by granular medium filtration or microscreens. Nutrient removal may also occur under this definition. Disinfection is typically part of tertiary treatment. Maturation ponds or wetland systems may also reside under this section due to its 'final polishing' functionality.

Chlorination (or other forms of chemical disinfection)

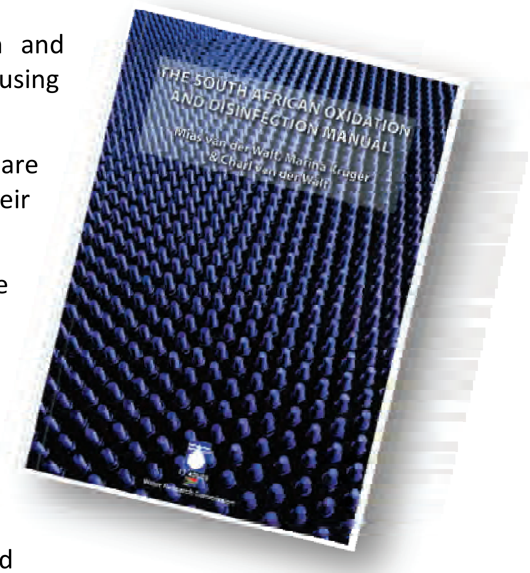
The poor performance of chlorine disinfection poses a serious hazard risk as this process typically acts as the final barrier between the plant and downstream water users. Inadequate disinfection constitutes a direct threat to public health by release of pathogens to the environment (under-dosing) or by formation of Disinfectant Byproducts (DBP), i.e. trihalomethanes (THM) in the presence of free (and combined) chlorine (over-dosing). The disinfection process unit represents a Critical Control Point (CCP) and is often included in the Disaster Management Plan. Disinfection problems and potential hazards related to chlorination include:

- chlorine gas cylinders are empty and are not replaced, stand-by cylinders for exchange are not held in stock;
- HTH is used to replace the chlorine gas dosing system, but is not regularly replaced/replenished;
- over and under dosing of chlorine gas;
- chlorine system design and installation is flawed;
- chlorine dosing is done on partially- or poorly treated wastewater and released directly into a stream;
- chlorination equipment is removed or by-passed; and
- chlorine contact tanks are partially filled with sludge.
- Incorrectly designed chlorination building, inappropriate or non functioning ventilation systems, emergency showers, etc.; and
- Regrowth (aftergrowth) of microorganisms after disinfection

☑ **Important Note:**
Chlorine gas is highly toxic even at low concentrations.

Control measures would include:

- controlling the organic precursors, free chlorine, pH, temperature, bromide, etc. to ensure optimal disinfection;
- maintain the required chlorine residual in final effluent, especially when reuse and reclamation of the effluent;
- developing and implementing stringent control mechanism and procedure regarding the use of chlorine and preferable not using gaseous chlorine systems;
- restricted access to relevant personnel, ensuring personnel are using PPE, and ensuring that personnel are competent in their functions;
- review of system design and management processes to ensure that system design is effective and safe, specifically if there are changing circumstances in terms of operational requirements and receiving influent quality. At minimum the system should be reviewed on an annual basis;
- developing effective maintenance procedures and schedules and ensure that they are implemented; and
- ensuring that the implementation of regular sampling and testing to measure the effectiveness of chlorination. Sampling and testing procedures are known and prescribed, but are not necessarily implemented.



Maturation Ponds

Poor performance of maturation ponds could also constitute a threat to public health. Pond systems are designed to achieve a degree of nitrogen and carbon removal, as well as disinfection. Problems, which can lead to hazardous situations, include:

- unrestricted access by people and animals, due to lack of access control;
- inadequate sludge removal causing maturation ponds to be partially filled with sludge;
- the maturation ponds are overgrown with vegetation; and
- Algal growth causes plant effluent quality compliance problems.

Similar control measures are applicable as for integrated ponds systems, which would include:

- developing effective maintenance procedures (infrastructural, mechanical & electrical) and schedules and ensure that they are implemented;

- effective and safe sludge removal;
- basic housekeeping and care for terrain;
- restricted access through fencing and education of surrounding community as to the health and safety dangers posed by accessing these areas; and
- ensuring effective retention time.

Advanced treatment

Advanced treatment is defined as the additional treatment needed to remove suspended, colloidal and dissolved constituents remaining after conventional treatment. Treatment requirements are becoming more stringent as potential toxic and biologically active constituents are being limited. Often, existing secondary process units are being refitted and new advanced treatment facilities constructed to meet stricter standards and for reuse requirements or direct potable reuse applications.

Technologies for advanced treatment are not discussed in detail but are vast: depth-, filter- or micro and ultra filtration, nanotechnology, electro-dialysis, adsorption, air stripping, ion exchange, advanced oxidation, distillation, chemical precipitation or oxidation. The most common problems encountered with advanced treatment are:

- scaling and corrosion due to precipitation of inorganic salts;
- sensitivity to effluent quality, e.g. high TSS or grease build up can plug treatment systems and result in high headlosses and inefficient operation;
- disposal of concentrated waste streams from membrane processes; and
- high competency of operational staff is required on the plant.

Control measures are thus geared to:

- competent control and management of the process;
- ensuring that all personnel are adequately trained, accredited and competent, in line with the requirements of the legislation;
- use of appropriate chemical and polymers to optimise treatment efficiency; and
- advanced treatment options are effluent specific and pilot testing is a prerequisite to foresee and prevent possible problems.

Nelson Mandela Bay

WASTEWATER RISK ABATEMENT PLAN
LIST OF HAZARD EVENTS - WASTEWATER TREATMENT

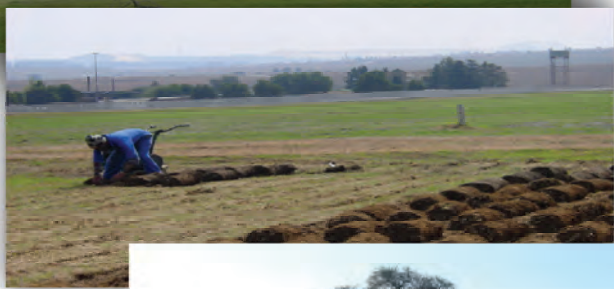
Section	No	Hazard event	Risk assessed	Control measure in place	Last updated
Wastewater Treatment: **Fishwater Flats**	2.1	Flow exceeds design limits of WwTW	Yes	Yes	Nov-10
	2.2	Biological loading exceeds design limits of WwTW	Yes	Yes	Nov-10
	2.3	Blockages on pipelines or channels	Yes	Yes	Nov-10
	2.4	Power failures	Yes	Yes	Nov-10
	2.5	Mechanical failures/Inadequate redundancy on pumps	Yes	Yes	Nov-10
	2.6	Odour problems	Yes	Yes	Nov-10
	2.7	Failure of screening and/or screenings removal	Yes	Yes	Nov-10
	2.8	Failure of grit removal	Yes	Yes	Nov-10
	2.9	Failure on flow measurement equipment	Yes	Yes	Nov-10
	2.10	Overloading of the system due to inadequate flow balancing	Yes	Yes	Nov-10
	2.11	Ineffectiveness of activated sludge system	Yes	Yes	Nov-10
	2.12	Inadequate sludge wasteage from bio-reactors (RAS & WAS)	Yes	Yes	Nov-10
	2.13	Mechanical failures - aerators & mixers	Yes	Yes	
	2.14	Failure to thicken sludge	[illegible]		
	2.15	Failure to stabilize sludge			
	2.16	Failure to de[illegible]			

WASTEWATER RISK ABATEMENT PLAN
ANNEXURE B3 - WASTEWATER TREATMENT - FISHWATER FLATS WWTW
FORM 3 - HAZARD & RISK ANALYSIS AND CONTROL MEASURES

No.	Hazard event	WWTW (area where hazard most evident)	Critical limit (trigger)	Probability	Severity	Risk rating	Preventive actions	Control measure (during an incident)	Validation of control measure	Critical control point/s	Risk rating (following corrective action)	Responsible person (Preventive actions)	Responsible person (Control Measure)	Reaction time (control measure)
2.7	Failure of screening and/or screenings removal	Inlet works/ screens	Plant not operational	Medium	High	High	Develop and implement a operations and maintenance plan that includes infrastructure replacement and backlog maintenance	Replace pipelines and provide adequate protection where problem persists	W$_2$RAP Standard Operating Procedures	Sewer manholes/ WWTW	Low	[illegible]	[illegible]	As per W$_2$RAP
2.8	Failure of grit removal	Degritters	Plant not operational	Medium	High	High	Develop and implement a operations and maintenance plan that includes infrastructure replacement and backlog maintenance	Replace pipelines and provide adequate protection where problem persists	W$_2$RAP Standard Operating Procedures	Sewer manholes/ WWTW	Low	[illegible]	[illegible]	As per W$_2$RAP

Table 7: Typical application of the risk tool to manage and track risk control measures at Nelson Mandela wastewater treatment plants

5.3 Sludge management and disposal



Sewage sludge is produced during the biological treatment of sewage and wastewater, originating from residential areas, trade and industrial premises. The sludge consists almost entirely of microorganisms, including pathogenic organisms, various metals as well as inorganic and organic chemicals. In order to protect humans, animals and the receiving environment, it is thus important to carefully consider the potentially dangerous and hazardous properties when considering the use or disposal of sewage sludge.

Historically in South Africa, sludge was classified in three main categories in a decreasing order of potential to cause odour nuisances and fly-breeding as well as to transmit pathogenic organisms to man and his environment. In addition there is a fourth category, which can be viewed as a sub-category of Type C. The categories as described in the guide "*Permissible Utilisation and Disposal of Sewage Sludge*" published by the Water Research Commission (TT 85/97) in August 1997 (Edition 1), also known as PUDSS 1997, are:

- TYPE A SLUDGE:

  Unstable with a high odour and fly nuisance potential; high content of pathogenic organisms.

- TYPE B SLUDGE:

  Stable with low odour and fly nuisance potential; reduced content of pathogenic organisms.

- TYPE C SLUDGE:

  Stable with insignificant odour and fly nuisance potential; containing insignificant numbers of pathogenic organisms.

- TYPE D SLUDGE:

  Sewage sludge included in this classification is of similar hygienic quality as TYPE C but since it is produced for unrestricted use on land at a maximum application rate of 8 dry t/ha.yr, the metal and inorganic content are limited to acceptable low levels. TYPE D SLUDGE products must be registered at the Registrar of Act 36 of 1947.

This process of classification has been replaced by new Sludge Management Guidelines:

New Sludge Management Guidelines

"*Guidelines for the Utilisation and Disposal of Wastewater Sludge Volumes 1 to 6*" outline the **new sludge management guidelines** which replace the previously used guidelines as from **March 2006**.

The new guidelines classify the sludge in terms of:

- Microbiological content
- Stability
- Organic & inorganic pollutants

The classification system is illustrated in Table 8 (Table 2 of the Guidelines Vol 1, Part 6), shown as below and described in the information that follows.

Table 8: Sludge Classification System

Microbial class	A	B	C
Stability class	1	2	3
Pollution class	a	b	c

The characterisation and classification should be repeated if any major sludge production or processing changes occur that could affect the classification. This could include:

- When major extensions are implemented at the wastewater treatment plant;
- When major operational changes are made at the wastewater treatment plant;
- When the raw influent quality to the wastewater treatment plant changes in such a way that the sludge quality could be affected. In other words, when any major new wastewater contributor starts/ceases to discharge to the plant."

Microbiological Class

The results of the microbiological analyses of the sludge samples can be used to determine the Microbiological Class as indicated in Table 9 (Table 3 of the Guidelines Vol 1, Part 6).

Table 9: Preliminary classification of sludge according to 'Microbiological Class'

Microbiological class	A	B		C
	All three samples comply with the following standard	Two of the three samples comply with the following standard	The sample that failed does not exceed the following standard	One or more of the samples exceed the following concentration
Faecal coliforms (CFU/g_{dry})	< 1000	< 1×10^6	1×10^7	> 1×10^7
Helminth ova (Total viable ova/g_{dry})	< 0.25 (or one viable ova/4g_{dry})	< 1	4	> 4

Stability Class

"Since the beneficial use of sludge is promoted in the Guidelines, the stability of the sludge is of utmost importance. Odour is often the only factor that influences public perception of sludge reuse. Very seldom does a member of the public register a concern or complain about sludge due to a concern related to food safety. They usually complain due to odours from the sludge spreading activity. If sewage sludge did not smell, the public would probably not complain and the overall public perception of the reuse of sludge would improve. The increased stability of sludge with associated lower odour risk should enable more wastewater treatment facilities to dispose of sludge beneficially."

Table 10 (Table 4 of the Guidelines Vol 1, Part 6) can be used to assign a preliminary stability class. Note that the stability class is based on what is planned for the future, or to classify according to the current sludge handling practice. It is possible to address stability issues at a later stage in a management practice. The Guidelines therefore recommend that a worst case stability class be assigned based on the current situation or management plan.

Table 10: Preliminary sludge classification according to "Stability Class"

Stability class	1	2	3
	Plan/design to comply with one of the options listed below on a 90 percentile basis.	Plan/design to comply with one of the options listed below on a 75 percentile basis.	No stabilisation or vector attraction reduction options required.
Vector attraction reduction options (Applicable to Stability class 1 and 2 only)			
Option 1	Reduce the mass of volatile solids by a minimum of 38 percent		
Option 2	Demonstrate vector attraction reduction with additional anaerobic digestion in a bench-scale unit		
Option 3	Demonstrate vector attraction reduction with additional aerobic digestion in a bench-scale unit		
Option 4	Meet a specific oxygen uptake rate for aerobically treated sludge		
Option 5	Use aerobic processes at a temperature greater than 40°C (average temperature 45°C) for 14 days or longer (eg during sludge composting)		
Option 6	Add alkaline material to raise the pH under specific conditions		
Option 7	Reduce moisture content of sludge that do not contain unstabilised solids (from treatment processes other than primary treatment) to at least 75 percent solids		
Option 8	Reduce moisture content of sludge with unstabilised solids to at least 90 percent solids		
Option 9	Inject sludge beneath the soil surface within a specified time, depending on the level of pathogen treatment		
Option 10	Incorporate sludge applied to or placed on the surface of the land within specified time periods after application to or placement on the surface of the land		

Pollutant Class

"The organic and inorganic pollutant limits and load restrictions will vary for different applications. For example, the pollutant limits applicable for agricultural use of sludge will be completely different to those pertaining to landfill or incineration. The requirements for sampling and analysis would also be different for each option.

However, it is important to have an indication of the pollutant class for planning purposes. To do a preliminary classification, it is recommended that the metal limits designed for the agricultural use of sludge are used. Table 11 (Table 5 of the Guidelines Vol 1, Part 6) can be used to assign a preliminary pollutant class for the eight (8) metals based on the results from the three sludge samples collected and analysed (according to Table 1 in Part 5 of the Guideline)."

Table 11: Preliminary sludge classification according to "Pollutant Class"

Metal limits for South African Wastewater Sludges (mg/kg)			
Pollutant class	**a**	**b**	**c**
Arsenic (As)	<40	40 - 75	>75
Cadmium (Cd)	<40	40 - 85	>85
Chromium (Cr)	<1200	1200 - 3000	>3000
Copper (Cu)	<1500	1500 - 4300	>4300
Lead (Pb)	<300	300 - 840	>840
Mercury (Hg)	<15	15 - 55	>55
Nickel (Ni)	<420	420	>420
Zinc (Zn)	<2800	2800 - 7500	>7500
Benchmark Metal Values (mg/kg)			
Pollutant class	**a**	**b**	**c**
Antimony (Sb)	<1.1	1.1 - 7	>7
Boron (B)	<23	23 - 72	>72
Barium (Ba)	<108	108 - 250	>250
Beryllium (Be)	<0.8	0.8 - 7	>7
Cobalt (Co)	<5	5 - 38	>38
Manganese (Mn)	<260	260 - 1225	>1225
Molybdenum (Mo)	<1	1 - 12	>12
Selenium (Se)	<5	5 - 15	>15
Strontium (Sr)	<84	84 - 205	>205
Thallium (Tl)	<0.03	0.03 - 0.14	>0.14
Vanadium (V)	<85	85 - 430	>430

The sampling procedure (number of samples, sampling frequency and sample location) for the classification of sludge is the same as for the monitoring of the sludge.

Sewage sludge from sewage works falls under the definition of waste and falls under the authority of Department of Water Affairs and its relevant legislation due to the potential impact on the water resource. There are clear guidelines as to the manner in which waste should be disposed of as set out in the Department's Waste Management Series, "Minimum Requirements" documents. To date, three documents have been published. These are: *"Minimum Requirements (1998) for the Handling, Classification and Disposal of Hazardous Waste", "Minimum Requirements (1998) for Waste Disposal by Landfill",* and *"Minimum Requirements (1998) for Water Quality Monitoring at Waste Disposal Facilities"*.

Hazard identification

Although there is significant potential for the beneficial use of wastewater sludge, it needs to be recognised that not all sludge can be used beneficially and where the wastewater sludge cannot be used as a resource, it needs to be disposed of in a responsible manner. Due to the impact of industrial effluent, through the addition of heavy metals, the domestic sewage and the corresponding sludge are further rendered potentially hazardous.

