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Kind regards,

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# Minimizing risks in wastewater reuse: proposed operational principles and guidelines for South Africa

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## Abstract:

Treated wastewater represents a significant potential source of reclaimed water for some beneficial reuses. However, public concern on the risks/health related hazards of wastewater reuse has limited the general acceptability of reuse systems in many countries. It is important to manage the operation of recycled water systems in such a way that it will not adversely affect public health and environment. Management of recycled water involves process control and compliance monitoring. This paper presents a proposed unit process monitoring guidelines to classify the performances of treatment units according to the pollutant removal efficiencies and frequency of sampling to test for effluent quality suitable for reuse. The paper also highlights the procedure for proper inspection of treatment facilities to ensure optimum performances. It also propose minimum quality requirement for different reuse activities in South Africa such as domestic (toilet flushing, landscape irrigation, public and park irrigation), irrigation (agricultural, crops, landscape, parks and golf cemeteries), industrial (system cooling and process water) and other activities (construction works, street cleaning, fire protection and groundwater recharge). By employing the wastewater treatment monitoring and sampling procedure proposed in this paper, health related hazards can be minimized while public confidence on reuse schemes will be better enhanced.

**Keywords:** wastewater reuse, guidelines, monitoring, sampling, risks and health hazards.

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## 1. Introduction

Water demand already exceeds supply in many parts of the world, and many more areas are expected to experience this imbalance in the near future. In order to meet an ever increasing demand for freshwater, past efforts have centred on the development of additional water resources schemes i.e. water supply interventions such as the exploitation of distant surface water and deeper groundwater sources, construction of new dams and desalination (Friedler and Hadari, 2006). However, implementation of these measures usually requires significant capital investment (planning, construction, operation, maintenance, and replacement) and is frequently accompanied by negative long term environmental effects such as the depletion of renewable water resources, deterioration of water quality, seawater intrusion, and alteration of ecosystem dynamics.

Wastewater reuse for irrigation to crop plants was evaluated in a laboratory-scale experiment to assess growth and water saving potential from natural resources by Jimenez et al. (2011). Their results shows that plant growth was visibly greater in suspended growth sequencing batch bioreactor (SGSBBR) treated wastewater than attached growth sequencing batch bioreactor (AGSBBR) because of less nutrient removal. Abdel-Shafy et al. (2011) evaluated the upgrading of a pond system for municipal wastewater treatment in a decentralized area for restricted reuse. Their results indicated that remarkable improvement in the treated effluent was achieved after upgrading the pond system via aeration.

Efficient and sustainable water use involves wastewater reuse. The main benefits of wastewater reuse are: protection of water resources, prevention of coastal pollution, recovery of water and nutrients for agriculture, savings in clear water use and wastewater treatment costs (Capra and Scicolone, 2007; Saba et al. 2011). Wastewater reuse may expose the public to a variety of diseases causing pathogens such as bacteria, viruses, protozoa, or helminths. The factors influencing the transmission of these diseases in wastewater reuse are: the degree of wastewater treatment, reuse applications and the degree of contact with wastewater. To reduce potential risks to public health and promote public acceptance, there is a well established guideline for water reuse for agricultural irrigation by the World Health Organization (WHO, 2006) while the US Environmental Protection Agency (USEPA,2004) has standards for various non-potable applications. Also, there are standards available in many developed (e.g. USEPA, 2004) and developing (e.g. Mexico and Indonesia, Blumenthal et al., 2000) countries. In Europe, some member states or autonomy regions have their own standards/guidelines/regulations (Bixio, et al., 2005). Salgot et al. (2003) highlight pollutants of importance in water reuse and the need to develop a better tool for risk assessment and management while economic analysis of pollutants in wastewater for reuse are reported in Salgot, et al. (2006).

In South Africa, there are no clear guidelines specifically targeted at the use of wastewater. However, the existing regulation that partially addresses the use of wastewater is the DNHPD (1978). This guideline is an outdated guideline that needs to be revisited in light of the current local and international experience (Ilemobade, et al, 2009). This paper presents a proposed unit process monitoring guidelines to classify the performances of treatment units according to the pollutant removal efficiencies (i.e., minimum, average and maximum) and frequency of sampling to test for effluent quality suitable for reuse. The paper also presents the procedure for proper inspection of treatment facilities to ensure optimum performances.