In the Water Research Commission Report on the project: "*An evaluation of dedicated land disposal practices for sewage sludge* " (March 2005), it is identified that most of the wastewater treatment facilities in South Africa dispose of their sewage sludge on dedicated land disposal (DLD) sites (sacrificial lands), since this is the quickest and most inexpensive way to discharge of the waste. The sludge is regularly applied at high rates to the surface soils. No crops are grown and the land is only used for the disposal of sewage sludge. The impact of this practice on the environment is believed to be negative, but more research is required to determine the extent of the damage to the soil and water resources.

Negative impact can be caused by erosion and run-off after rainstorms that will cause surface water pollution. The groundwater may also be contaminated due to the movement of heavy metals and nitrogen through the soil. It should also be determined whether the same set of guidelines for the maximum permissible levels of heavy metals in soils should be used for DLD areas as for agricultural land.

Stockpiling is a common practice used by most of the wastewater treatment facilities, either as the only disposal method or a means to store the dried sludge until it is utilised by farmers and municipalities, disposed off at landfill sites or is composted. Liquid sludge is applied to soils of the remaining disposal sites. This includes practices like irrigation, flooding, sludge ponds l lagoon, instant lawn irrigation and paddies.

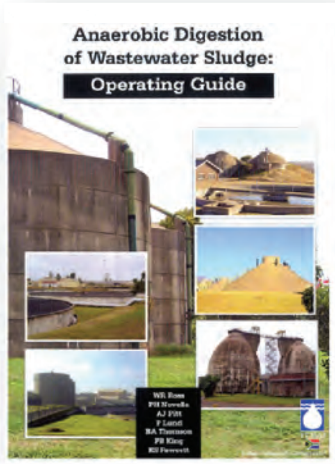
Control measures

Most countries follow a similar approach to protect its public from infection caused by pathogens originating from wastewater sludge. The use of wastewater sludge is regulated, which would define and stipulate how sludge should be disinfected and through prescribed management practices related to the potential of infection.

Some control measures would include:

- clearly demarcating the sludge disposal areas and ensure that restrictive access is maintained;
- set up procedures for continuous groundwater and surface water monitoring, as well as soil condition monitoring at various soil depths;
- ensure effective erosion control measures, where necessary;
- ensure sound management practices at the disposal site to regulate disposal;
- do not allow disposal on sandy soils, and ensure that disposal is at a safe distance from water bodies, etc.;
- nitrogen should be considered in the guideline for sludge disposal because it poses a bigger threat than the metals;
- monitor for the accumulation of heavy metal in the soil; and
- guidelines should be set for DLD specifically.

In the South African context an effective guideline for sludge disposal has been made available by the Water Research Commission in "*Guidelines for the Utilisation and Disposal of Wastewater Sludge: Volume 3: Requirements for the on-site and off-site disposal of sludge*" (WRC Report No. TT 349/09 – June 2009).

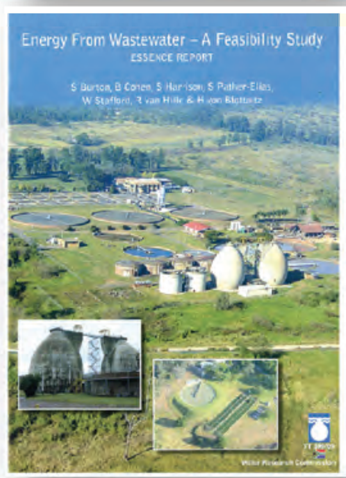


A control measure with regard to heavy metals, as supported by legislation, is to force the industries to develop their own Cleaner Production Systems (CPS) in order to recover some of the metals that are lost through the sewer. Controlling this at source is imperative to succeed in mitigating the impacts of heavy metals in wastewater.

Sludge Treatment

Wastewater sludge constitutes mainly the solids removed during the wastewater treatment processes and includes:

- Raw or primary sludge from a primary clarifier
- Primary sludge from an elutriation process *(elutriation: decanting or racking off by means of water, as finer particles from heavier)*
- Anaerobically digested sludge, both heated and cold digestion
- Oxidation pond sludge
- Septic tank sludge and other sludge from on-site sanitation units
- Surplus or waste activated sludge
- Humus sludge
- Pasteurised sludge
- Heat-treated sludge
- Lime-stabilised sludge.



The treatment of wastewater sludge consists of a combination of processes such as sludge thickening, sludge stabilisation, dewatering, composting, etc. Each form of treatment will not be discussed in the Guideline, but needs to be assessed and identified as a potential risk. The appropriate control measures must be put in place. Specific sludge handling facilities are often Critical Control Points. Rupture of sludge lagoon walls and breakdown of sludge pumpstations are potentially high risk areas with high likelihood and consequence ratings.

The various treatment processes are shown below.

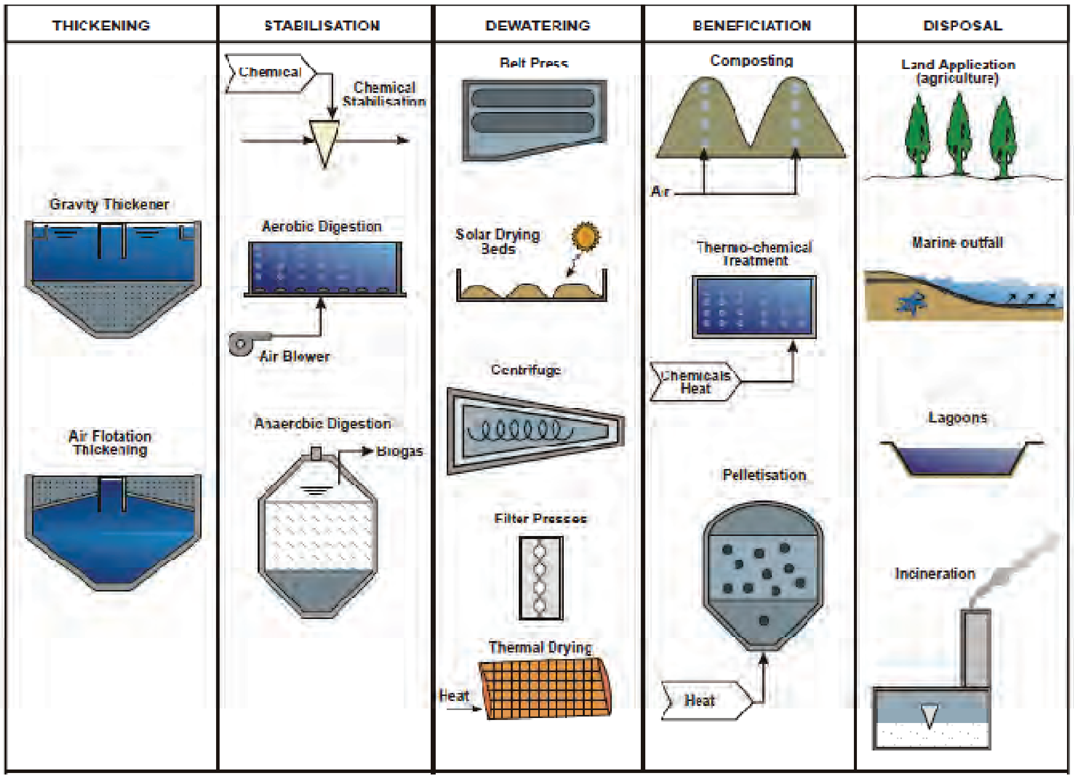


Figure 12: Various sludge treatment processes/methods, as described in WRC Report TT 375/08)

5.4 Effluent returned to catchment

Most of the potential hazards relating to the discharge of effluent into the receiving resource environment, either through direct discharge or through irrigation, relate to ineffective treatment, which thus creates a hazard potential to either the downstream user of the river and or environment. The expected constituents that are being removed via the various process units include: suspended solids, biodegradable organics, nutrients (phosphorus, nitrogen or both), pathogens, colloidal and dissolved solids, volatile organic compounds and odours.

Control measures for these have been identified in the previous sections.

However, because of the changing face of wastewater where domestic municipal wastewater has gradually come to contain increased industrial wastewater, the character of wastewater changed as well. The amounts of heavy metals and synthesised organic compounds have increased, and constituents that were previously undetected, are now detectable and raises concerns. Examples of constituents that represent hazardous circumstances and may have to be catered for in future include: medically active substances such as endocrine disruptors, pesticides, phenolic compounds commonly found in nonionic surfactants, NDMA (*n*-nitrosodimethlamine) and MTBE (methyl tertiary butyl ether).

Hazard identification

Hazards may be introduced post-treatment, or hazardous circumstances may allow contaminants to enter the treated effluent. This is often linked to unsafe operating practices of locating sludge disposal, or stock piling of screenings too close to the discharge channel, allow for the potential re-infection of the treated water. The changing face of industrial constituents and its impact and occurrence in municipal wastewater is also noted, and future technology and regulations may have to be designed to address these.

Control measures

Control measures in terms of preventing re-contamination of treated effluent have been identified in previous sections and relate to safe disposal and storage of sludge and screening or grit residue. Additional measures that can be taken are to:

- monitor water quality upstream and downstream of discharge point, which would provide an indicator of potential contamination, when compared to the quality monitoring during and at the end of the process, just prior to discharge.
- use of natural barriers, such as wetland polishing, or sand filters, can assist in further improving effluent quality if necessary.

In terms of irrigation with wastewater, the necessary monitoring processes are discussed in Section 2(7) and the controls measures could include:

- ensuring that sampling and testing is taking place prior to use to ensure that it complies with the safety and legal requirements;
- where necessary additional disinfection can take place prior to use, through inline chlorination of the irrigation system.

5.5 Wastewater reclamation and reuse

The inclusion of planned water reclamation, recycling and reuse in water resource systems reflects the increasing scarcity of water sources to meet societal demands, technological advancement, increased public acceptance and improved understanding of public health risks. Concerns about potential health effects are slowly being outweighed by plans and technologies that cater for reuse beyond agriculture and landscape irrigation, groundwater recharge for repelling saltwater intrusion and non-potable industrial uses. An example of this with Beaufort West town where the municipality has indicated that the reuse of treated sewerage effluent will augment water supplies from January 2011.

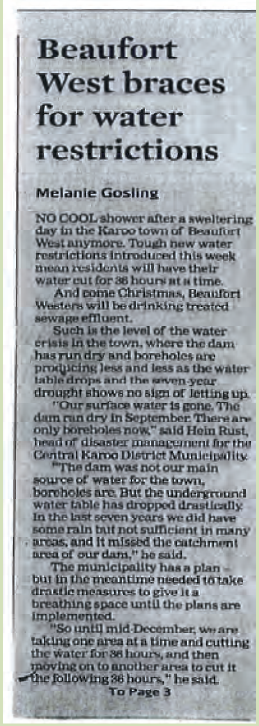
The following categories of municipal wastewater reuse include:

- agricultural irrigation, crop irrigation and commercial nurseries;
- landscape irrigation, parks, school yard, freeway medians, golf courses, cemeteries, green belts and residential;
- industrial recycling and reuse, cooling water, boiler feed, process water and heavy construction;
- groundwater recharge, groundwater replenishment, march enhancement, stream-flow augmentation, fisheries;
- non-potable urban uses, fire protection, air conditioning, toilet flushing; and
- potable reuse, blending in water supply reservoirs, pipe-to-pipe water supply.

NOTE: ISO STANDARDS ARE CURRENTLY DEVELOPED FOR THE REUSE AND RECLAMATION OF EFFLUENTS (2010-2012)

Case Study: Beaufort West

The municipality servicing Beaufort West Town needs to identify alternative water sources to augment the water supply system to the town. For the first time the municipality must consider the use of treated sewer effluent.



Beaufort West braces for water restrictions

Melanie Gosling

NO COOL shower after a sweltering day in the Karoo town of Beaufort West anymore. Tough new water restrictions introduced this week mean residents will have their water cut for 38 hours at a time.

And come Christmas, Beaufort Westers will be drinking treated sewage effluent.

Such is the level of the water crisis in the town, where the dam has run dry and boreholes are producing less and less as the water table drops and the seven-year drought shows no sign of letting up.

"Our surface water is gone. The dam ran dry in September. There are only boreholes now," said Hein Rust, head of disaster management for the Central Karoo District Municipality.

"The dam was not our main source of water for the town, boreholes are. But the underground water table has dropped drastically. In the last seven years we did have some rain but not sufficient in many areas, and it missed the catchment area of our dam," he said.

The municipality has a plan – but in the meantime needed to take drastic measures to give it a breathing space until the plans are implemented.

"So until mid-December, we are taking one area at a time and cutting the water for 38 hours, and then moving on to another area to cut it the following 38 hours," he said.

To Page 3

TECHNICAL MANAGEMENT BOARD RESOLUTION 141/2009
NWIP Standard for treated wastewater reuses implementation

… for a standard on treated wastewater reuse implementation…
Requests that SII (Israel) organize a preliminary meeting and provide the TMB with a report and recommendations of the meeting.

Hazard identification

Hazards associate with wastewater reuse are numerous and need to be controlled effectively:

- surface and groundwater contamination if not controlled;
- marketability of crops and public acceptance;

- public health concerns related to pathogen transmission, especially enteric viruses;
- constituents related to scaling, corrosion, biological growth and fouling;
- for most developing regions, the presence of intestinal nematodes (*Ascaris, Tricuris*, hookworms);
- cross-connection of potable and reclaimed water lines; and
- toxicity of organic chemicals in reclaimed water.

Control measures

Control measures are specific to the application of reused wastewater, but can be listed broadly as follows:

- water quality guidelines for the specific reuse categories, whereby each category have suggested levels of treatment, minimum reclaimed water quality, water monitoring and setback distances;
- regulations strategies that encourage responsible reuse as alternative water resource and water conservation, but with primary focus on public health;
- accepting that the practice of using reclaimed wastewater is not risk-free, and plan according to the risk applicable to the reuse application;
- defining the acceptable level of risk as per the regulatory agency responsible for health and environmental risk management and endorsement by the public as part of integrated water resource management;

- avoid consumption of uncooked crops;
- optimise design of ponds system to include a series of pond systems with higher surface area;
- safety measures for non-potable reuse applications to include;

    separate storage and distribution systems for potable water

    use of colour-coded pipes (normally purple) and labels to distinguish reclaimed water from potable water piping

    cross connection and back flow prevention devices

    periodic use of tracer dyes to detect occurrence of cross contamination in potable supplies irrigation during off hours to minimise human contact.

The question is posed whether science is sufficiently advanced to undertake risk-based decisions in water reuse practice. It is however, critical that the issues of reclaimed water quality and the corresponding exposure risks must be addressed if the safety of reuse practices is to be debated on a rational basis.

5.6 Facility Safety Guidelines and Worker protection

Historically, the wastewater treatment industry has three major safety concerns:

- confined space entry;
- lack of lockout/tagout; and
- personnel protective equipment (PPE).

All three safety concerns cover very specific issues—and all are equally important. Methods of defense against some of these life-threatening conditions include air monitoring, proper ventilation, respiratory protection and fall protection.

In addition to these there is also the aspect of personal sanitation habits and attitude which, with the lack thereof, can lead to potentially hazardous situations.

Hazard identification

Confined Spaces:

Confined space is one of the most critical hazards related to the wastewater-treatment industry and although there are many dangers associated with it, one of the primary hazards is atmospheric.

Recognising the potential hazards of confined spaces as a major threat can mean the difference between life and death. Depending on individual sites, the following locations have the potential to be considered confined spaces in the wastewater-treatment industry:

- sewers,
- pipelines
- manholes
- aeration basins
- digesters
- applicator machines
- primary tanks
- vaulted sampling pits
- storage tanks
- wetwells

- pumpstations.

Additionally, atmospheric hazards may exist in other areas where wastewater or wastewater residues (biosolids, sludge) are processed. As a result of the natural decomposition and treatment of wastewater or wastewater residues, gases are produced and or consumed. Examples of the gases produced include methane, hydrogen sulfide, and carbon dioxide. Additionally, oxygen may be displaced or consumed by organisms thus resulting in an oxygen depleted atmosphere. Atmospheric hazards can also come from industrial or commercial sources as well. There are documented cases of gasoline finding its way into sewer systems.

Lack of Lockout/Tagout:

Another potential hazard encountered during routine maintenance, inspections, repairs and testing is electrocution or mechanical hazards due to energising circuits on equipment being repaired or serviced where there is no Lockout/Tagout system in place. "Lockout/Tagout (LOTO)" refers to specific practices and procedures to safeguard employees from the unexpected energisation or startup of machinery and equipment, or the release of hazardous energy during service or maintenance activities. This requires that a designated individual turns off and disconnects the machinery or equipment from its energy source(s) before performing service or maintenance and that the authorised employee(s) either lock or tag the energy-isolating device(s) to prevent the release of hazardous energy and take steps to verify that the energy has been isolated effectively.

Personal hazards:

A wastewater treatment facility presents a variety of different personal hazards to an employee. These include, but are not limited to:

- machines or operations present the hazard of flying objects, glare, liquids, injurious radiation, or a combination of these hazards;
- potential for injury to the head from falling objects;
- potential for foot injuries due to falling or rolling objects, or objects piercing the sole, and electrocution, where such employee’s feet are exposed to electrical hazards;
- contamination / infection by water borne diseases;
- a worker falling in wastewater system; and
- injuries from heavy lifting in wastewater treatment facilities. Most equipment found in wastewater systems is quite heavy. Proper techniques for lifting objects are necessary to prevent injury. Crush injuries from this equipment is a threat as well.

Control measures

There are a number of potential control measures which could assist in securing the safety of the worker:

Confined Spaces:

The potential for deadly environments exists in confined space areas. Workers need to be able to identify and deal with hazards associated with confined spaces. It is recommended that wastewater workers obtain and follow all OSHA (Occupational Safety and Health Act) requirements for working in confined spaces.

The use of personal gas detection equipment while working in a wastewater facility is recommended. The use of fixed or permanent mounted gas detection equipment (in addition to personal gas detection) will also protect property and lives. It is further recommended that such gas detection equipment is calibrated and maintained as per manufacturers' recommendations. **Atmospheric and explosion hazards** * (especially methane) are especially prevalent at facilities that utilise anaerobic digestion in their treatment process. Controlling gas as vapor concentrations outside the explosive limits is a major consideration in occupational safety and health. Methods used to control the concentration of the potentially explosive gas or vapor include:

- use of sweep gas, an unreactive gas such as nitrogen or argon to dilute the explosive gas before coming in contact with air; and
- use of scrubbers or adsorption resins to remove explosive gases before releases is also common.

***Flammability limit:** Flammable proportion of combustible gases in mixture, between which limits this mixture is flammable. References use the term flammability limit (LFL, UFL) and explosive limit (LEL, UEL) interchangeably. **Lower Explosive limit** (LEL): The Explosive limit of a gas or a vapor is the limiting concentration (in air) that is needed for the gas to ignite and explode. Methane gas has a LEL of 4.4% (at 138 ^{0}C) by volume, meaning 4.4% of the total volume of the air consists of methane. At 20^{0}C the LEL is 5.1% by volume. If the atmosphere has less that 5.1% methane, an explosion cannot occur even if a source is ignition is present. When methane (CH_4) concentration reaches 5.1% an explosion can occur if there is an ignition source.*

***Important**: Percentage reading on combustible air monitors should not be confused with the LEL concentrations. A 5% displayed LEL reading for methane, for example, would be equivalent to 5.1% multiplied by 5%, or approximately 0.25% methane by volume at 20^{0}C.*

Higher temperature results in lower LFL and higher UFL, while greater pressure increases both values. Oxygen enriched atmospheres lower the LFL and increases the UFL. An atmosphere devoid of an oxidiser is neither flammable or explosive regardless of the fuel gas concentration.

***Dust:** Dust also has upper and lower explosion limits, though the upper limits are hard to measure and of little practical importance. Lower explosive limits for many organic materials are in the range of 10-50 g/m^3.*

Table 12: Flammable limits of gas types associated with wastewater systems

Substance	LFL/LEL in % by volume of air	UFL/UEL in % by volume of air	NFPA Class	Flash point	Minimum Ignition Energy in mJ expressed as percent by volume in air
Diesel fuel	0.6	7.5	IIIA	>62°C (143°F)	
Hydrogen sulfide	4.3	46	IA	Flammable gas	0.068
Methane (Natural Gas)	4.4-5	15-17	IA	Flammable gas	0.21 @ 8.5%
Propane	2.1	9.5-10.1	IA	Flammable gas	0.25 @ 5.2% (in pure oxygen 0.0021)

Identifying and properly marking a confined space would also assist in providing safety for persons working in a wastewater-treatment facility. Several of these locations are below ground level and have stair / ladder entry for access to routine maintenance, inspection, testing, sampling and repairs. The level of fall protection necessary depends on the facility and their required activities and job tasks being performed. Full-body harnesses, ladder safety systems, tripods and hoists are among the more important fall protection products frequently used. Although some of the locations identified above may not be deemed a confined space (according to regulations), many facilities lean toward the side of safety and do treat them as confined spaces.

Although the use of fall protection devices can prevent serious injury, good housekeeping can help by removing slipping or tripping hazards.

Lockout/Tagout:

Lockout/Tagout is important and should be an integral part of a confined space safety program to prevent accidental starting of equipment. It plays an important role in system testing, inspections, servicing/ repairs and routine maintenance by ensuring that energised equipment and/or a system is de-energised/ shut down and then locked out and tagged. Most activities requiring lockout/tagout are applications that require de-energising an electrical source that provides power to a system or equipment components within the system. To name a few, these may include pumps, electrical motors, valves and mixing systems. The remaining activities include lock-out/ tagout of pipelines/systems and valves in which the energised source of potential danger could be water entry, high water pressure, air pressure and/or steam. For example, valves to process tanks should also be locked to prevent accidental flooding during maintenance.

> ☑ **Important Note:** PPE is **only one aspect** of a comprehensive program for ensuring the safety and health of workers. Careful planning, work practices and engineering controls (isolation) and administrative (avoidance) controls should be considered to reduce the worker exposures.

Personal hazards:

Employees depend on a variety of Personnel Protective Equipment (PPE) to protect themselves from hazards and perform daily job functions. PPE includes—but is not limited to—safety glasses, face shields, hard hats, gloves, waders, foot protection and both durable and disposable chemical-protective clothing. Respiratory and fall protection may also be required however, these two fall under separate OSHA standards.

In order to properly determine what type of PPE employees need, the employer should (often this is legislated) perform a hazard assessment or a walk-through survey of each work area and certify that it has been done. The survey should consider the following: impact, penetration, compression (roll-over), chemicals, heat, harmful dust, light (optical) radiation. After the survey is complete, the employer shall select the proper PPE to suit the hazard.

Once the need for PPE is established, a careful evaluation of the hazards is necessary so that a selection can be made that minimises the risk to the user. For chemical situations knowing the hazard includes: being aware of the type of chemical; its physical state (liquid, solid or gas); and the physiological effect (i.e. toxin, carcinogen, asphyxiate, corrosive, etc.). Knowing the level of exposure is also important. The requirements for each type of personal protective equipment, as well as additional selection criteria follow.

Eye and Face Protection

Protective safety glasses, goggles and face shields are required where machines or operations present the hazard of flying objects, glare, liquids, injurious radiation, or a combination of these hazards. Goggles offer the most complete impact protection because they form a seal around the eye area—keeping dangerous objects out. They also prevent tiny dust particles, chemical splashes and vapors from getting in the eyes.

Head Protection

It is recommended that affected employees should wear protective helmets when working in areas where there is a potential for injury to the head from falling objects. This also relates to conditions where electrical hazards are present.

Foot Protection

It needs to be ensured that each affected employee should wear protective footwear when working in areas where there is a danger of foot injuries due to falling or rolling objects, or objects piercing the sole, and where such employee's feet are exposed to electrical hazards.

Hand Protection

Employers should select appropriate hand protection for employees exposed to hazards such as those from skin absorption of harmful substances, severe cuts or lacerations, severe abrasions, punctures, chemical burns, thermal burns and temperature extremes. When choosing the proper glove, it is necessary to match material with each application or task. This includes assessing the job for chemical exposures and then selecting the appropriate glove based on material, thickness, length and other traits.

Clothing

Chemical resistance and suit design need to be considered when selecting appropriate chemical protective clothing. Chemical resistance data is frequently published and available from many manufacturers and distributors. Unpublished data may also be requested from the manufacturer. Suit design deals with how the garment is assembled, designed and how it fits. Suits may also be selected of durable or disposable materials depending on the chemical and its permeation and breakthrough data.

Respiratory Protection

A system of local and/or general exhaust is recommended to keep exposure below the airborne exposure limits. If the exposure limit is exceeded, the use of a one-half or full-face air purifying respirator with a cartridge, worn in accordance to specified exposure limit, or to the maximum use concentration specified by the appropriate regulatory agency or respirator supplier—whichever is lowest.

For emergencies or instances where exposure levels are unknown, use a full-face piece, pressure-demand supplied-air respirator with an egress bottle. A self-contained breathing apparatus is also appropriate for this application.

As with any personal protective equipment, employees should be trained in several aspects of PPE. These include (but are not limited to) when PPE must be worn; what type of PPE is necessary; how to properly adjust, wear and remove PPR; limitations of PPE; the care and maintenance; and useful life and disposal of PPE. In addition, hazard areas must undergo a hazard assessment any time there is a process change, new equipment bring used or when accident statistics point to a problem area.

Chemical Storage and Handling

Chemicals play an important role in many aspects of wastewater treatment. By minimising the quantity of stored chemicals, such as chlorine, the inherent hazards of chemicals can be reduced. However, when chemicals must be retained / stored, in-house proper storage and handling can reduce or eliminate associated risks. Chemicals should be properly labeled and stored according to information specified on the Material Safety Data Sheet (MSDS). Emergency equipment should also be taken into account when storing or handling chemicals. The equipment includes—but is not limited to—first aid supplies, emergency phone numbers, eyewash and shower facilities, fire extinguishers, spill cleanup supplies and personal protective equipment; all of which should be readily available.

Laboratory /Environmental Sampling

Practicing safety in the laboratory involves more than just keeping the laboratory area clean and wearing proper protective equipment. It requires the cooperation and involvement of everyone associated with laboratory work. Examples of equipment that could be of assistance in ensuring safety in the laboratory include, acid storage cabinets, emergency deluge showers, eye wash stations, appropriate fire extinguishers, fire blanket, fume hoods and spill cleanup kits.

Eating, smoking or drinking in the laboratory should be discouraged. Neither should unsafe practices such as pipetting by mouth be allowed as many reagents are corrosive and/or poisonous. Other unsafe practices that should not be allowed are storing food in the same refrigerator with reagents or samples and cleaning up all spills promptly using the appropriate materials. All reagents and products in a laboratory should be clearly labeled. Strict guidelines for laboratory safety including aspects such as having a chemical hygiene plan and providing employees with training and information should be in place.

Wastewater treatment includes testing for pH, turbidity, dissolved chemicals, hardness, colour, alkalinity, chlorine, ammonia, nitrates and nitrites, and phosphate. The testing involves following designated test procedures. Maintaining and controlling levels is essential to the wastewater-treatment in order to produce safe effluent. The first step in controlling these levels is measuring it. For example, pH can be measured by various methods including pH paper, digital readout pocket testers, and portable and bench top meters. In wastewater-treatment facilities where accuracy is required, portable meters are a good choice over the pocket pH tester. Most portable meters are larger than pocket testers, are more durable and are best suited for accurate pH readings in the field.

Wastewater treatment operations fall under many specific regulations that apply to all site personnel. Developing written safety procedures that are specific to the worksite in order to be in compliance is critical. Regardless of the many safety issues that pertain to wastewater treatment workplaces, training and enforcing the safety procedures and processes is most critical to ensure the safety of employees. Regular health checks, assisted by medical employee cards that stipulate the hazards that the employee is exposed to, is a good management practice.

Contamination prevention and basic hygiene:

It is recommended that wastewater practitioners and workers should be current on their tetanus-diphtheria immunisation. An area which still requires clarity is the need for vaccination in terms of hepatitis A for workers. There may be some potential risk for water borne pathogens and one of the best defenses against water borne disease for sewage workers is to practice good hygiene and good housekeeping. These include, but are not limited to:

- Workers at wastewater facilities should wash their hands frequently with anti-bacterial soap. Be sure to wash thoroughly and scrub under nails with a brush. Especially be sure to wash up before eating, smoking or drinking. **Formalised facilities for such purposes must be available.**
- Open cuts or wounds should be protected, be sure to replace contaminated dressings.
- Avoid direct contact with wastewater through the wearing of rubber gloves and protective clothing when working with wastewater.
- Workers should not wear contaminated or soiled clothing. Work clothes must be washed regularly to remove contaminants. It is suggested that work clothing for wastewater workers be washed on-site, it is not recommended that workers are allowed to take/wear sewage contaminated clothing home. Similarly, work clothing (and work boots) should remain at work. Bringing the contaminated clothing home may expose other family members to pathogens. It is also recommended that facilities are made available and workers be encouraged to take a shower at the end of their shift.
- Situations may arise where substantial amounts of wastewater or wastewater residues falls onto workers. In such events where a worker gets sprayed or soaked down with sewage or sewage residues, they must change clothes and take a shower.
- Workers should be encouraged to keep their fingernails short and not to bite their nails, or stick their fingers or hands in their mouth, nose, eyes or ears.
- Regular “Toolbox Talks” need to be part of the safety programme at a works covering the above aspects.
- Regular medical surveillance (regular physical examination) is also recommended and may even be a necessity especially for workers who are exposed to hazardous materials.

All facilities should develop plans on how to deal with emergencies. Examples of emergency plan aspects which need to be included are aspects such as fire, explosion, flood, and spills into the sewer system, chemical releases, severe weather, medical emergencies, or other natural and manmade disasters. It is recommended to occasionally test and update plans, especially where plans involve the interaction of several agencies or groups. Voluntary employee emergency information sheets can provide emergency medical workers with valuable information about the injured person (especially if they are unconscious). Medical information is a private matter and needs to be kept confidential.

5.7 Non-reticulated wastewater systems

This aspect relates to community and/or household managed systems being:

- non-reticulated systems such as VIP toilets, septic tanks and conservancy tanks;
- on-site treatment plants (aka package plants):

Some areas have no access to full waterborne sewage systems and the soil conditions often do not permit the use of septic tank/soak-away systems. In such events the only option is, to install conservancy tanks or privately owned, on-site sewage treatment systems, commonly known as "package plants". Most often the effluent is used for irrigation and or discharged into the nearest water course.

Hazard identification

Hazardous circumstances that may develop relate to poor design and installation, lack of monitoring and maintenance, and personal unsanitary / unhygienic practices, and include aspects such as:

- Leakage of sewage to "open" environment, thereby creating a situation where people are exposed to untreated sewage, which can lead to sickness / infection. This can occur through:

    Structures are often built by community and or households, with little or no experience and specific knowledge, and are not being built to recognised standards (VIP) and or building codes (septic tanks and or conservancy tanks). These structures are prone to develop cracks, attract flies, odour related problems or are inadequately sized for the load received (blockage and overflowing), located close to ground water supplies or are unsuitable for the soil conditions;

Most often these structures are only maintained on a reactive repair basis and little or no preventative maintenance (emptying of tanks) takes places, leading to blockages, overflowing and odours. Instances where the tanks are emptied the disposal of the waste is uncontrolled, by either not being buried and left open or covered with shallow soil layers; and

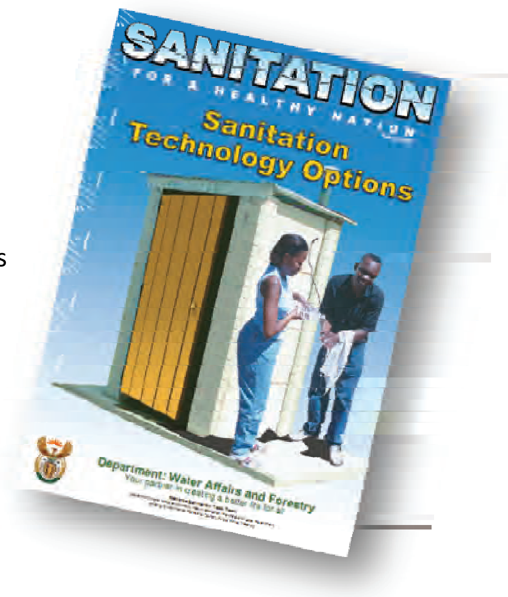
Lack of operation and monitoring of the final effluent.

- Maintenance is often undertaken by the community members and or household members, with little or no personal safety equipment protection, i.e. gloves, masks, closed shoes and effective disinfection of body afterwards. Such expose can lead to sickness /infection, most common of which would be gastro-intestinal infections, cholera, skin infections, etc.;
- Unsanitary personal practices, i.e. hand washing after use of facilities, regular cleaning and disinfection of facilities, etc. also lead to situations of infection / contamination.

Hazardous circumstances that may develop in relation to “package plants”, are in many aspects similar to those of general wastewater treatment work. Some of the causes that lead to these circumstances of bad odour or poor effluent quality include:

- Inadequate design and or influent received differs from that which the plant was designed for;
- Overflows caused by pump failure, power failures and covers that do not seal properly due to poor construction;
- No standby pumps or standby generators;
- Inadequate training of plant operators or no plant operators to attend to the daily tasks often result in incorrect plant operations;
- Excessive foaming resulting in overflows and bad odours at plants which receive large quantities of detergents as part of their influent, i.e. shopping centers;
- Irrigation sprinkler systems tend to block due to excessive solids in the effluent resulting in holding tanks overflowing and malfunctioning of sprinklers.

Control measures



Control measures for community or household system may include:

- Provision of readily available and easily understood guidelines on developing and maintaining non-reticulated wastewater systems DWA and sector partners have developed a number of Sanitation Tools and Guidelines which can be obtained from the website (website: http://www.dwaf.gov.za/dir_ws/content/lids/tools.asp). These include:

    Sanitation technology options

Guidelines for the costing of household sanitation projects

Guidelines for on-site sanitation with difficult technical circumstances

Guidelines for the formulation of a strategy & implementation plan for the provision of sanitation services in informal settlements

Guidelines for sanitation facilities for people with disabilities

Options for dealing with full pits

Sanitation directory summary of current sanitation guides & tools

A Protocol to manage the potential of Groundwater Contamination from on-site sanitation Version 2

Four Stage Sanitation System

Sanitation Technology Options

- Development and implementation of Bylaws relating to the standard of the structures and incentives programmes to communities to adhere to bylaws;
- Implementation of Bylaw clauses that deal with unauthorised discharge of vacuum tank content and test/checks of content prior to discharge;
- Schedules for emptying and discharge of pit sludge;
- Conditions for receiving of chemical toilet sludge;
- Community outreach programmes (many of these already exist), focusing on training individuals:

to construct and

maintain on-site community and household systems

basic sanitation.