## **2. Overview of Wastewater Treatment Performance in South Africa**

The quality of discharges from wastewater treatment plants in South Africa has become a matter of national importance and priority. The National Water Services Regulation Strategy (DWAF, 2008) provides a clear statement of strategic intent to regulate the water and wastewater services sector in South Africa. The driving force of this strategy is the mitigation of risk associated with the management of water and wastewater facilities and the development of more comprehensive and effective regulation for the country. The three main programmes identified to mitigate risks are (DWAF, 2008):

- concentrated regulatory efforts to address compliance and performance problems in priority municipalities, particularly where risks pose threats to health and the environment;
- a national drinking water quality regulatory initiative to manage potentially serious risks associated with unsafe drinking water; and
- a national wastewater discharge regulation initiative to manage potentially serious risks to health and the environment.

In line with international good practice, Department of Water and Environmental Affairs (DWEA) embarked on the assessment of all wastewater treatment plants in South Africa in 2008 (Manus and van der Merwe-Botha, 2010). This assessment is aimed at developing the following two-pronged regulatory approach to raise the performance of wastewater treatment plants and effluent quality:

- an approach that is based on a risk profile of all wastewater treatment plants and that targets the plants that have the greatest impacts on the receiving environment;
- an incentive-based approach that recognises excellence in the wastewater industry and that encourages service providers (i.e. municipalities) to work towards the achievement of Green Drop Certification which acknowledges the state of excellence in wastewater services. A Purple Drop Certification is issued if a service provider fails to comply with a predetermined level of green drop.

The above two-pronged approach to wastewater treatment plant assessment allows for incentive, punitive or assisted measures to be taken depending on the specific circumstances of non-compliance by the service provider. Manus and van der Merwe-Botha (2010) reported the findings on the assessment of wastewater treatment plants carried out in the nine provinces of South Africa during November 2008 to August 2009. The report clearly indicated that the general situation in the operation and management of wastewater treatment works (WWTWs) in South Africa demands an urgent attention. Hence, there must be a paradigm shift in the operation and management of WWTWs in order to guarantee the sustainable implementation of recycled water.

### **3. Suggested Operational Guidelines for Wastewater Reuse**

Different hazards could occur due to WWTWs failures. From the public health and environment standpoint, it is reasonable that a high standard of reliability should be required for a system producing reclaimed water for uses where direct or indirect human contact is likely. Therefore, water reuse requires strict conformity to all applicable water quality standards.

Several elements are combined together to make up a reclaimed water system's treatment and distribution. These include the power supply, individual treatment units, the maintenance program, and the operating personnel. Backup systems are important in maintaining reliability in the event of failure of vital components. Critical units within this system include the disinfection system, power supply, and various treatment unit processes (USEPA, 2004).

For reclaimed water production, EPA Class I reliability is recommended as a minimum criteria. EPA Class I reliability requires redundant facilities to prevent treatment abnormality during power and equipment failures, flooding, peak loads, and maintenance shutdowns. Reliability for water reuse should also consider the followings (USEPA, 2004):

- operator certification to ensure that qualified personnel operate the water reclamation and reclaimed water distribution systems ;
- instrumentation and control systems for on-line monitoring of treatment process performance and alarms for process malfunctions;
- a comprehensive quality assurance program to ensure accurate sampling and laboratory analysis protocol;
- adequate emergency storage to retain reclaimed water of unacceptable quality for re-treatment or alternative disposal and supplemental storage to ensure that the supply can match user demands;
- a strict industrial pre-treatment program and strong enforcement to prevent the illicit disposal of hazardous or other similar material that may interfere with the treatment and intended use of the reclaimed water.

Based on the above points and additional references, suggested guidelines for the operation of non-potable reuse are presented below:

### ***Operator Training and Competence***

No matter how sophisticated the automation of a plant is, mechanical equipments are subject to breakdown. Hence, qualified and well-trained operators are necessary to ensure the production of reclaimed water of the required quality. Plant operators are considered to be the most critical technical personnel in the wastewater treatment and reuse systems.

The knowledge, skills, and abilities that an operator must possess vary considerably depending on the complexity of the plant. In general, an operator must be familiar with the following:

- the function of each unit in the plant;
- how each unit accomplishes its function;
- how to evaluate the operation of each function; and
- how each unit fits into the overall plant process.

The National Water Act (Gazette 28557 of 24/02/2006) requires operator certification as a reasonable means to expect competent operation. Frequent training via continuing education courses or other means enhances operator competence. Since actions of the system operator have the potential to adversely or positively affect reclaimed water quality, a knowledgeable and well trained operator is critical to the sustainable generation of good reclaimed water quality. Consideration should be given to provide special training and certification for reclaimed water operations staff.