Control measures for package plant systems may include:

- development and implementation of clear municipal policy guidelines relating to the installation, operation and maintenance of an on-site package plant, which could include aspects such as:

development of training programmes for plant operators;

annual auditing of package plants

development of guidelines and control mechanisms to ensure that basic tasks occurs, such as;

  - checking sludge levels in the septic tanks and the regular clearing of sludge
  - cleaning clarifiers
  - cleaning UV tubes where ultra violet lights are used for disinfection

  - frequent replacement of chlorine for disinfection
  - cleaning pump baskets
  - raking screens.

- develop guideline/policy documents with conditions for approval and operation of package plants;
- use of approved water treatment chemicals and materials;
- control of water treatment chemicals;
- process controls;
- availability of backup and early warning (alarm) systems;
- availability of contingency plans
- water treatment process optimisation, including;
  chemical dosing
  flow rate
- security to prevent unauthorised access and tampering;
- safe disposal of effluent and sludge.

5.8 Validation

A reliable and successful W_2RAP should be effective in controlling the hazards and hazardous events for which it was set in place. However, it needs to be supported by accurate and reliable technical information that forms part of the validation process.

This process of obtaining evidence that the W_2RAP is effective is known as ***validation***. Such information could be obtained from:

- relevant industry bodies,
- partnering and benchmarking with larger authorities (to optimise resource sharing),
- scientific and technical literature
- expert judgment.

Assumptions and manufacturer specifications for each piece of equipment and each barrier need to be validated for each system to ensure that the equipment or barrier is effective within that system. System-specific validation is essential, as variability in wastewater composition, for instance, may have a large impact on the efficacy of a certain treatment technology and processes.

Why validate?

Validation normally includes **more** extensive and intensive monitoring **than routine operational monitoring**, in order to determine whether system units are performing to their design specification in the system assessment. This process often leads to improvements in operating performance through the identification of the most effective and robust operating modes.

Additional benefits of the validation process may include identification of more suitable operational monitoring parameters for unit performance.

Validation focuses on obtaining evidence on the performance of control measures. The purpose is to ensure that the information supporting the W_2RAP is credible and accurate, to assist in achieving the health and environmental based targets.

Validation of a wastewater treatment process is required to show that the treatment processes can operate as required. Validation can occur during:

- the pilot stage studies;

- feasibility stage;
- during the initial implementation of a new or modified wastewater treatment system; and/or
- during the optimisation of existing treatment processes.

The first stage of validation is to consider data that already exist. These will include data from the scientific literature, trade associations, regulation and legislation departments and professional bodies, historical data and supplier knowledge. This will inform the testing requirements. Validation is not used for day-to-day management of wastewater treatment; as a result, microbial parameters that may be inappropriate for operational monitoring can be used, and the lag time for return of results and additional costs from pathogen measurements can often be tolerated.

EXAMPLE: A project is earmarked for methane gas recovery and combustion, as generated by the existing anaerobic wastewater treatment systems. The international GHG regulator requires the validation of specific criteria by and independent expert party, before registering this project as a CDM project.

EXAMPLE
Methane gas recovery project validation

Project title:	MY08-WWP-30, Methane Recovery in Wastewater Treatment, Pahang, Malaysia
Host Country:	Malaysia
Methodology:	AMS-III.H Version 13 ☐ Large Scale ☒ Small Scale
Annual average emission reductions (estimate):	**26,983tCO_2e/yr**

GHG reducing measure/technology: Introduction of methane recovery and combustion to an existing anaerobic wastewater treatment system such as anaerobic reactor, lagoon, septic tank or an on site industrial plant

1.1 Objective

The purpose of a validation is to have an independent third party assess the project design. In particular, the project's baseline, monitoring plan, and the project's compliance with relevant UNFCCC and host Party criteria are validated in order to confirm that the project design, as documented, is sound and reasonable and meets the identified criteria. Validation is a requirement for all CDM projects and is seen as necessary to provide assurance to stakeholders of the quality of the project and its intended generation of certified emission reductions (CERs).

Validation Protocol Table 1: Mandatory Requirements for CDM Project Activities

Requirement	***Reference***	***Conclusion***	***Cross reference / comment***
The requirements the project must meet.	*Gives reference to the legislation or agreement where the requirement is found.*	*This is either acceptable based on evidence provided **(OK)**, a **Corrective Action Request (CAR)** of risk or non-compliance with stated requirements or a request for **Clarification (CL)** where further clarifications are needed.*	*Gives comments with reference to the findings raised for each CL / CAR*

Figure 13: Extracts from a typical Validation Report demonstrate objective and criteria used during a validation process for methane extraction from an existing anaerobic treatment facility

5.9 Upgrade and improvement

The assessment of the wastewater treatment system may indicate that existing practices and technologies may not ensure that released effluent and disposed sludge is sufficiently safe or in compliance with the health and environmental safety requirements. In some instances, all that may be needed is to review, document and formalise these practices and address any areas where improvements are required. Under different conditions, major infrastructure changes may be needed. An example of the latter would be where extensive housing developments are planned with water-borne sewage that would require extensive upgrades to the existing collector and treatment facilities. The assessment of the system should be used as a basis to develop a plan to address identified needs for full implementation of a W_2RAP.

Improvement of the wastewater treatment system may encompass a wide range of issues, such as:

- integrated development planning to include new housing developments and informal settlements;
- plan and implement capital works;
- sustainable and appropriate technology and levels of service choices;
- training and knowledge transfer;
- enhanced operational procedures;
- stormwater and water demand management;
- electronic or manual data/information management systems;
- design drawings, 'as-built' and maps;
- operations and maintenance manuals;
- standard operating procedures;
- community consultation programmes;
- research and development;
- developing incident response management protocols;
- monitoring, evaluation and reporting;
- allow higher priority to resourcing and intervention actions;
- communication to public; and
- sensitising and education at of local leaders and decision makers.

Upgrade and improvement plans can include short-term (<1 year) or long-term programmes (>5 years). Short-term improvements might include, immediate improvement to effluent quality via adjustments in process control points (i.e. operate plant as extended aeration with longer sludge age). Long-term project relate to capital works projects which could include expansion, enhancement of systems or developing system back structures (i.e. emergency diversion weir and pond).

Implementation of improvement plans may have significant budgetary implications and therefore may require detailed analysis and careful prioritisation in accord with the outcomes of risk assessment. Implementation of plans should be monitored to confirm that improvements have been made and are effective. Control measures often require considerable expenditure, and decisions about wastewater treatment quality improvements cannot be made in isolation from other aspects of drinking-water supply that compete for limited financial resources. Priorities will need to be established, and improvements may need to be phased in over a period of time.

Table 13: A practical approach to ensure by time-based risk abatement process by determining the inherent risk position and the future (residual) risk target

HAZARD:	**FLOODING OF PLANT DURING RAIN EVENTS**	**HIGH CONSEQUENCE X HIGH LIKELIHOOD = HIGH RISK**

RISK POSITION	RISK RATING	CONTROL MEASURE	RISK RATING (after control measure implementation)
Inherent (current) risk *(before control measure implementation)*	HIGH	Install flow meter, measure flood magnitude	HIGH
Planned risk	HIGH	Divert flow from inlet to maturation pond with chlorination	MEDIUM
Development risk	MEDIUM	Develop and implement Stormwater Management Plan	LOW
Residual (remaining) risk	LOW	Maintenance of ingress control measures (e.g. seal manholes, replace covers, building inspections)	LOW

TIP

To allow for a phased risk abatement process over time, work from a status quo risk position (with control measures) to planned risk positions - EXAMPLE…

Note: keep things simple by limiting the use of risk positions to 2 risk positions (e.g. inherent risk and residual risk) and drive these as the primary risk abatement objectives

6. OPERATIONAL MONITORING AND MAINTAINING CONTROL

Operational monitoring of control measures allows the system operator to assess, in a timeous manner, the effectiveness of the management and the performance of the system and under take the necessary remedial action if and when required. It needs to be noted that the time interval for the various aspects of operational monitoring may vary, based on the control measure, i.e. on-line /immediate control of chemical process to annual monitoring of structural integrity.

Legislative requirements

The Department of Water Affairs has issued legislation and guidance documentation **to ensure that monitoring is being undertaken** according to "*General and Special Standards: Government Gazette 18 May 1984 No. 9225: Regulation No. 991 18 May 1984: Requirements for the Purification of Wastewater or Effluent*". In addition, each WWTW should be registered and have a license (permit historically) which indicates the operating conditions/limitation applicable, methodology and regularity of monitoring. For example, some of these include, but are not limited to:

- Conditions and monitoring of irrigation of land with irrigation water containing waste:
  - ❖ WQ criteria and limits are defined in each event and the quantity of water containing waste shall be metered and recorded daily;
  - ❖ Monitoring for the quantity of the water containing waste for irrigation shall be done at the point where the effluent is piped into the irrigation dam;
  - ❖ Flow metering, recording and integrating devices shall be maintained in a sound state of repair and calibrated by a competent person at intervals of not more than two years. Calibration certificates shall be available for inspection by the Regional Director or his representative upon request;
  - ❖ The monitoring point/s shall not be changed without prior notification to and written approval by the DWA;
  - ❖ A monitoring program to determine compliance with the ground water quality reserve on the property/properties must be designed in consultation with the affected parties; and
  - ❖ Monitoring data is to be submitted monthly to the Regional Director (DWA).
- Conditions and monitoring of discharging water containing waste into a water resource:
  - ❖ water quality criteria and limits are defined in each event and the quantity of water containing waste irrigated shall be metered and recorded daily;
  - ❖ water quality measurements upstream and downstream of discharge point need to be undertaken at regular intervals, and specific focus on the WQ monitoring of the discharge effluent, prior to discharge.

Analyses shall be carried out in accordance with methods prescribed by and obtainable in accordance with the South African National Standards (SANS) [as per the SA Bureau of Standards], ito Standards Act, Act 30 of 1982.

6.1 Determining system control measures

The identity and number of control measures are system specific and will be determined by the number and nature of hazards and magnitude of associated risks.

Any set of control measures should always include the availability of:

- ✓ **Standard Operating Procedures (SOPs),**
- ✓ **Contingency measures,**
- ✓ **Training,**
- ✓ **Emergency procedures.**

Control measures should reflect the likelihood and consequences of loss of control. Control measures have a number of operational requirements, including the following:

- operational monitoring parameters that can be measured and for which limits can be set to define the operational effectiveness of the activity;

- operational monitoring parameters that can be monitored with sufficient frequency to reveal failures in a timely fashion; and
- procedures for corrective action that can be implemented in response to deviation from limits.

6.2 Selecting operational monitoring parameters

The parameters selected for operational monitoring should reflect the effectiveness of each control measure, provide a timely indication of performance, and be readily measured and provide opportunity for an appropriate response. Examples include:

- measurable variables, such as wastewater balancing, MLSS, Dissolved Oxygen, COD, Ammonia, Nitrates & Nitrites, pH, Ortho-phosphate;
- observable factors, related to the effectiveness of the infrastructure, such as grid and screenings moisture, primary sludge density, earthy odour of activated sludge.

Table 14: Operational monitoring parameters should consider the wastewater constituents and characteristics and its importance in a risk environment

Constituent	Reason for importance
Suspended solids	Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged in the aquatic environment.
Biodegradable organics	Composed principally of proteins, carbohydrates, and fats, biodegradable organics are measured most commonly in terms of BOD (biochemical oxygen demand) and COD (chemical oxygen demand). If discharged untreated to the environment, their biological stabilisation can lead to the depletion of natural oxygen resource and to the development of septic conditions.
Pathogens	Communicable diseases can be transmitted by pathogenic organisms that may be present in wastewater.
Nutrients	Both nitrogen and phosphorus, along with carbon, are essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. When discharged in excessive amounts on land, they can also lead to the pollution of groundwater.
Priority pollutants	Organic and inorganic compounds selected on the basis of their known or suspected carcinogenicity, mutagenicity, teratogenicity, or high acute toxicity. Many of these compounds are found in wastewater
Refractory organics	These organics tend to resist conventional methods of wastewater treatment. Typical examples include surfactants, phenols, and agricultural pesticides.
Heavy metals	Heavy metals are usually added to wastewater from commercial and industrial activities and may have to be removed if the wastewater is to be reused.
Dissolved inorganic	Inorganic constituents such as calcium, sodium, and sulphate are added to the original domestic water supply as a result of water use and may have to be removed it the wastewater is to be reused.

The Department of Water Affairs has existing formalised measurement parameters, linked to the specific authorisation or general authorisation applicable to each WWTW.

Frequencies of testing, if not defined by the legislated authority, i.e. DWA in South Africa, should reflect the need to balance the benefits and costs of obtaining more information. Sampling frequencies are usually based on the size of the works, the cost of testing, the availability of testing or laboratory equipment, the proximity of a commercial laboratory and the sensitivity of the receiving environment.

Frequency of testing for individual characteristics will also depend on variability. The number and types of tests will vary for different processes and plants and should be viewed in a holistic manner to plant performance. Tests should thus be linked to a structured, regular appraisal of plant performance. Plant performance can be assessed under the following headings:

- Visual inspection and observations conducted on a daily basis;
- In-situ measurements (taken either manually or automatically);
- Laboratory analysis of samples, (either on site or off-site); and
- Systematic and ordered filing of observations / records and analysis with constant referral to past information and analyses to improve plant performance.

The most common testing frequencies / sampling ranges are:

- **Daily, hourly or more frequent if in-line monitoring =** macro- sized plants
- **Daily =** large-sized plants
- **Weekly** = medium sized plants (most common)
- **Monthly** = small to micro-sized plants

Wastewater treatment plants can be categorised according to the following size (flow/time related):

- micro size plants <0.5 Mℓ/day
- small size plants 0.5-2 Mℓ/day (General Authorizations could apply)
- medium size plants 2-10 Mℓ/day
- large size plants 10-25 Mℓ/day
- macro size plants >25 Mℓ/day

Source: WRC, 2006

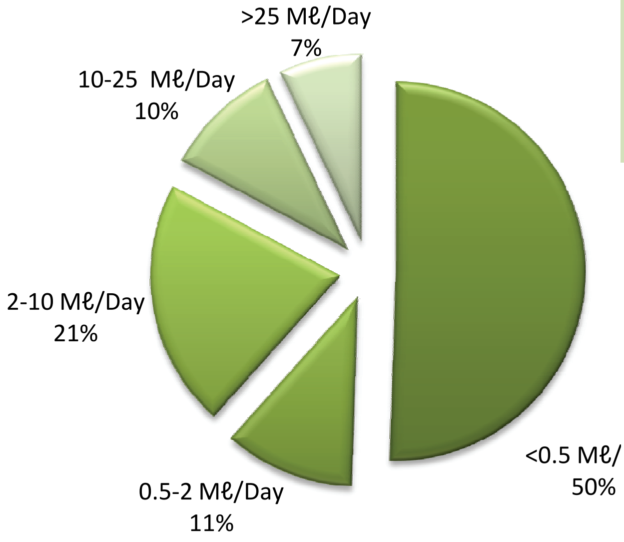


Figure 14: Size Distribution of Wastewater Treatment Works in SA

The Water Research Commission report "*Operating Manual for Biological Nutrient Removal Wastewater Treatment Works*" (WRC Report No. TT 83/97, February 1997) recommends the following on the recording, sampling and analysis requirements to evaluate fully the performance of a BNR works:

"Sampling and analyses:

Raw sewage

Daily samples should be taken as described above. A 24-hour composite sample of the raw sewage should be taken. The sample should be taken immediately downstream of the screens at the inlet works.

The following analyses should be carried out on the **raw (unsettled) wastewater**:

- pH
- COD
- TKN
- Free and saline ammonia (as N)
- Suspended solids
- Total P
- Ortho-phosphate (as P)
- Conductivity

If primary sedimentation has been included in the process, a 24-hour composite sample of the **settled wastewater** is recommended. The following analyses are recommended:

- COD
- TKN
- [Total] Suspended solids (TSS)

These analyses are required to monitor the performance of the PSTs in removing COD, TKN and TSS."

"Biological reactor

Grab samples should be taken of the **mixed liquor** in the anaerobic, anoxic and aerobic basins of the biological process. The following analyses should be carried out on each sample:

- MLSS
- DSVI (described below)
- NO_3 (as N)

Regular dissolved oxygen (DO) readings and the temperature of the reactor should also be recorded. If ortho-P is to be measured, the sample should be filtered immediately. No inhibitor should be used as this will cause any sludge present to release phosphorus.

"Diluted Sludge Volume Index (DSVI)

The MLSS concentration is used in conjunction with a 30-minute settling test to estimate the diluted sludge volume index (DSVI). The DSVI for the aeration basin should be determined weekly or more often if bulking or badly settling sludge occurs.

The purpose of the DSVI is to monitor the settling characteristics of the mixed liquor and to bring to the attention of the operator whether or not the sludge has bulking characteristics. A DSVI result in excess of 150 is indicative of a "bulking" sludge, i.e. a sludge with poor settling characteristics, whereas a DSVI <70 is considered to have good settling properties. The DSVI test should be carried out independently for each process stream."