### ***Instrumentation and Control***

According to USEPA (2004), Major considerations in developing an instrumentation/control system for a reclamation facility include:

- ability to analyze appropriate quality parameters;
- ability to maintain, calibrate, and verify accuracy of on-line instruments;
- monitoring and control of treatment process performance;
- monitoring and control of reclaimed water distribution;

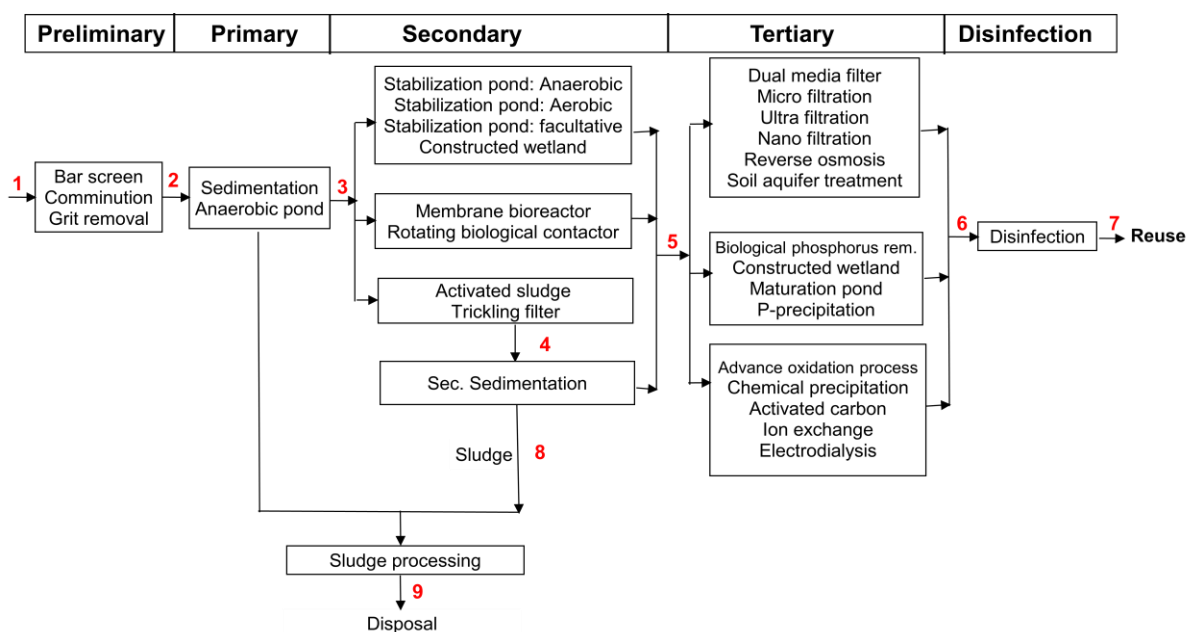
In a water reuse system, the potential uses of the reclaimed water determine the degree of instrument sophistication and operator attention required. Each water reclamation plant is unique, with its own requirements for an integrated monitoring and control instrumentation system. The process of selecting monitoring instrumentation should address aspects such as frequency of reporting, parameters to be measured, sample point locations, sensing techniques, future requirements, availability of trained staff, frequency of maintenance, availability of spare parts, and instrument reliability. Bourgeois et al. (2001) and Olsson et al. (2003) presented a review of available methods for monitoring above

mentioned parameters. Such systems should be designed to detect operational problems during both routine and emergency operations. If an operating problem arises, activation of a signal or alarm permits personnel to correct the problem before an undesirable situation is created.

### **Effluent Quality Assurance and Monitoring**

An effluent quality assurance for a reclaimed project involves the selection of appropriate parameters to monitor and handling of the necessary sampling and analysis in an acceptable manner. Standard procedures for sample analysis may be found in the Handbook for the Operation of Wastewater Treatment Works (WISA/WRC/ERWAT, 2002). Sampling techniques, frequency, and location are critical elements of monitoring and quality assurance.

A sample is a part or piece taken from a larger entity and presented as being representative of the whole. Samples can be collected manually and automatically. Process control sampling and testing is used to evaluate the performance of the unit process. During testing, Turbidity, Total Suspended Solids, Biochemical Oxygen Demand, Chemical Oxygen Demand, pH, Total Nitrogen, Total Phosphorus, Faecal Coliforms and Total Coliforms testing are routinely accomplished. Figure 1 shows typical sampling points in a treatment plant.



**Figure 1: Typical sampling locations for the treatment plants**

The recommended volume of sample to be taken, frequency and test to be carried out at each sample point are shown in Table 1.

**Table 1: Sample volume, tests and frequency of test at each sample point of Figure 1 (USEPA, 2004; Dettrick and Gallagher, 2002)**

Sample Points	Sample Volume (ml)	Tests to be carried out	Frequency of tests
1	100 – 500	Turbidity, Turb	continuous
	100 – 500	Total Suspended Solids, TSS	daily
	100 – 500	Biochemical Oxygen Demand, BOD	daily
	50 – 100	Chemical Oxygen Demand, COD	weekly
	50 – 100	pH	daily
	50 – 100	Total Nitrogen, TN	weekly
	50 – 100	Total Phosphorus, TP	weekly
	50 – 100	Faecal Coliforms, FC	weekly
	50 – 100	Total Coliforms, TC	weekly
2	100 – 500	Total Suspended Solids, TSS	bi-monthly
3	100 – 500	Total Suspended Solids, TSS	weekly
	50 – 100	Biochemical Oxygen Demand, BOD	weekly
	50 – 100	Chemical Oxygen Demand, COD	weekly
4	100 – 500	Total Suspended Solids, TSS	daily
	100 – 500	Biochemical Oxygen Demand, BOD	daily
	50 – 100	Chemical Oxygen Demand, COD	weekly
	50 – 100	pH	daily
	50 – 100	Total Nitrogen, TN	weekly
	50 – 100	Total Phosphorus, TP	weekly
	50 – 100	Faecal Coliforms, FC	weekly
	50 – 100	Total Coliforms, TC	weekly
5	100 – 500	Turbidity, Turb	continuous
	100 – 500	Total Suspended Solids, TSS	weekly
	50 – 100	Biochemical Oxygen Demand, BOD	weekly
	50 – 100	Chemical Oxygen Demand, COD	weekly
	50 – 100	pH	daily
	50 – 100	Total Nitrogen, TN	weekly
	50 – 100	Total Phosphorus, TP	weekly
	50 – 100	Faecal Coliforms, FC	daily
	50 -100	Total Coliforms, TC	daily
6	100 – 500	Turbidity, Turb	continuous
	100 – 500	Total Suspended Solids, TSS	weekly
	50 – 100	Biochemical Oxygen Demand,	weekly



Sample Points	Sample Volume (ml)	Tests to be carried out	Frequency of tests
		BOD	
	50 – 100	Chemical Oxygen Demand, COD	weekly
	50 – 100	pH	daily
	50 – 100	Total Nitrogen, TN	weekly
	50 – 100	Total Phosphorus, TP	weekly
	50 – 100	Faecal Coliforms, FC	daily
	50 – 100	Total Coliforms, TC	daily
	200	Residual Chlorine	continuous

As stated earlier, tests conducted on the sample at each sampling point can be used to assess the performance of each unit process. As a guide to judge the performance of each unit process, Table 2 shows the percentage pollutant removal (minimum, average or maximum) of each unit process classified as preliminary, primary, secondary, tertiary and disinfection.

The general requirements of any reuse permit should ideally specify minimum sampling and testing that must be performed on the plant discharge. The permit should also specify the frequency of sampling, sample type, and length of time for composite samples. Unless a specific method is required by the permit, all sample preservation and analysis must be in compliance.

**Table 2: Unit process pollutant removal efficiencies (Cheremisinoff, 2002; Ahmed *et al.*, 2002; ESCWA, 2003 and Joksimovic, 2006).**