"Final effluent

A 24-hour composite sample should be taken of the **effluent from the secondary clarifiers**. The analyses recommended are:

- pH
- Conductivity
- COD
- Free and saline ammonia (as N)
- Nitrate (as N)
- Total P
- Ortho-phosphate (as P)
- [Total] Suspended solids

The results can be used in conjunction with the DO reading and the weekly analyses to ensure that all sections of the plant are operating correctly or to establish where a problem may lie, e.g. insufficient recycling into the anoxic zone. The overall performance of the plant with regard to nutrient removal can also be determined."

"Fermentation

Where primary fermentation is part of a treatment process, **weekly samples must be taken** from the fermenter. The following analyses are required:

- MLSS of underflow
- Short Chain Fatty Acids (SCFA)concentration of the overflow

Sludge treatment

Where sludge is being thickened prior to further treatment or disposal weekly samples must be taken of the thickened sludge. The following analyses are recommended:

- MLSS

Weekly samples should also be taken from the clear water of the thickening process. The following analyses are required:

- Ortho-phosphate (as P)"

"Recording

Flow measurement

The most convenient method for determining flow into a treatment works is by means of a venturi flume at the inlet with a flow recorder to record the flow rate and cumulative flows.

The **cumulative flow** should be recorded daily as

- Total flow into the BNR works
- Total flow discharged to the fermenter/thickeners,
- WAS flow

Every week the accuracy of the flow meters should be checked by measuring the depth of flow in the approach channel to the flume and comparing the indicated flow with that calculated for the flume from the measured depth. The results of these checks should be entered in a record book. The variation between measured and indicated value should be within 5%. Should the two readings differ by more than 5% the flow should be measured again. If the difference is still greater than 5%, the supplier should be contacted and asked to come out and check the calibration of the flow meter."

"Running hour meters

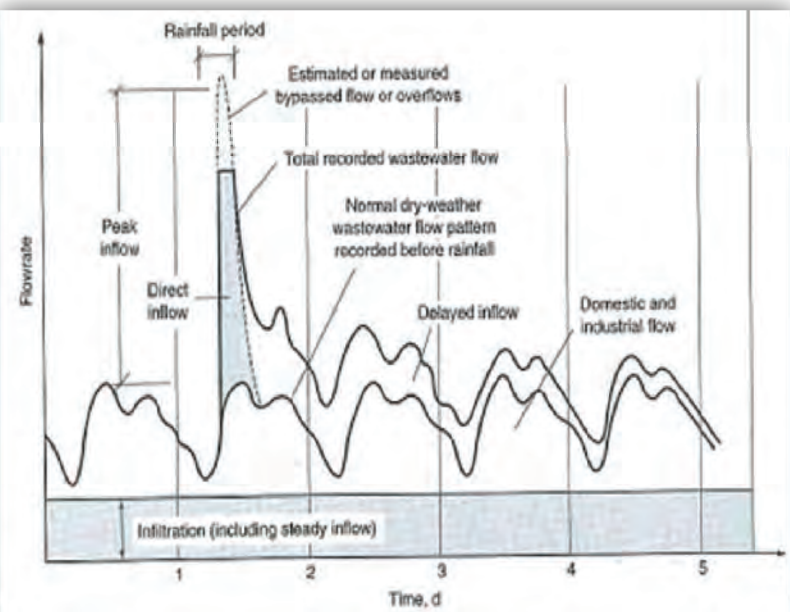
The data have to be recorded in a book maintained specifically for this purpose. Selection of the duty items of the plant is done manually by the operator for some of the equipment supplied e.g. duty mixer selections should be made so that near equal running hours are maintained between various duty/standby motors. For the automatically selected items, a large discrepancy in running hours between the duty/standby motors could mean a fault in the control system. This should be reported and rectified."

"Dissolved Oxygen (D0)

The most crucial task that an operator must perform daily is to ensure that the DO in both aeration basins is maintained in the range of 1,0 to 2.0 mg/l. The operator should use the portable meter to check the DO at points away from the fixed probes. Regular cleaning of the oxygen probes will be required to obtain the optimum performance of the system."

TIP

Important: Besides the totalised daily influent flow, it is important to measure diurnal profiles for both the wet season and dry season to minimise the hydraulic overloading. This is an essential element to mitigate risks in future designs.



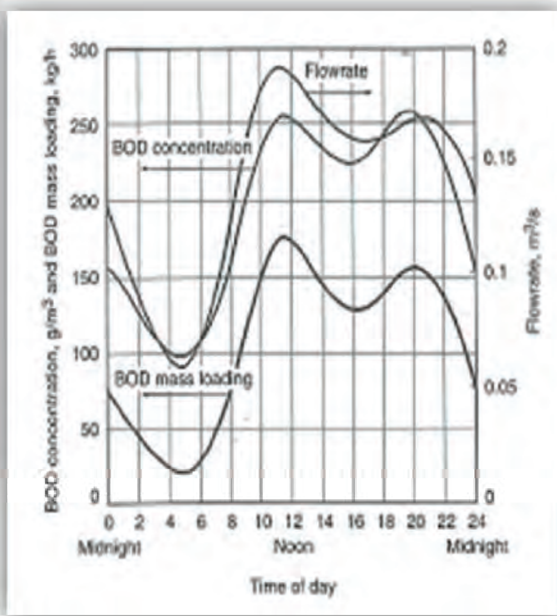


Figure 15: a) illustration of diurnal wastewater flow, BOD, and mass loading variability b) graphic identification of infiltration / inflow (Metcalf & Eddy, 2005)

6.3 Establishing operational and critical limits

Control measures need to have defined limits for operational acceptability – termed operational limits – that can be applied to operational monitoring parameters. Operational limits should be defined for parameters applying to each control measure. If monitoring shows that an operational limit has been exceeded, then predetermined corrective actions need to be applied. The detection of the deviation and implementation of corrective action(s) should be possible in a time frame adequate to maintain performance and safety.

For some control measures, a second series of "critical limits" may also be defined, outside of which confidence in water safety would be lost. Deviations from critical limits will usually require urgent action, including immediate notification of the appropriate health authority.

Operational and critical limits can be upper limits, lower limits, a range or an "envelope" of performance measures. In the South African situation, it is possible that different sets of critical limits apply, depending on that status of the Water Services Authority's license approval process. It is thus prudent that the Guide considers three 3 sets of critical limits – each of which will be a site-specific application.

i) General Authorisation – General and Special Limits
ii) 1984 General Standards and Special Standards
iii) Licenses will replace that above as/when issued.

Table 15: Wastewater limit values applicable to discharge of wastewater into a water resource, as per the General Authorisation (Section 39 of the National Water Act no 36 of 1998)

SUBSTANCE/PARAMETER	GENERAL LIMIT	SPECIAL LIMIT
Faecal Coliforms (cfu/per 100 ml)	1 000	0
Chemical Oxygen Demand (mg/l)	75*	30*
pH	5,5-9,5	5,5-7,5
Ammonia (ionised and un-ionised) as Nitrogen (mg/l)	3	2
Nitrate/Nitrite as Nitrogen (mg/l)	15	1.5
Chlorine as Free Chlorine (mg/l)	0.25	0
Suspended Solids (mg/l)	25	10
Electrical Conductivity (mS/m)	70 mS/m above intake to a maximum of 150 mS/m	50 mS/m above background receiving water, to a maximum of 100 mS/m
Ortho-Phosphate as phosphorous (mg/l)	10	1 (median) and 2,5 (maximum)
Fluoride (mg/l)	1	1
Soap, oil or grease (mg/l)	2.5	0
Dissolved Arsenic (mg/l)	0.02	0.01
Dissolved Cadmium (mg/l)	0.005	0.001
Dissolved Chromium (VI) (mg/l)	0.05	0.02
Dissolved Copper (mg/l)	0.01	0.002
Dissolved Cyanide (mg/l)	0.02	0.01

Dissolved Iron (mg/l)	0.3	0.3
Dissolved Lead (mg/l)	0.01	0.006
Dissolved Manganese (mg/l)	0.1	0.1
Mercury and its compounds (mg/l)	0.005	0.001
Dissolved Selenium (mg/l)	0.02	0.02
Dissolved Zinc (mg/l)	0.1	0.04
Boron (mg/l)	1	0.5

**After removal of algae*

Table 16: General and Special Effluent Standards (Government Gazette 10 May 1984, no 9225) specify the requirements for the purification of wastewater. These are standards enforced under previous legislation, but remains in place until the DWA issues new licenses – in which case the General and Special Limits and General and Special Standards will be replaced with the new conditions

SUBSTANCE/PARAMETER	GENERAL STANDARD	SPECIAL STANDARD
Colour Odour or taste	The wastewater or effluent shall not contain any substance in a concentration capable of producing any colour, odour or taste.	The wastewater or effluent shall not contain any substance in a concentration capable of producing any colour, odour or taste
Chemical Oxygen Demand (mg/l)	Not to exceed 75 milligrams per liter after applying the chlorine correction	Not to exceed 30 milligrams per liter after applying the chlorine correction
pH	5.5-9.5	5.5-7.5
Dissolved oxygen	Shall be at least 75 per cent saturation	Shall be at least 75 per cent saturation
Typical (faecal) coli	n/a	The wastewater or effluent shall contain no typical (faecal) coli per 100 milliliters
Temperature	Shall be a maximum of 35°C	Shall be a maximum of 25°C
Oxygen absorbed	The oxygen absorbed form acid N/80 potassium permanganate in 4 hours at 27°C shall not exceed 10 milligrams per liter	The oxygen absorbed form acid N/80 potassium permanganate in 4 hours at 27°C shall not exceed 5 milligrams per liter
Conductivity	Not to be increased by more than 75 milli-Siemens per meter (determined at 25°C) above that of the intake water. The conductivity of any water, wastewater of effluent seeping or draining from any area referred to in Section 21(6) of the aforementioned Water Act shall not exceed 250 milli-Siemens per meter (determined at 25°C).	Not to be increased by more than 15 per cent above that of the intake water. The conductivity of any water, wastewater of effluent seeping or draining from any area referred to in Section 21(6) of the aforementioned Water Act shall not exceed 250 milli-Siemens per meter (determined at 25°C).

Suspended solids	Not to exceed 25 milligrams per liter	Not to exceed 10 milligrams per liter
Sodium content	Not to be increased by more than 90 milligrams per liter above that of the intake water	Not to be increased by more than 50 milligrams per liter above that of the intake water
Soap, oil or grease	Not to exceed 2.5 milligrams per liter	None
Other constituents:	Maximum concentration in milligrams per liter	Maximum concentration in milligrams per liter
Residual Chlorine (as CP)	0.1 mg/l	0 mg/l
Free and saline ammonia (as N)	10.0 mg/l	1.0 mg/l
Nitrates (as N)	0.5 mg/l	1.5 mg/l
Arsenic (as AS)	1.0 mg/l	0.1 mg/l
Boron (as B)	0.05 mg/l	0.5 mg/l
Total chromium (as Cr)	0.5 mg/l	0.05 mg/l
Copper (as Cu)	1.0 mg/l	0.02 mg/l
Phenolic compounds (as phenol)	0.1 mg/l	0.01 mg/l
Lead (as Pb)	0.1 mg/l	0.1 mg/l
Soluble ortho-phosphate (as P)	n/a	1.0 mg/l
Iron (as Fe)		0.3 mg/l
Manganese (as Mn)	0.4 mg/l	0.1 mg/l
Cyanides (as CN)	0.5 mg/l	0.5 mg/l
Sulphides (as S)	1.0 mg/l	0.05 mg/l
Fluoride (as F)	1.0 mg/l	1.0 mg/l
Zinc (as Zn)	5.0 mg/l	0.3 mg/l
Cadmium (as Cd)	0.05 mg/l	0.05 mg/l
Mercury (as Hg)	0.02 mg/l	0.02 mg/l
Selenium (as Se)	0.05 mg/l	0.05 mg/l
Phosphate		Wastewater or effluent arising in the catchment area within which water is drained to any river specified in Schedule II or a tributary thereof at any place between the source thereof and the

		point mentioned in the schedule, in so far as such catchment area is situated within the territory of the Republic of South Africa shall not contain soluble orthophosphate (as P) in higher concentration than 1.0 milligram per liter
Other	The sum of the concentrations of the following metals shall not exceed 1 mg/l: Cadmium (as Cd), chromium (as CR), Copper (as CU, mercury (as Hg) and lead (as Pb).	The wastewater or effluent shall contain no other constituents in concentrations which are poisonous of injurious to trout or other fish or other forms of aquatic life

The above limits related to final effluent compliance, which are legally enforceable standards. Other limits that are also required in the South African wastewater water industry include (but not limited to):

- Sea outfall standards / limits
- Sludge characterisation and use
- Water Quality Objectives (use to inform license conditions and standards).

Apart from above 'compliance' limits and standards, it is also good practice to establish operational limits and standards within the municipal systems. These limits are not legally enforceable, but if set and managed, with result in compliance to legally set limits such as final effluent quality.

Table 17: Operational targets set by Johannesburg Water for critical operational parameters (electricity, chemical dosing, effluent quality compliance, machinery/equipment, sludge production and spillage events)

Works	Power KWh/Ml Oct 2010	Power 1 month ave	Target	Ferric kg/Ml	Ave	Target	Poly kg/d	Ave	Target	Compliance %	Ave %	Target	DBF kg / Ml	Ave	Target
Northern	377	369	365	5	5	10	3.9	4.0	4.0	100.0	97.8	96	64	67	85
Driefontein	376	377	365	0	9	10	2.4	2.7	3.0	96.7	95.2	96	57	66	75
Goudkoppies	359	360	360	7	12	20	3.0	2.6	3.0	100.0	98.3	96	71	69	75
Bushkoppie	350	370	360	0	0	5				93.0	95.2	96	54	57	65
Olifantsvlei	376	359	360	25	20	30	4.9	3.8	4.0	99.4	99.6	96			
Ennerdale	520	565	550	11	30	70				100.0	98.6	96	46	49	55
Combined	369	370	370	8	8	15	4.0	3.5	3.6	98.1	97.5	96	63	64	67

Works	Plant Availability Oct 2010	Ave 1 month ave	Target	YM %	Ave %	Target	Sludge Drying	Ave	Target %	Spills Number Month	Total Number Year	Target
Northern	no result	no result		82.7	87.0	75	9.5	12.5		3	16	100
Driefontein	no result	no result								0	0	20
Goudkoppies	99.4	99.1	97.5	100.0	89.5	75	73.2	56.6	50	0	4	10
Bushkoppie	99.3	99.3	97.5							19	48	100
Olifantsvlei	97.8	97.5	97.5	100.0	100.0	75	65.0	47.0	50	0	1	50
Ennerdale	99.2	99.8	97.5							0	0	
Combined	98.9	98.9	97.5							22	69	

EXAMPLE
Johannesburg Water Operational Targets

Although this aspect is not yet a normal/ formalised procedure, there is a need to start monitoring non-piped community and household systems, specifically considering the extensive use of septic tanks, VIP, urine diversion systems, conservancy tanks, etc.

Monitoring of household systems by community operators or households could typically involve periodic sanitary inspection. The sanitary inspection forms used should be comprehensible and easy to use; for instance, the forms may be pictorial. The risk factors included should be preferably related to activities that are under the control of the operator and that may detrimentally affect the surrounding / receiving environment and or health quality of the households. The links to action from the results of operational monitoring should be clear and training and means of communicating and encouraging household to address their situation will be required.

Regular physical assessments of the wastewater system is recommended, especially after heavy rains, to monitor whether any obvious problems may be forming, i.e. blockages and inadequate flushing.

Good hygiene practices are required and should be supported through hygiene education. Hygiene education programmes should provide households and communities with skills to monitor and manage their sanitation hygiene, i.e. appropriate use of facilities, unacceptable materials and basic visual maintenance checks.

Package / on-site treatment plants:

When the proposed discharge of treated wastewater is into a watercourse, either directly or via a constructed stormwater drain, the Unit will require quality compliance with the “General Limit Values” (GLVs). As these are national standards, no local relaxation of these values is possible. It is possible that these can be made stricter at local level.

The only alternatives to full compliance with the GLVs is for the applicant to make a “license” application to DWA or to motivate for the introduction of “catchment specific” limits.

Daily on-site monitoring and regular (usually monthly) sampling and submission of results to the relevant local authority, is the responsibility of the operator / owner of the plant and would typically involve reporting on the following aspects, based on the size of the package plant:

- Faecal Coliforms (per 100 ml)
- Free residual chlorine (mg/l)
- pH
- Electrical Conductivity (mS/m)
- Chemical Oxygen Demand (mg/l)
- Ammonia as Nitrogen (mg/l)
- Total Suspended Solids (mg/l)
- Nitrate/Nitrite as Nitrogen (mg/l)
- Free Chlorine (mg/l)
- Ortho-Phosphate as Phosphorous (mg/l)

For the sampling and testing, a recognised laboratory which is accredited under the SANAS or approved by DWA, need to be engaged. Alternative, a laboratory can be used that has quality control in place, i.e. Proficiency Testing (Z-score) system. The results must be reported in writing by the laboratory directly to the local authority (and to DWA as required) with a copy to the Professional Engineer / Technologist responsible for the O & M service contract for the plant.