Unit Process	Unit Process Pollutant Removal Efficiencies (%)																							
	Turb			TSS			BOD			COD			TN			TP			FC			TC		
	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max
Bar screen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Coarse screen	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Grit chamber	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pond: Anaerobic	< 15	15-50	> 50	< 30	30-45	> 45	< 40	40-65	> 65	< 30	30-60	> 60	> 30	30-50	> 50	< 5	5-7	> 7	< 30	30-50	> 60	<20	20-35	>35
Pond: Aerobic	<50	50-60	> 60	< 30	30-45	> 45	< 40	40-60	> 60	< 35	35-40	> 40	< 25	25-45	> 45	< 20	20-40	> 40	< 10	10-15	> 15	< 5	15-10	> 10
Pond: Facultative	< 40	40-50	> 50	< 50	50-70	> 85	< 50	50-70	> 70	< 60	60-80	> 80	< 20	20-40	> 40	< 25	25-50	> 50	< 10	10-15	> 15	< 5	5-10	> 10
Equalization basin	-	-	-	< 5	5-10	> 15	< 4	4-12	> 12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sedimentation	< 50	50-70	> 70	< 60	60-70	> 70	< 40	40-50	> 50	< 40	40-50	> 50	< 3	3-15	> 15	< 60	60-70	> 70	< 10	10-15	> 15	< 5	5-10	> 10
Activated sludge + Sec. sedimentation	< 10	10-40	> 40	< 50	50-70	> 70	< 50	50-70	> 70	< 60	60-80	> 80	< 10	10-30	> 30	< 10	10-23	> 23	< 20	20-35	> 35	< 15	15-30	> 30
Trickling filter + Sec. sedimentation	< 20	20-30	> 30	< 50	50-70	> 70	< 50	50-70	> 70	< 65	65-80	> 80	< 20	20-30	> 30	< 20	20-30	> 30	< 60	60-80	> 80	< 50	50-60	> 60
Rotary biological contactor	< 50	50-70	> 70	< 35	35-60	> 60	< 35	35-60	> 60	< 65	65-70	> 70	< 20	20-30	> 30	< 20	20-30	> 30	< 60	60-80	> 80	< 50	50-60	> 60
Membrane bioreactor	< 90	90-92	> 92	< 90	90-92	> 92	< 90	90-92	> 92	> 90	90-92	> 92	< 30	30-40	> 40	< 60	60-70	> 70	< 80	80-85	> 90	< 70	70-75	> 75
Biological Phosphorus removal	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 90	90-95	> 95	-	-	-	-	-	-
P- precipitation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 90	90-95	> 95	-	-	-	-	-	-
Chem. precipitation	< 20	20-30	> 30	< 40	40-60	> 60	< 20	20-30	> 30	< 15	15-35	> 35	< 5	5-8	> 8	< 10	10-15	> 15	< 10	10-20	> 30	< 5	5-15	> 15
Denitrification	-	-	-	-	-	-	-	-	-	-	-	-	< 90	90-95	> 95	-	-	-	-	-	-	-	-	-
Constructed wetland	< 10	10-15	> 15	< 60	60-75	> 75	< 25	25-35	> 35	< 10	10-15	> 15	< 50	50-60	> 60	< 80	80-85	> 85	-	-	-	-	-	-
Maturation pond	< 30	30-45	> 45	< 15	15-25	> 25	< 8	8-13	> 13	< 10	10-20	> 20	< 30	30-40	> 40	< 20	20-30	> 30	< 30	30-50	> 50	< 20	20-35	> 35
Dual medial filter	< 80	80-90	> 90	< 80	80-90	> 90	< 65	65-75	> 75	< 60	60-70	> 70	< 5	5-10	> 10	< 5	5-10	> 10	< 90	90-93	> 93	< 80	80-85	> 85
Micro filtration	< 80	80-90	> 90	< 80	80-90	> 90	< 65	65-75	> 75	< 60	60-70	> 70	< 5	5-10	> 10	< 5	5-10	> 10	< 90	90-93	> 95	< 80	80-85	> 85
Ultra filtration	< 80	80-90	> 90	< 80	80-90	> 90	< 65	65-75	> 75	< 60	60-70	> 70	< 5	5-10	> 10	< 5	5-10	> 10	< 90	90-93	> 95	< 80	80-85	> 85
Nano filtration	< 30	30-50	> 50	< 80	80-90	> 90	< 20	20-35	> 35	< 60	60-70	> 70	< 40	40	> 40	< 80	80-90	> 90	< 90	90-95	> 95	< 90	90-93	> 93
Reverse osmosis	< 30	30-50	> 50	< 80	80-90	> 90	< 20	20-35	> 35	< 60	60-70	> 70	< 40	40	> 40	< 80	80-90	> 90	< 90	90-95	> 95	< 90	90-93	> 93
Soil aquifer treatment	< 85	85	> 85	< 80	80-90	> 95	< 85	85	> 85	< 85	85	> 85	< 85	85	> 85	< 80	80-90	> 90	< 70	70-75	> 80	< 65	65-70	> 75
Activated carbon	< 20	20-40	> 20	< 40	40-45	> 45	< 40	40-45	> 45	< 20	30-30	> 40	0	0	0	< 8	8-15	> 15	< 15	15-30	> 30	< 10	10-20	> 20

Unit Process	Unit Process Pollutant Removal Efficiencies (%)																							
	Turb			TSS			BOD			COD			TN			TP			FC			TC		
	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max	Min	Ave	Max
Ion exchange	< 10	10-20	> 20	< 40	40-45	> 45	< 10	10-20	> 20	0	0	0	< 60	60-70	> 70	< 70	70-80	> 80	0	0	0	0	0	0
Advanced oxidation ponds	< 70	70-80	> 90	0	0	0	< 70	70-80	> 90	< 70	70-80	> 80	0	0	0	0	0	0	< 60	60-70	> 80	< 55	55-65	> 65
Electrodialysis	< 70	70-80	> 80	0	0	0	0	0	0	0	0	0	< 40	40-50	> 50	< 40	40-50	> 50	< 60	60-70	> 70	< 55	55-65	> 65
Chlorine gas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	100	100	100	100	100
Chlorine dioxide	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100	100	100	100	100	100
Ozone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 90	90-95	> 95	< 90	90-95	> 95
UV Radiation	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	< 60	60-70	> 70	< 55	55-65	> 65

#### **4. Emergency/Supplemental Storage Facilities**

Wastewater is continuously generated through residential and industrial activities. Hence, treatment plants also treat wastewater continuously unless there is a breakdown. In case of a breakdown of major component(s) of a treatment plant, there is need to provide emergency storage to retain reclaimed water of unacceptable quality for re-treatment in order to safeguard public health and the environment. Usually, piping within a treatment plant is done in such a way that an emergency diversion is provided to convey reclaimed water of unacceptable quality to a temporary storage. At a later time, the diverted wastewaters are pumped back to the treatment plant for re-treatment.

Also, reclaimed water that cannot be used immediately may be stored or disposed of. Supplemental storage is provided to ensure that the reclaimed water supply can match user's seasonal demands. Reclaimed water must be treated and preserved to maintain its quality during storage. Storing reclaimed water can result in a change in quality, particularly microbiological quality. Therefore, if reclaimed water is stored, the quality should be tested regularly and any hazards managed accordingly. The frequency of testing and need for subsequent treatment will have to be decided on the basis of the level of risk at each site. Reclaimed water to be stored should have adequate chlorine residual and the circulation process to minimize stagnation and to maximize the distribution of the disinfection process.

#### **5. Inspection and Approval of Recycled Water Facilities**

DWAE has the responsibility for issuing with the responsibility of issuing permits to operate and periodically inspect wastewater treatment plants (National Water Act, 1998). The inspection of WWTWs by the DWAE is to ensure compliance with the DWAE standards for effluent discharge in order to protect public health and the ecosystem of the receiving watercourse. Therefore, the main concerns in the inspection of WWTWs are influent hydraulic and organic loadings, quality of effluent, and proper disposal of sludge solids. The inspection of recycled water facilities should, in addition, include the assessment of both the recycled water service provider's facilities and user's facilities. The inspection of service provider's facilities should include a detail examination of each unit process, its operation and how the process functions in the overall treatment scheme. In the user's facilities, the inspector should look out for improper connections, unclear markings, insufficient depths of pipe installation and possible overloading (i.e. altering soil permeability, pH, electrical conductivity, cation exchange capacity, etc.) of the irrigated land. Follow-up inspections are routine, and in some cases, fixed interval inspections and random inspections are planned as explained in Salgot et al., 2006.

##### ***Inspection of Recycled Water Service Provider's Facility***

In order to undertake an inspection of a recycled water service provider's facility, it is imperative that the inspector must understand the complex nature of various unit processes involved in the treatment of wastewater. The inspector must be trained in flow

measurement, sampling, laboratory testing, and record keeping. A summary of an inspection procedure for WWTWs producing recycled water is shown in Table 3.

**Table 3: Inspection procedure for wastewater treatment plants (Boyd and Mbelu, 2009)**

Classification	Facilities for inspection	What to look for
WWTW configuration	<b>Flow diagram</b> – this is necessary in order to understand how the WWTW has been structured and should be operated. It must be drawn and made available on site.	a flow diagram of the WWTW
	<b>Design capacity</b> – this enables plans to be made for future development. It answers the question of how much of wastewater can still be accommodated.	confirm the design capacity
Screen	<b>Manual/automatic screen</b> – screens are used to remove debris from raw wastewater	<ul style="list-style-type: none"> <li>• screens that are free of debris</li> <li>• hand rake and wheelbarrow that are easily accessible and in working condition</li> <li>• unusual sounds or vibrations</li> <li>• maintenance schedule</li> <li>• screening that are washed and return to WWTW</li> </ul>
Grit removal	<b>Manual/automatic operated grit removal</b> – Grit material can include sand, silt, glass, small stones as well as other large-sized organic and inorganic substances. It is essential to protect moving mechanical equipment and pumps from abrasion	<ul style="list-style-type: none"> <li>• channels that are clean of grit</li> <li>• channels that are in working order, i.e. one that can be used while the other is closed for grit removal</li> <li>• a spade and container that are easily accessible</li> </ul>
	<b>Automate de-gritters</b> – a pump is required to remove a slurry of grit	<ul style="list-style-type: none"> <li>• a pump in working order</li> </ul>
	<b>Screenings and grit disposal</b> – if left lying around will cause nuisance conditions such as odours and will encourage fly breeding	<ul style="list-style-type: none"> <li>• non nuisance conditions (odours and flies)</li> <li>• grit or screenings lying around</li> <li>• covered bins that are used for storage of grit</li> <li>• proof that grit and screenings buried on site are covered daily</li> </ul>
Flow	<b>Flow metering</b> – WWTW is designed to a specific volume of wastewater per day.	<ul style="list-style-type: none"> <li>• flow measurement</li> <li>• knowledge of flow in relation to</li> </ul>