7. VERIFICATION THAT THE W_2RAP IS EFFECTIVE AND MEET HEALTH-BASED AND ENVIRONMENTAL TARGETS

Verification of treated effluent quality provides an indication of the overall performance of the treatment system and the ultimate quality of the effluent being released into the receiving environment. This incorporates monitoring of final effluent quality (chemical, physical, microbiological), as well as assessment of the impact on the receiving environment, for example:

- determination of the condition of the biological communities in-stream, using indices such as the South African Scoring System (SASS5),
- Invertebrate Habitat Assessment Systems (IHAS] toxicity testing for use with rapid biological assessment protocols, which expresses the suitability of biotopes, where 100% represents "ideal" habitat availability.
- Aquatic toxicology, particularly applied within Ecological Risk Assessment (ERA), is of most use to those who discharge wastewater or whose activities contribute to non-point source pollution.

In addition to operational monitoring of the performance of the individual components of a wastewater treatment system, it is necessary to undertake final verification for reassurance that the system as a whole is operating safely. Verification may be undertaken by;

- the regulatory / enforcement agency (inspectorate);
- the supplier;
- by an independent authority; or
- by a combination of these, depending on the administrative regime in a given country.

For South Africa, this would be the responsibility of the Department of Water Affairs to oversee the registration of monitoring programmes and regular submission of analysis results.

☑ **Important:** Verification provides a final check on the overall safety and effectiveness of the wastewater treatment process. Verification may be undertaken by the regulatory or surveillance agency and/or can be a component of supplier quality control.

Nation-wide programmes such as the RPMS (Regulatory Performance Monitoring System), the Green Drop Certification and risk-based assessment and prioritisation allow for data collection, assembly and verification on an ongoing basis (mostly annually).

green drop
CERTIFICATION
waste water service
REGULATION

Table 18: Regulatory Performance Management system dashboard

Level: National

KPI Dashboard					
Key Performance Indicators	**Achieved KPI Score**	**Required score**	**Compliance Assessment**	**Performance assessment**	**Trend of KPI Score**
KPI 1: Access to water supply [Overall KPI compliance score]	2.978	3		Concern	
KPI 2: Access to sanitation [Overall KPI compliance score]	2.718	3		Concern	
KPI 3: Access to Free Basic Water [Overall KPI compliance score]	3.987	3		Excellent	
KPI 4: Access to Free Basic Sanitation [Overall KPI compliance score]	0.000	3		Crisis	
KPI 5: Drinking Water Quality management [Overall KPI compliance score]	1.249	3		Crisis	
KPI 6: Wastewater quality management [Overall KPI compliance score]	1.775	3		Concern	
KPI 7: Customer service quality [Overall KPI compliance score]	2.720	3		Concern	
KPI 8: Institutional effectiveness [Overall KPI compliance score]	2.793	3.5		Concern	
KPI 9: Financial performance [Overall KPI compliance score]	1.940	4		Crisis	
KPI 10: Strategic asset management [Overall KPI compliance score]	2.075	3		Concern	
KPI 11: Water use efficiency [Overall KPI compliance score]	0.620	3		Crisis	

Wastewater limit values for discharge of wastewater into a water resource, have either a General Limit or Special Limit and the components that are measured are: Faecal Coliforms, Chemical Oxygen Demand, Ammonia (ionised and un-ionised) as Nitrogen, Nitrate/Nitrite as Nitrogen, Chlorine as Free Chlorine, Suspended Solids, Electrical, Ortho-Phosphate as phosphorus, Fluoride, Soap, fats, oil or grease, Dissolved Arsenic, Dissolved Cadmium, Dissolved Chromium (VI), Dissolved Copper, Dissolved Cyanide, Dissolved Iron, Dissolved Lead, Dissolved Manganese, Mercury and its compounds, Dissolved Selenium, Dissolved Zinc and Boron.

Wastewater Limit Value means the mass expressed in terms of the concentration and/or level of a substance which may not be exceeded at any time. **It is therefore important that control measures take into account that limits must be reached ALL THE TIME.**

Wastewater Limit Values apply at the last point where the discharge of wastewater enters into a water resource, dilution being disregarded when determining compliance with the Wastewater Limit Values. According to the Department of Water Affairs, where discharge of wastewater does not directly enter a water resource, the Wastewater Limit Values shall apply at the last point where the wastewater leaves the premises of collection and treatment. However, in the face of changing priorities for the beneficial use of treated effluent and stabilised sludge, revised limits is expected to apply to such cases in the foreseen future. In light of food security issues and the cost of fertiliser, a strong case is made for the use of effluent in agriculture, where the nutrients in the final effluent is needed by the farmer and Limits would therefore need to be reviewed based on the different situations.

For microbial verification, testing is typically for faecal indicator bacteria (Faecal Coliforms and *Escherichia coli* (E. coli)) in the discharged treated effluent. For verification of chemical safety, testing for chemicals of concern such as (Nitrates and Nitrites, Free chlorine residual, Chemical Oxygen Demand, Ammonia: Operational) may be during and at the end of treatment.

7.1 Verification of microbial quality

Verification of microbial quality of effluent must be designed to ensure the best possible chance of detecting contamination. Pathogenic organisms found in wastewater are usually few and difficult to isolate the specific strains or species. For this reason "Indicator Organisms" are used for the target pathogens. *Escherichia coli* and Faecal coliform is the most common indicators used in wastewater treatment works.

- *Faecal coliform bacteria:*

  Primarily used as a practical indicator of faecal pollution; more specific for faecal pollution than total coliforms; mainly used for assessment of faecal pollution of wastewater, raw water supplies and natural water environments used for recreational purposes.
- *Escherichia coli:*

  This indicator organism is found in the feces of warm-blooded animals and been historically the target organism tested for with the total coliform test. This was later reviewed when found that some of the coliform organisms of the genus Escherichia can grow in soil and other substrates. Thus the presence of coliforms does not always mean contamination with human wastes. It is now recognised that that E coli forms less than 1% of the faecal bacteria. Estimates of numbers of total and viable counts agree to be about 10^{12} bacteria per gram of faecal material.

- Others:

  Total coliform bacteria
  Klebsiella
  Bacteroides
  Faecal streptococci
  Enterococci
  Clostridium perfringens
  P aeruginosa and *A hydrophila*

Several conventional water purification processes, including sedimentation, absorption, coagulation and flocculation will all result in the partial removal of microorganisms in water. These processes, however, do not necessarily inactivate the microorganisms and additional disinfection processes need to be applied. Chlorine disinfection is often practiced. Disinfection, however, requires careful process control of the disinfection species, dosage and contact time.

7.2 Verification of chemical, physical and microbiological quality

Issues that need to be addressed in developing chemical verification include the availability of appropriate analytical facilities, the cost of analyses, the possible deterioration of samples, the stability of the contaminant, the likely occurrence of the contaminant in various supplies, the most suitable point for monitoring and the frequency of sampling.

For a given chemical, the location and frequency of sampling will be determined by its principal sources and variability. Substances that do not change significantly in concentration over time require less frequent sampling than those that might vary significantly.

- *pH: aesthetic:*

  The main significance of pH in domestic water supplies relates to its effects on water treatment processes. The pH of water can be adjusted up or down by the addition of an alkali or an acid. Commonly used alkaline reagents are sodium carbonate, sodium hydroxide and lime. Acidic reagents commonly used are carbon dioxide (a gas which forms carbonic acid in water), hydrochloric acid or sulphuric acid. The reagent is usually added in dilute form using a dosing pump controlled by a pH monitor. The adjustment of pH in water will inevitably increase the salinity of the water by adding ions such as sodium, carbonate, hydroxyl, sulphate or chloride. Reagents should be chosen to minimise secondary effects. For certain purposes the pH of the water will need to be stabilised within a chosen range by the addition of buffering reagents. The handling of acids and alkalis is often hazardous requiring special precautions.
- *Ammonia: Operational:*

  Nitrogen (along with phosphorous and carbon) essential nutrients for growth. When discharged to the aquatic environment, these nutrients can lead to the growth of undesirable aquatic life. In a wastewater treatment plant, ammonia is normally oxidised to nitrites and then to nitrates. A low ammonia concentration in final treated wastewater effluent therefore normally indicates that effective nitrification has occurred within the wastewater treatment process. If the median value exceeds the required limits, intervention is required to rectify the situation (e.g. optimise operation at the treatment plant).
- *Nitrites And Nitrates:*

  In a wastewater treatment plant, ammonia is normally oxidised to nitrites and then to nitrates. If the median value exceeds the required limits, intervention is required to rectify the situation (e.g. ensure source protection, ensure that the treatment plant can effectively remove nitrate/nitrite, optimise operation at the treatment plant).
- *Free chlorine residual*

  Free chlorine residual is an indication of the efficiency of the disinfection process and is thus a rapid indicator of the probable microbiological safety or otherwise of the treated water. In distribution systems, the free chlorine residual protects against secondary contamination. Absence of residual chlorine means either that the water was not treated with chlorine, or that insufficient chlorine was used to successfully disinfect the water. Where the untreated water contains pathogenic microorganisms, the absence of free residual chlorine indicates that there is a risk of microbial infection. However, if the concentration of chlorine is too high then irritation of mucous membranes, nausea and vomiting may occur. If the median value does not meet the required limits shown above, intervention is required to rectify the situation (e.g. optimise disinfection).
- *Chemical Oxygen Demand*

  Biodegradable organics are principally composed of proteins, carbohydrates and fats, and are commonly measured in terms of Chemical Oxygen Demand (COD). COD measures the total amount of chemically oxidisable organic material plus other reduced substances such as sulphides and ferrous ion. If discharged untreated to the environment, their biological stabilisation can lead to depleted oxygen levels and the development of septic conditions. If the median value exceeds the required limits shown above, intervention is required to rectify the situation (e.g. optimise operation at the treatment plant).

- *Biological Oxygen Demand*

  In many cases, treatment plants receive a high unbiodegradable soluble COD, with a low biodegradable faction. In such cases, BOD would be a more reliant verification parameter than COD. Practically this would then allow that if COD in the effluent persist above 75 mg/l (Critical Limit), mitigation would only be possible if BOD is determined and use to develop the control measure. BOD measures the oxygen required by bacteria, under standard conditions to oxidise organic material to CO_2 and H_20. It is a 5 day test used to measure the oxygen demand of the microbes for oxidation of organic matter and ammonia.

> Typically, a BOD/COD ratio of:
>
> >0.5 indicate that the wastewater is easily treatable by biological means
>
> <0.3 indicate that toxic compounds are present and need acclimatised microbes for stabilisation.

Any verification process is only as valuable in its final application of measuring compliance of the verified parameters against the required standards. Effectively, this provides the PERFORMANCE of the treatment system against regulated or design criteria. The following example from the Green Drop Certification programme indicate a simplistic form of calculating compliance of a particular system's final effluent quality against the General Limit Values, as set by DWA (as national regulator):

Table 19: Example of simplified manual calculation of effluent quality compliance (%) against site-specific DWA standard

WASTEWATER TREATMENT PLANT: ……………………………………..

STANDARD *	DETERMINANTS																	
	Microbiological				Physical						Chemical							
	E coli		F coliforms		SS		pH		EC		COD		NH_3-N		$NO_{3/2}$-N		PO_4-P	
General Authorisation – General Limits	1000 cfu/100 ml		1000 cfu/100 ml		25 Mg/l		5.5-9.5		70 above intake, max 150 mS/m		75 mg/l		10 mg/l		15 mg/l		10 mg/l	
MONTH	Monthly averages																	
June	750	C	NM	-	30	N	7.61	C	85	C	80	N	24	N	0.5	C	8	C
July	850	C	NM	-	35	N	7.71	C	90	C	95	N	22	N	0.6	C	9	C
August	888	C	NM	-	36	N	7.56	C	95	C	95	N	19	N	1.2	C	12	N
September	1050	N	NM	-	42	N	7.65	C	98	C	101	N	21	N	1	C	11	N
October	2005	N	NM	-	45	N	6.76	C	55	C	100	N	22	N	4	C	9.5	C
November	2341	N	NM	-	42	N	6.89	C	70	C	89	N	14	N	2.1	C	9.8	C

December	2004	N	NM	-	39	N	7.12	C	87	C	78	N	9	C	4.1	C	10.1	N
January	90	C	NM	-	38	N	7.12	C	95	C	75	C	11	N	4.6	C	10.0	C
February	65	C	NM	-	55	N	7.15	C	79	C	75	C	9	C	7.8	C	9.8	C
March	4	C	NM	-	70	N	6.99	C	80	C	76	N	8	C	7.2	C	7.7	C
April	2	C	NM	-	60	N	7.01	C	83	C	72	C	4	C	8.7	C	7.3	C
May	2	C	NM	-	58	N	7.09	C	94	C	59	C	10	C	6.8	C	5.1	C
% Compl per determinant	8/12 =66.7%		Not monitored	-	0/12 =0%		12/12 =100%		12/12 =100%		8/12 =66.7%		5/12 =41.7%		12/12 =100%		9/12 =75%	
% Compl per category	8/12 = 75% Or **75%**				24/36 = 66.7% OR 0+100+100/3 = **66.7%**						34/48 X 100 = 70.8% OR 66.7+41.7+100+75/4 = **70.8%**							

* Use the applicable DWA authorisation to calculate %compliance against:

Water Use License
General Authorisation (General Limits)
General Authorisation (Special Limits)
Permit / Exemption (General Standards)
Permit / Exemption (Special Standards).

C = Compliant
N = Not compliant
NM = Not monitored
W = Waivered (not a requirement by DWA)

7.3 Verification of Physical Quality

- *Electrical Conductivity: aesthetic*
  Electrical Conductivity (EC) is the measure of the ease with which water conducts electricity and gives an indication of the total dissolved salt (TDS) content of the water. Health effects related to EC occur only at levels above about 370 mS/m. The EC measurement (in mS/m) can also be used to estimate the TDS (in mg/L). If the median value exceeds the required limits, intervention is required to rectify the situation (e.g. ensure source protection, ensure treatment plant can effectively reduce EC/TDS, optimise operation at the treatment plant).
- *Suspended Solids: aesthetic*
  Suspended solids can lead to the development of sludge deposits and anaerobic conditions when untreated wastewater is discharged to the aquatic environment. If the median value exceeds the required limits shown above, intervention is required to rectify the situation (e.g. ensure source protection, optimise operation at the treatment plant).
- For treatment, parameters may include disinfectant concentration and contact time, UV intensity, pH, light absorbency, membrane integrity, turbidity and colour, e.g.:

Turbidity: As the turbidity of water increases, the amount of chlorine required for disinfection of the water increases. Low turbidity therefore minimises the required chlorine dose and reduces the formation of chloro-organics that often give rise to taste and odour problems and trihalomethanes. Due to the many advantages associated with water of low turbidity and the relative ease of monitoring, it is often used as an indicator of potential water quality problems during treatment.

7.4 Water Sources and Catchment Monitoring

Testing the natural resource water quality is particularly important for the following reasons:

- Upstream of effluent discharge point, where there is a potential that the resource water into which treated effluent is being released is already polluted beyond or close to safety levels or as part of an investigation of a waterborne disease outbreak, which may therefore require more extensive treatment of the released effluent
- Downstream of effluent discharge point will also be useful following a failure event of the treatment process, in order to identify what remedial actions are required in terms of health and safety for downstream users.
- Groundwater – to ensure that there is no unknown contamination taking place or to monitor the extent of contamination.

The frequency of testing will depend on the reason that the sampling is being carried out. Testing frequency may be:

- on a periodical basis, should typically be undertaken by the regulation agency (inspectorate) and/or an audit team;
- increased following degradation of source water quality resulting from predictable incidents, emergencies or unplanned events considered likely to increase the potential for a breakthrough in contamination (e.g. following a flood, upstream spills); and
- during seasonal event, such as rainstorms and high runoff, which is often accompanied with high sediment moving through the river systems.

7.5 Verification for Non-Reticulated Systems

Periodic testing (annually) of surrounding groundwater in areas where there are non-reticulated systems such as VIP toilets, septic tanks and conservancy tanks should be undertaken by the local authority. The testing should follow prescribed sampling and control procedures and will provide an indication of the extent of contamination of the resource. The findings should then be followed with clear control measures and validation if the controls have been implemented successfully. If contamination has already occurred, typical control measures would be to remove the source of contamination and cleaning up the polluted and affected areas.

An important aspect of risk management is to weigh local health versus water contamination versus access to safe potable water and sanitation facilities. A well constructed risk profile is likely to indicate that the cost and losses in terms of deteriorated health and compromised water resource validate investment in safe water and sanitation services.

Sanitary inspection (bi-annually) of community wastewater systems and household wastewater systems should typically be undertaken by the surveillance agency and should assess the conditions of the various systems in terms of suitability and structural and operational integrity.

Regarding package / on-site treatment plants, in addition to the periodic testing of the receiving resource to ensure that effluent is not negatively impact on it, the relevant Pollution Division of the local authority should also inspect the plant and sample the effluent on at least a six monthly basis. This is in addition to the monthly sampling undertaken by the operator of the plant.

7.6 Quality assurance and quality control

Appropriate quality assurance and analytical quality control procedures should be implemented for all activities linked to the production of treated wastewater quality data. These procedures will ensure that the data are fit for purpose – in other words, that the results produced are of adequate accuracy. Fit for purpose, or adequate accuracy, will be defined in the water quality monitoring programme, which will include a statement about accuracy and precision of the data. Because of the wide range of substances, methods, equipment and accuracy requirements likely to be involved in the monitoring of drinking-water, many detailed, practical aspects of analytical quality control are concerned. These are beyond the scope of this publication.