Classification	Facilities for inspection	What to look for
	It is important to know how much wastewater is entering so as not to overload the plant	<p>design capacity</p> <ul style="list-style-type: none"> <li>the flow mechanism and determine whether it is in working order and is calibrated</li> </ul>
	<b>Flow balancing</b> - Flow balancing, also called flow equalization, is used to overcome the operational problems caused by flow rate variations and to improve the performance of the downstream unit processes	<ul style="list-style-type: none"> <li>mixers – are they working?</li> <li>aerators – are they working, if in place?</li> <li>pumps – are they working?</li> <li>odours – are odours controlled?</li> </ul>
Primary sedimentation	<b>Primary sedimentation tank (PST)</b> - The main purpose of primary sedimentation is to allow separation of the solid and liquid phase fractions in the wastewater.	<ul style="list-style-type: none"> <li>inflow that should be light grey in colour</li> <li>overflow at the weirs that is similar where more than one PST is present</li> <li>weirs in good condition</li> <li>scum or floating sludge layer</li> <li>layer of fats/grease/oil</li> <li>a schedule for desludging and check that it is implemented</li> <li>records of process sampling</li> </ul>
Pond systems	<b>Oxidation ponds</b> - Pond systems are relatively shallow bodies of wastewater in which the self-purification processes of water are used under controlled conditions to purify raw or settled wastewater.	<ul style="list-style-type: none"> <li>ponds operated in series</li> <li>the presence of short-circuiting (water is flowing through a course. This means the detention time is inadequate)</li> <li>aerators - are they working if present?</li> <li>evidence of desludging - is it done periodically to a schedule and is sludge correctly disposed of?</li> <li>area around the ponds – is it well maintained?</li> <li>visible erosion around the ponds</li> </ul>
Trickling filter (TF)	Trickling filter – Trickling filter utilize microorganisms that grow on a medium (i.e. stones) to remove organic matter	<ul style="list-style-type: none"> <li>access to the top of the filter</li> <li>movement of the rotating distributor arm – is it smooth?</li> </ul>

Classification	Facilities for inspection	What to look for
	found in wastewater	<ul style="list-style-type: none"> <li>• distribution of wastewater to the filter media through the rotating distributor arm – is it even?</li> <li>• filter media – is it free of ponding?</li> <li>• underdrains - are they clear of any obstructions?</li> </ul>
Rotating biological contactors (RBC)	<b>Rotating biological contactors</b> - it utilize microorganisms that grow on disc system to remove organic matter found in wastewater	<ul style="list-style-type: none"> <li>• the motor - is it working?</li> <li>• the disk system – does it rotate freely at a steady rate?</li> <li>• the sludge return pump - is it working?</li> <li>• the ammeter - does it fluctuate as the disk turns?</li> <li>• floating sludge in the final settling tank?</li> </ul>
Activated sludge (ASP)	<b>Activated sludge</b> – activated sludge is a biological process of developing an activated mass of microorganisms capable of stabilizing waste aerobically. Visual observation of the ASP is very important. The color, smell and appearance of the biomass give a good indication of whether the ASP is working well	<ul style="list-style-type: none"> <li>• records of the sludge age</li> <li>• scum on the surface</li> <li>• records of the Mixed Liquid Suspended Solid (MLSS) (mg/l)</li> <li>• records of the Dissolved Oxygen (DO)</li> <li>• dark brown biomass (colour)</li> <li>• an earthy smell</li> <li>• clean chemical dosing area</li> <li>• records of daily process monitoring as appropriate to the ASP</li> <li>• on-line equipment - is it in working order and calibrated; are calibration certificates available?</li> <li>• aerators - are they in working order?</li> <li>• recycling - is it taking place and is a record of the correct ratio of inflow to sludge recycle maintained?</li> </ul>