On an international basis the design and implementation of a quality assurance programme for analytical laboratories are described in detail in Water Quality Monitoring (Bartram & Ballance, 1996). The relevant chapter draws upon the standard ISO 17025:2000 General requirements for the competence of testing and calibration laboratories, which provides a framework for the management of quality in analytical laboratories.

Table 20: International Organisation for Standardisation (ISO) standards for water quality giving guidance on sampling

ISO standard no.	Title (water quality)
5667–1:1980	Sampling – Part 1: Guidance on the design of sampling programmes
5667–2:1991	Sampling – Part 2: Guidance on sampling techniques
5667–3:1994	Sampling – Part 3: Guidance on the preservation and handling of samples
5667–4:1987	Sampling – Part 4: Guidance on sampling from lakes, natural and man-made
5667–5:1991	Sampling – Part 5: Guidance on sampling of drinking-water and water used for food and beverage processing
5667–6:1990	Sampling – Part 6: Guidance on sampling of rivers and streams
5667–13:1997	Sampling – Part 13: Guidance on sampling of sludges from sewage and water-treatment works
5667–14:1998	Sampling – Part 14: Guidance on quality assurance of environmental water sampling and handling

5667–16:1998	Sampling – Part 16: Guidance on biotesting of samples
5668–17:2000	Sampling – Part 17: Guidance on sampling of suspended sediments
13530:1997	Water quality – Guide to analytical control for water analysis

In the South African context, guidelines have been developed in terms of a series of eight volumes comprising the South African Water Quality Guidelines:

- ✓ Volume 1: South African Water Quality Guidelines – Domestic Water Use
- ✓ Volume 2: South African Water Quality Guidelines – Recreational Water Use
- ✓ Volume 3: South African Water Quality Guidelines – Industrial Water Use
- ✓ Volume 4: South African Water Quality Guidelines – Agricultural Water Use: Irrigation
- ✓ Volume 5: South African Water Quality Guidelines – Agricultural Water Use: Livestock Watering
- ✓ Volume 6: South African Water Quality Guidelines – Agricultural Water Use: Aquaculture
- ✓ Volume 7: South African Water Quality Guidelines – Aquatic Ecosystems
- ✓ Volume 8: South African Water Quality Guidelines – Field Guide.

*www.**dwa**.gov.za/documents/*

8. MANAGEMENT PROCEDURES FOR WASTEWATER TREATMENT SYSTEMS

Effective management requires the explanation of actions to be taken in response to variations that occur during normal operational conditions; of actions to be taken in specific "incident" situations where a loss of control of the system may occur; and of procedures to be followed in unforeseen and emergency situations.

Management procedures should be documented alongside system assessment, monitoring plans, supporting programmes and the communication required to ensure safe operation of the system.

The value of effective and implemented management systems in achieving successful operations of wastewater treatment plant has been emphasised throughout this Guideline. Much of a management plan will describe actions to be taken in response to "normal" variation in operational monitoring parameters in order to maintain optimal operation in response to operational monitoring parameters reaching operational limits.

A significant deviation in operational monitoring where a critical limit is exceeded (or in verification) is often referred to as an "incident." An incident is any situation in which there is reason to suspect that water being supplied for drinking may be, or may become, unsafe (i.e. confidence in water safety is lost). As part of a W_2RAP, management procedures should be defined for response to predictable incidents as well as unpredictable incidents and emergencies. Incident triggers could include:

- non-compliance with operational monitoring criteria;
- inadequate performance of a sewage treatment plant discharging to source water;
- spillage of a hazardous substance into source water;
- sewer losses during reticulation and pumping of wastewater – not arriving at treatment plant;
- failure of the power supply to an essential control measure;
- extreme rainfall in a catchment;

- detection of unacceptable levels of metals, ammonia, etc.;
- unusual odour or appearance of returned effluent water;
- detection of microbial indicator parameters, including unusually high faecal indicator densities and unusually high pathogen densities in returned effluent; and
- public health indicators or a disease outbreak for which water is a suspect vector.

Incident response plans can have a range of alert levels. These can range from early detection via trends analysis or early warning systems (necessitating no more than additional investigation) through to emergency (dealt with through Disaster Management Plans). Emergencies are likely to require the resources of organisations beyond the drinking water supplier, particularly the public health authorities.

☑ **Important:** The plan may need to be followed at very short notice; hence standby rosters, effective communication systems and up-to-date training and documentation are required.

Incident response plans typically comprise:

- accountabilities and contact details for key personnel, often including several organisations and individuals;
- lists of measurable indicators and limit values/conditions that would trigger incidents, along with a scale of alert levels;
- clear description of the chain of events / actions required in response to alerts; location and identity of the standard operating procedures (SOPs) and required equipment; location of backup equipment;
- contingency plans;
- Standard Operating Procedures;
- relevant logistical and technical information;
- communication protocol to national water agency, as well as public; and
- checklists and quick reference guides.

Staff should be trained in response to ensure that they can manage incidents and/or emergencies effectively. Incident and emergency response plans should be periodically reviewed and practiced. This improves preparedness and provides opportunities to improve the effectiveness of plans before an emergency occurs.

Following any incident or emergency, an investigation should be undertaken involving all concerned staff. The investigation should consider factors such as:

- What was the cause of the problem?
- How the problem was first identified or recognised?
- What were the most essential actions required?
- What communication problems arose, and how were they addressed?
- What were the immediate and longer-term consequences?
- How well did the emergency response plan function?
- Did the turnaround plan match the seriousness of the incident?
- Should documentation (e.g. SOPs) be updated or reviewed?

Appropriate documentation and reporting of the incident or emergency should also be established. The organisation should learn as much as possible from the incident or emergency to improve preparedness and planning for future incidents. Review of the incident or emergency may indicate necessary amendments to existing protocols. Each incident represents a learning opportunity. Documentation and sharing of ‘Learning Journeys’ will improve understanding across the services sectors and organisations.

EXAMPLE
eThekwini Municipal Incident Response Management Protocol

ETHEKWINI MUNICIPALITY: PHOENIX WWTW
INCIDENT REPORTING PROTOCOL

STEP 1: INCIDENT IDENTIFICATION

Incident identified:

- **Death on Duty**
- **Accidental contact with Chlorine**
- **Injuries (requiring medical attention)**
- **Near misses**
- **Power failure with no back-up power for more than 4 hrs**
- **Critical process equipment failure or malfunction**
- **Critical process equipment taken off-line**
- **Security incidents**
- **Sludge spills**
- **Sludge discharge to river or ponds**
- **Chemical spills**
- **Stormdam discharge to river**
- **Unsafe practices**
- **Fire**
- **Sewage discharge to river or ponds**
- **Chlorine leak – uncontrolled release of chlorine gas**
- **Pollution in the inflow**
- **Sewage spills**
- **Abnormal flows**
- **Odour and Air pollution**
- **Critical delay in commencing or completing process equipment maintenance or repairs**

STEP 2: INCIDENT REPORTING – PHASE 1

Any member of staff must IMMEDIATELY report the incident to the Works Superintendent: *P Nosworthy* in person or by telephone. *P Nosworthy* will ensure that the necessary corrective actions are taken. If *P Nosworthy* is not contactable then contact the Works Area Engineer: *Hilton Blair*.

STEP 3: INCIDENT REPORTING – PHASE 2

The Works Superintendent: *P Nosworthy* is to IMMEDIATELY report the incident to the Works Area Engineer, and, in the event of a pollution incident, report this to Pollution Control as well.

STEP 4: INCIDENT REPORTING – PHASE 3

The Works Area Engineer must report the incident to the Manager: Works within 24 hours, giving as much detail as possible.

STEP 5: INCIDENT RESPONSE

The Superintendent must respond to the incident immediately if he is on site. If he is not on site, he must personally and physically respond to the incident within 4 hours of notification.

STEP 6: INCIDENT RECORDING

The incident must be recorded in all relevant logbooks and the Incident Register as soon as possible giving as much detail as possible.

STEP 7: INCIDENT INVESTIGATION AND REVIEW

The Works Area Engineer, where necessary, will arrange or conduct an investigation into the incident. The Works Area Engineer is to convene a meeting with relevant stakeholders and the Manager: Works to review the details of the incident, find the root cause and implement recommendations.

TELEPHONE NUMBERS

P Nosworthy (cell) 083 375 2654 031 464 3101 **(home)**
H Blair (cell) 083 274 5573
Pollution control: 031 311 8685 (office hours) 0801313013 (all hours)

Figure 16: Example of a typical (site specific) Incident Reporting Protocol

In the event of an incident situation, it is good practice to have an Alert Protocol in place. The protocol could define the level of alert, i.e.:

- **Alert level 1** = No significant risk to health and the incident can be contained or controlled
- **Alert level 2** = Potential risk to public health and/or environment and the root cause is identifiable but cannot be immediately contained and will last for approximately 24 hours. Management, Council and the Regulating Authority are notified. Emergency procedures have been initiated.
- **Alert level 3** = The impact of the incident is severe and the root cause is not easily identifiable or easily contained or controlled. The impact of the incident has significant consequences and will last longer than 24 hours. Emergency procedures have been initiated.

Alert protocols could be coupled with specific operational, environmental values, types of incidents, etc. Example of operational levels:

- Alert level 1 = reaching operational capacity
- Alert level 2 = exceeding operational COD, NH_3 levels
- Alert level 3 = levels are within 20% of operational capacity.

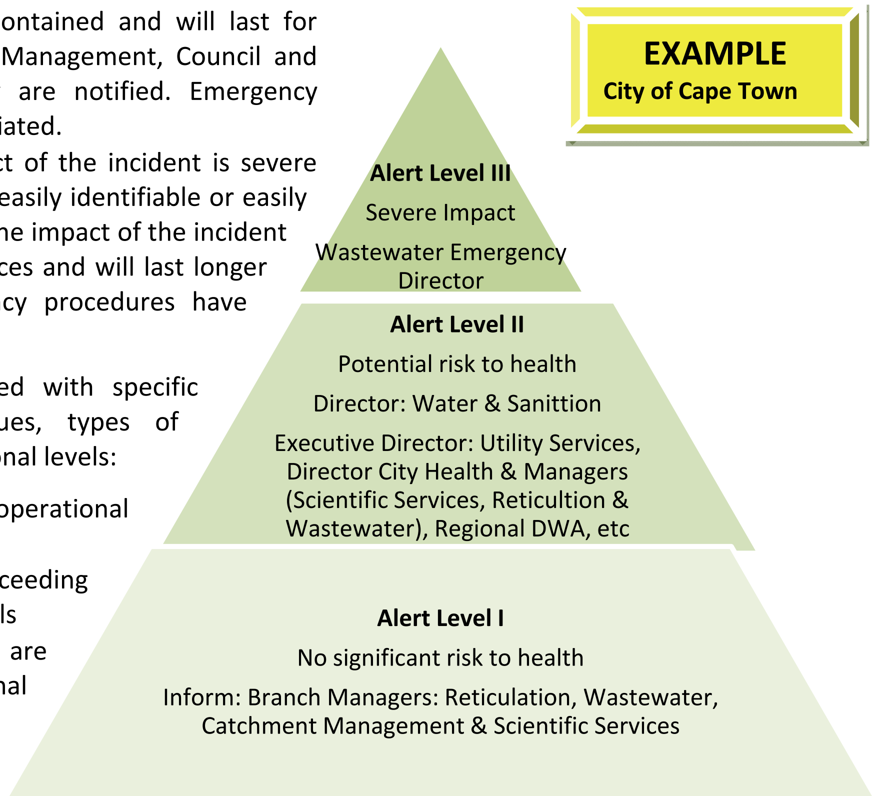


Figure 17: A typical example of an alert level and reporting protocol in a municipal environment

8.1 Predictable incidents ("deviations")

Many incidents (e.g. exceedance of a critical limit in terms of influent quantity and quality; effluent quality parameters, system breakages, power outages, etc.) can be foreseen, and management plans can specify resulting actions. Actions may include, for example, temporary diversion or prior balancing of influent (if possible), increasing dosing, use of backup disinfection or increasing disinfectant concentrations, access to backup power, bypassing peak stormwater influx to disinfection process unit, etc. These actions would also be documented as part of the contingency plans dealing with various incidents.

8.2 Unforeseen events

Some scenarios that lead to returned effluent being considered potentially unsafe might not be specifically identified within incident response plans. This could be due to the fact that the events may either have been unforeseen or because they were considered too improbable / unlikely to justify preparing detailed corrective action plans. To allow for such events, a general incident response plan should be developed, which often will be linked to existing disaster management plans of the local authority. The plan would be used to provide general guidance on identifying and handling of incidents along with specific guidance on responses that would be applied to many different types of incident.

A protocol for situation assessment and declaring incidents would be provided in a general incident response plan that includes personal accountabilities and categorical selection criteria. The selection criteria may include:

- time to effect;
- population affected;
- nature of the suspected hazard;
- provision of alternative safe drinking water (e.g. in cases where water is drawn from downstream contaminated river); and
- impact on infrastructure condition and equipment functionality.

The success of general incident responses depends on the experience, judgment and skill of the personnel operating and managing the treatment systems. However, generic activities that are common in response to many incidents can be incorporated within general incident response plans. For example, Standard Operating Procedures (SOPs) for rapidly changing or bypassing system components can be prepared, tested and incorporated. The development of such a "toolkit" of supporting material limits the likelihood of error and speeds up responses during incidents.

8.3 Emergencies

Disaster Management Plans (DMPs) must be developed and where necessary be incorporated in to the local and provincial authorities DMPs. These plans should consider potential natural disasters (e.g. earthquakes, floods, damage to electrical equipment by lightning strikes), accidents (e.g. spills, structural failure of tanks/ponds, etc.), damage to treatment plant and reticulation system and human actions (e.g. strikes, sabotage). Emergency plans should clearly specify responsibilities for coordinating measures to be taken, a communication plan to alert and inform users of the drinking-water supply and practical plans for providing and distributing emergency supplies of drinking-water, and plans to clean and remediate spillages to the receiving environment or water resource.

Plans should be developed in consultation with relevant regulatory authorities and other key agencies and should be consistent with national and local emergency response arrangements. Key areas to be addressed in emergency response plans include:

- response actions, including increased monitoring;
- responsibilities and authorities internal and external to the organisation;
- plans for emergency drinking-water supplies;
- plans for clean up and remediation of contaminated sites;
- communication protocols and strategies, including notification procedures (internal, regulatory body, media and public);
- mechanisms for increased public health surveillance; and
- 'triggers' that alert and gear clinics to treat infections and waterborne disease in affected communities.

Response plans for emergencies and unforeseen events involving microorganisms or chemicals should also include the basis for health and safety advisories. The objective of the advisory should be taken in the public interest, and the advisory will typically be managed by public health authorities. "Practice" emergencies are an important part of the maintenance of readiness for emergencies, as they assist to determine the potential actions that can be taken in different circumstances.

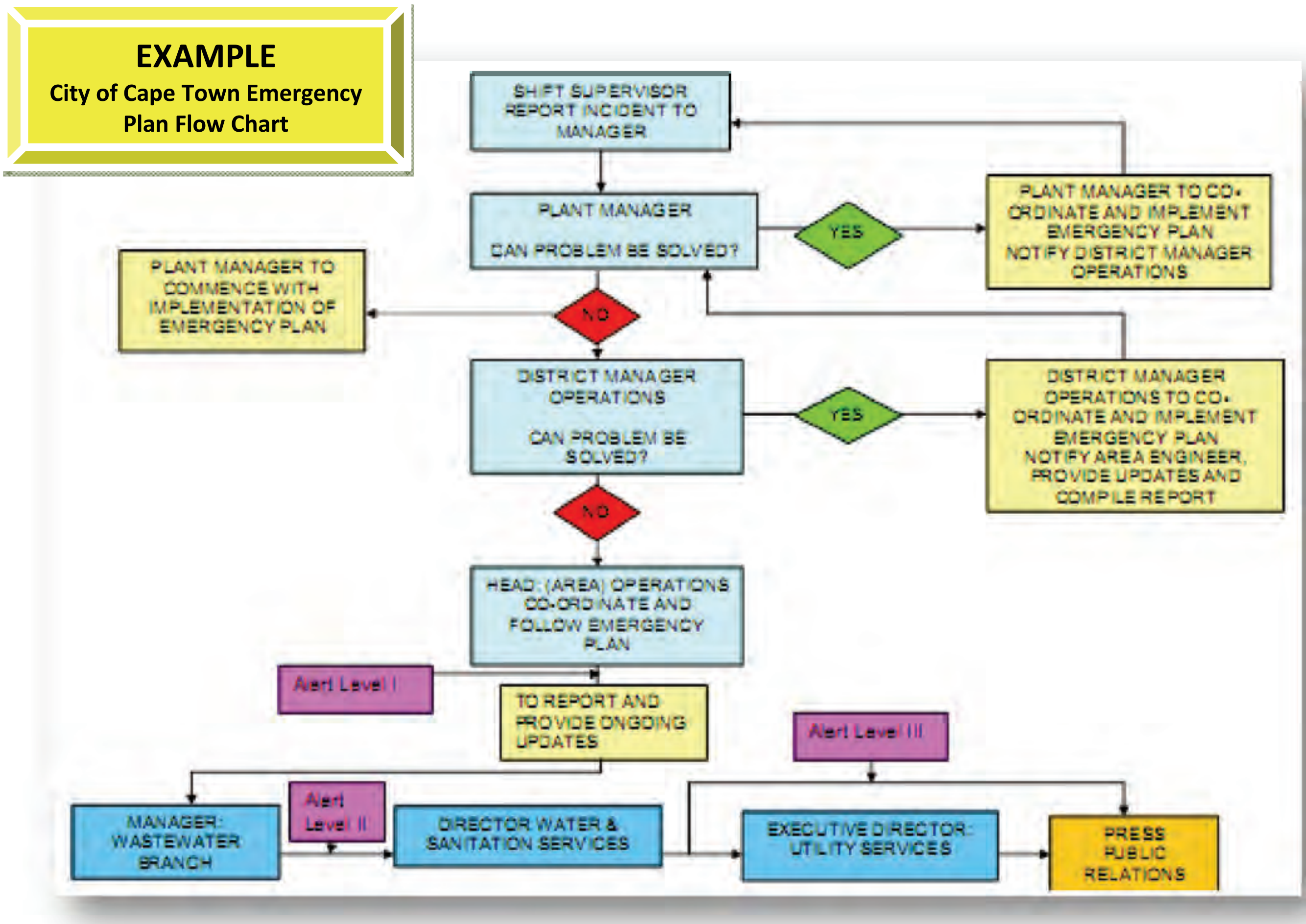


Figure 18: A typical example of an emergency plan flow chart in a municipal environment

8.4 Preparing a monitoring plan

Programs should be developed for operational and verification monitoring and documented as part of a W$_2$RAP, detailing the strategies and procedures to follow for monitoring the various aspects of the wastewater treatment system. The monitoring plans should be fully documented and should include the following information:

- parameters to be monitored;
- sampling or assessment location and frequency;
- sampling or assessment methods and equipment;
- schedules and frequency for sampling or assessment;
- methods for quality assurance and validation of results;
- requirements for checking and interpreting results;
- responsibilities and necessary qualifications of staff;

- requirements for documentation and management of records, including how monitoring results will be recorded and stored; and
- requirements for reporting and communication of results.

8.5 Supporting programmes

Supporting programmes contain actions that are important in ensuring wastewater treatment safety but do not directly affect wastewater quality.

Many actions are important in ensuring the safe discharge of effluent and disposal of sludge, but do not directly affect wastewater quality and may therefore not necessarily be considered control measures. These are referred to as "supporting programmes" and should also be documented in a W_2RAP.

Supporting programmes could involve:

- controlling access to treatment plants, pumpstation, sewers, discharge points, disposal sites, etc., and implementing the appropriate security measures to prevent transfer of hazards from people;
- developing verification protocols for the use of chemicals and materials in the wastewater treatment – for instance, to ensure the use of suppliers that participate in quality assurance programmes;
- using designated equipment for attending to incidents such as sewer leaks, pumpstation failures, mains bursts (e.g. equipment should not be designated for potable water work and not for sewage work); and
- training and educational programmes for personnel involved in activities that could influence wastewater treatment safety; training should be implemented as part of induction programmes and frequently updated.

Supporting programmes will consist almost entirely of items that wastewater treatment operators and management will ordinarily have in place as part of their normal operation. For most, the implementation of supporting programmes will involve:

- collation of existing operational and management practices;
- initial and, thereafter, periodic review and updating to continually improve practices;
- trends analysis using historical data to depict trends and make future projections;
- promotion of good practices to encourage their use; and
- audit of practices to check that they are being used, including taking corrective actions in case of non-conformance.

Codes of good operating and management practice and hygienic working practice are essential elements of supporting programmes. These are often captured within SOPs. They include, but are not limited to:

- hygienic working practices documented in maintenance SOPs;
- attention to personal hygiene;
- training and competence of personnel involved in wastewater treatment;
- tools for managing the actions of staff, such as quality assurance systems;
- securing stakeholder commitment, at all levels, to the under taking of wastewater treatment;
- education of communities whose activities may be influence discharged wastewater (effluent or irrigation with wastewater) quality;
- calibration of monitoring equipment; and
- record keeping.

Comparison of one set of supporting programmes with the supporting programmes of other suppliers, through peer review, benchmarking and personnel or document exchange, can stimulate ideas for improved practice.

Supporting programmes can be extensive, be varied and involve multiple organisations and individuals. Many supporting programmes involve other water resource protection measures (e.g. stormwater management practices) and typically include aspects of land use control, spatial development and planning, and water demand management.

8.6 Management of Non-Piped, Community and Household Wastewater Systems

Due to the nature of this type of service (VIP toilets, septic tanks, etc.), where the individual most often is responsible for their own system, effective management is often problematic.

Options available to improve and exert a measure of control would include the following:

- regular groundwater monitoring by local authority to determine the impact on the groundwater, where such a monitoring process could also assist in the planning and budgeting to determine when there is a need to convert this system to a more controllable process such as water borne or small bore systems;
- developing and instituting support programmes such as ongoing public education processes to heighten the awareness of the community / consumer to the correct use of their system and possible self measuring activities / maintenance checks and repairs;
- setting controls in place (bylaws) to ensure that only qualified plumbers or trained community member work on or install such systems, e.g. register of approved certified plumber;
- register and train services providers responsible for VIP, septic tank, etc. construction; and
- most often the most effective and necessary support is to assist communities in undertaking effective sanitation and health and hygiene habits.

With regard to package / on-site treatment plants, these are to be fitted with the necessary failure alarms, are subject to the specific approval condition as determined by the local authority bylaws and the Department of Water Affairs. Some of the prerequisite information that should form part of the approval criteria by the local authority is:

- Details of proposed sewage treatment plant/process;
- Details of the registered professional engineer / technologist, responsible for undertaking the design / selection and supervision of the installation, construction and commissioning of the plant;
- Environment Impact Assessment (EIA) report;
- Local Authority Health Department approval;
- Department of Water Affairs (DWA) registration/license;
- Confirmation of contracts (for operation/maintenance/monitoring/reporting services);
- Drawing and calculation of irrigation area and confirmation of compliance with the minimum requirements for irrigation;

- Measures to be taken to provide for mechanical, electrical, operational or process failure and malfunction of the plant including details of all back-up systems;
- Measures to be taken to avoid or mitigate nuisance or complaint arising from the operation of the sewage treatment plant / system and to ensure protection of public health and safety, including the proposed method of disposal of byproducts / waste materials (sludge, detritus, screenings).

9. DOCUMENTATION AND COMMUNICATION

Regular update of records as the information becomes available reduces the amount of updating required at the end of an operational year, when a review of the W_2RAP is planned. Documentation of a W_2RAP should include:

- description and assessment of the wastewater treatment system (see Section 2-2), including programmes to upgrade and improve existing wastewater service (see Section 2-3);
- the plan for operational monitoring and verification of the wastewater treatment system (see Section 7);
- wastewater treatment safety management procedures for normal operation, incidents (specific and unforeseen) and emergency situations (see Sections 8.1-8.4), including communication plans (Section 9); and
- description of supporting programmes (see Section 8.5).

Records are essential to review the adequacy of the W_2RAP and to demonstrate the adherence of the wastewater treatment system to the W_2RAP. Five types of records are generally kept:

- supporting documentation for developing the W_2RAP including validation;
- records and results generated through operational monitoring and verification;
- outcomes of incident investigations;
- documentation of methods and procedures used; and
- records of employee training programmes.

By tracking records generated through operational monitoring and verification, an operator or manager can detect that a process is approaching its operational or critical limit. Review of records can be instrumental in identifying trends and in making operational adjustments. Periodic review of W_2RAP records is recommended so that trends can be noted and appropriate actions decided upon and implemented. Records are also essential when surveillance is implemented through audit-based and risk-based approaches.

Communication strategies should include:

- ongoing provision of monitoring data at the required interval to the relevant governing authorities, such as DWA;
- procedures for promptly advising of any significant incidents within the wastewater treatment process, including notification of the public health authority;
- summary information to be made available to consumers – for example, through annual reports, the Internet and dedicated e-systems (e.g. Green Drop System, RPMS); and
- establishment of mechanisms to receive and actively address community complaints in a timely fashion.

The right of consumers to health-related information on the wastewater treatment effectiveness, specifically in terms of discharge effluent, is fundamental. However, in many communities, the simple right of access to information will not ensure that individuals are aware of the environment and health implications of ineffectual wastewater treatment and effluent discharge. The agencies responsible for monitoring should therefore develop strategies for disseminating and explaining the significance of health-related information.

10. REVIEW OF W_2RAP

The review of the verification should be used to evaluate and review the W_2RAP to determine whether the field assessments need updates or modifications. This requires a process of verification data analysis with the sole purpose of determining any gaps in the W_2RAP. If the analysis indicates that critical limits are not achieved at critical control points, despite the implementation of control measures and preventative action plans, then it points to:

- risks have been identified incorrectly
- control measures are insufficient
- control measures have been identified incorrectly
- the critical limits are inappropriate

In such a case, an independent verification is recommended.

The W_2RAP should be reviewed:

- ✓ annually
- ✓ after an incident as part of the debriefing
- ✓ after any significant change in the value (production) chain
- ✓ when identifying a weakness in the plan
- ✓ additional information is received that warrant a revised risk level for that system.

11. CONCLUDING REMARKS BY FOUR MUNICIPAL W_2RAP USERS

Four municipalities tested the W_2RAP Guideline in practice to ensure that the Guideline is practical and relevant in the municipal wastewater business. All development work, including the W_2RAP documents and risk matrixes, is collated in a complimentary CD that will be distributed with this W_2RAP Guideline. The municipalities commented as follows:

- City of Cape Town: *"Risk management is non-negotiable and each manager must ensure that the W_2RAP is implemented. The W_2RAP is a living document and is required to be updated on an annual basis after an incident where risk control strategy may require a revision…"*
- Steve Tshwete Municipality: *"We have identified a number of risks after review of the Cumulative Risk Rating scores and our W_2RAP proposes implementation of actions to reduce these…"*
- eThekwini Municipality: *"We look forward to use the W_2RAP as our primary risk management tool in order to enhance our Wastewater Services in eThekwini…"*
- Nelson Mandela Bay Municipality: *"Our W_2RAP will be used as the primary tool for wastewater quality management. It is intended to be simple and practical in nature and can be applied using the following guideline which covers each section of wastewater system…"*

The following recommendations can be made with regard to the future roll out of the W_2RAP:

- Development of a tool that contain comprehensive and combined list of risks and list of control measures corresponding to the risks, as part of a master risk assessment template.
- Roll out of a basic risk assessment training course in municipalities to build specialist capacity that can serve across the departmental divides within the organisational structure, where such trained and competent individual can facilitate risk assessments in the solids waste unit, roads and stormwater unit, and so forth.
- That the financial sector considers the merits of the risk abatement approach to support municipalities in terms of funding requirements to implement the W_2RAP approach and plans.

SECTION 3

2. W_2RAP CHECKLIST

	YES	NO
1. Has a multi-disciplinary team of experts been assembled to carry out the W_2RAP development?	☐	☐
2. Has the team been informed of their duties and commitment?	☐	☐
3. Has the wastewater treatment system been described? (i.e. has each step in the system been considered for range and magnitude of hazards that may be present, and the ability of existing processes and infrastructure to manage actual or potential risk)	☐	☐
4. Following the description of the system above, has all the information been documented on three levels: catchment, collection and treatment?	☐	☐
5. Has the system been assessed and a flow diagram constructed?	☐	☐
6. Has the flow diagram been further developed to allow for flow and quality in-, during-, and out of the plant?	☐	☐
7. Have these hazards been identified and prioritised using the hazard assessment matrix provided?	☐	☐
8. Are there critical control points and control measures in place to reduce the identified hazards?	☐	☐
9. Is there a system in place to monitor the control measures?	☐	☐
10. Have corrective actions been identified for each control measure, especially if the control measure fails?	☐	☐
11. Are there procedures in place to verify that the W_2RAP is working effectively and will meet the health- and environmental based targets?	☐	☐
12. Have supporting programmes been developed to ensure that health based targets will be met?	☐	☐
13. Have management procedures been prepared to respond to "normal" and "incident" conditions?	☐	☐

14. Has all the relevant information regarding the wastewater system been documented? ☐ ☐
    (i.e. description and assessment of the system, plan for operational monitoring, plan for verification of wastewater system, management procedures, etc.)

15. Have communication procedures been established? ☐ ☐
    (i.e. general information on effluent quality through the media, annual reports, procedures for promptly advising of any significant incidents, mechanisms to receive and actively address community complaints, etc.)

16. Has the W_2RAP been reviewed at the following stages?

    Annually ☐ ☐

    After an incident ☐ ☐

    After any significant change to the wastewater system ☐ ☐

    In response to finding a weakness in the plan ☐ ☐

    Additional information regarding the system in received that might warrant a revised risk level for that system. ☐ ☐

3. REFERENCES

Following is a list of documents and publications accessed to provide direction or confirmation of the information contained in the guideline document:

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ANNEXURE A:

Possible Control Measures or Corrective Actions that can be applied to wastewater risk situations

POLICIES, PLANS AND PROCEDURES	**PHYSICAL DETECTION MEASURES**	**BACK-UP AND ALTERNATIVES**
Sanitation Master Plan	Site lighting	Redundant storage tanks or other facilities
Waste Services Development Plan	Safety and operational signage	Alternative or back up disinfection measures
Integrated Development Plan	Security, access control and sign-in registers	Alternative chemicals for phosphate removal, flocculation or sedimentation
O&M Plan	Manual remote access permission	Alternative vendors
Asset Management Plan	Card-key badge systems or entry code access	Back-up of key documents
Standard Operating Procedures	Camera surveillance (incl CCTV)	Back-up of drawings and maps
O&M Manuals	Sensors: motion control, boundary penetration, interior, etc.	Back-up of IT applications
Operations and Maintenance Schedules & Registers	Rapid response units	Back-up of key data & information
Stormwater Management Plans and Water Demand Management Plans	Metal detector doorways	Archives and filing systems to store documents for the legal year limit
Workplace Skills Plans	Security awareness program	**PHYSICAL DELAY or STRUCTURAL MEASURES**
Disaster Management Plans	Visitor safety awareness protocol	Fencing (razor, chain link, barb wire, palisade, etc.)
Institutional Memory Policy and Plans	In-line and on-line process monitoring	Hardened doors, gates, windows, ladder access
Emergency Policy and Plans	Chlorine leakage detectors	Perimeter concrete walls and bollards or barriers
Financial Management Policy and Plans	Pressure and level control sensors	Outfall entry barrier
Supply Chain Management Policy and Plans	Variable speed drive controls	Secured fill and vent pipes
Supplier/Contractor Agreements or Contracts	Flow sensors, flow meters, pump hour meters (and calibration thereof)	Secured manholes

Service Levels Agreements	IT application monitoring	Secured wellheads
Customer Contracts	IT network intrusion detection	Low value manhole covers, valves, etc.
Customer Information Services Charters	IT referential integrity	Retention dams at pumpstations
Technical Audit Reports	SCADA systems with user security level	Balancing/equilisation dams at treatment plants
Financial Audit Reports	LIMS with user security level	Stormwater plant-bypass
Water Services Bylaws and tariffs (including industrial users)	MIS applications with user security level	Storage dams (sludge and effluent) with recycle
APPOINTMENTS	Green Drop System with user security level	Replace older pipes (clay, concrete) with uPVC and AC piping
Appropriate Municipal Manager appointed (as regulated)	Technical Audits of IT systems	Telemetry on pumpstations
Appropriate Chief Financial Officer appointed (as regulated)	Data and information encryption (e.g. on sewer network)	Level switches and controls
Appropriate Technical Manager appointed	Access to and monitoring of weather conditions (e.g. floods, storms, rain fall)	Standby and duty pumping arrangements
Appropriate Supervisors appointed	ID check procedures	Flow balancing / equalisation dams
Regulation 2834 Process Controllers appointed	Information classification procedures	Lining of ponds
Trade tested mechanical and electrical staff appointed	Telephone and internet monitoring and audit checks	
Appropriate technicians appointed	Landscaping maintenance checks	
Qualified scientific and laboratory staff appointed	Explosive mixture detectors (e.g. methane)	
Specialist consultants appointed complimentary to existing staff	Biological contamination sensors	
Competency testing of candidate appointees	Chemical contamination sensors	
Performance Management Systems and Appraisals	TOC analysers	

PROCESS CONTROL MEASURES	PHYSICAL RESPONSE MEASURES
Reduce/divert excessive extraneous flows to the plant (with disinfection)	No-drinking notices, no-swimming notices, etc.
Use of approved water treatment chemicals & materials	Public address or other warning systems
Control of wastewater treatment chemicals;	Media contact (newspaper, radio, news)
Process controls at each process unit	Automatic flow gates / valves
Ensure plant operate within design capacity	Automatic chemical dosing
Periodic wastewater treatment process optimisation (including chemical dosing and flow rate)	Automatic flow measurement
Increase of MLSS and sludge age prior to holiday (tourist) influx	Alternate electric switching equipment
Routine operations rosters (flow recording, desludging, recycle ratio setting, etc.)	Alternate power sources
Harvesting of algae biomass from pond systems	On-site back-up power generation
	Personal Protection Equipment for staff
	Evacuation plans (fire, bomb, etc.)
	Coordination with emergency services (police, hospital, fire)
	HAZMAT procedural plans
	Duplicate keys
	Arrangements with critical suppliers
	Workshop, spare parts and critical equipment inventories
	Training in all procedures
	Alert levels and response management protocols