Classification	Facilities for inspection	What to look for
Secondary sedimentation	<b>Secondary sedimentation</b> – secondary sedimentation is used after the TF and ASP. Sludge from TF and ASP is in suspension and must be settled out in the clarifier to produce two streams, i.e. the sludge and the clear effluent.	<ul style="list-style-type: none"> <li>• trends of the Sludge Volume Index (SVI) test</li> <li>• clean effluent weirs/channel clean launders</li> <li>• operational desludging equipment</li> <li>• limited scum on the surface of the clarifier</li> <li>• an operational scum draw-off system</li> <li>• clear overflow</li> </ul>
Constructed wetlands	<b>Constructed wetlands</b> - artificial or constructed wetlands consist of a bed of granular material through which the effluent can flow without too much hydraulic resistance.	<ul style="list-style-type: none"> <li>• reeds are planted</li> <li>• reed growth is controlled using a schedule</li> <li>• selective seeding and planting is undertaken</li> <li>• periodically</li> <li>• samples are taken according to relevant authorization</li> <li>• herbicidal and insecticidal treatment is practiced</li> </ul>
Maturation ponds	<b>Maturation ponds</b> - maturation ponds give a final ‘polish’ to effluents. They are used to improve the bacteriological quality of the final effluent and can also act as a buffer in the event of a breakdown at the works	<ul style="list-style-type: none"> <li>• overflow is clear</li> <li>• no erosion is observed</li> <li>• the banks of the ponds are protected against erosion</li> </ul>
Membrane filtrations	Membrane filtration – membrane filtrations are used to remove dissolved organic and inorganic compounds from secondary effluent.	<ul style="list-style-type: none"> <li>• permeate flows uniformly through the membrane</li> <li>• records of membrane cleaning</li> <li>• pumps are working perfectly</li> <li>• methods of concentrate management and disposal</li> </ul>
Chemical disinfection	<b>Chemical disinfection</b> - the goal of disinfection is to remove pathogenic microorganisms	<ul style="list-style-type: none"> <li>• the dosing equipment is in working order</li> <li>• no chlorine can be smelled</li> <li>• relevant training has been given to the Process Controller/s</li> <li>• residual chlorine level is being</li> </ul>



Classification	Facilities for inspection	What to look for
		<p>measured in the final effluent</p> <ul style="list-style-type: none"> <li>the contact tank is clean (i.e. not sludged up) and free of algae</li> <li>final effluent samples are taken in accordance with water use authorization</li> </ul>

The primary purpose of regulatory inspections is to verify compliance with the DWAE standards. During inspection, water samples must be taken at sampling points 1, 5, 6 and 7 in Figure 1 for laboratory analysis to determine the operation efficiency by monitoring unit processes listed in Table 2. These points give a good representative of influent wastewater, secondary treatment, tertiary treatment and final effluent (after disinfection).

Beyond the final treatment effluent is the management of sludge produced. In most cases, the aerobic digestion method is used in treating the sludge produced from wastewater. The purpose of anaerobic sludge digestion is to stabilize bulky, odorous raw sludge to relatively inert materials that can be readily dewatered without obnoxious odours. Overall performance of sludge digester is determined by volatile solid reduction, gas production and composition. Operational controls include temperature of the digesting sludge, mixing in high rate digesters, rate of raw sludge feed, and solid retention time. Careful consideration is given to all unit operations that discharge flow back to the head of the plant.

#### **Wastewater Reuse Quality for Different Non-potable Uses**

Table 4 shows the authors suggested guidelines for reclaimed water quality for various types of water reuse in South Africa based on the best international practice.

**Table 4: Suggested guidelines for water reuse in South Africa**

Types of reuse	Reclaimed water quality	Reclaimed water monitoring
Domestic uses ( <i>toilet flushing, landscape irrigation, public park irrigation and water use fixtures</i> )	<ul style="list-style-type: none"> <li>pH = 6 – 9</li> <li>TSS <math>\leq</math> 5 mg/l</li> <li>Turb <math>\leq</math> 1 TNU</li> <li>BOD <math>\leq</math> 5 mg/l</li> <li>COD <math>\leq</math> 10 mg/l</li> <li>TN <math>\leq</math> 5 mg/l</li> <li>TP <math>\leq</math> 0.2 mg/l</li> <li>FC <math>\leq</math> 0</li> <li>TC <math>\leq</math> 0</li> </ul>	<ul style="list-style-type: none"> <li>pH – weekly</li> <li>BOD – weekly</li> <li>TSS – weekly</li> <li>Disinfection – daily</li> <li>Turbidity - continuous</li> <li>CL<sub>2</sub> residual - continuous</li> <li>Coliforms – daily</li> <li>Nutrient, toxicant and salinity – regularly</li> </ul>

Types of reuse	Reclaimed water quality	Reclaimed water monitoring
	<ul style="list-style-type: none"> <li>• <math>CL_2</math> residual <math>\leq 1</math> mg/l</li> </ul>	
Irrigation uses ( <i>agricultural, crops, landscape, parks, golf courses, cemeteries and green belts</i> )	<ul style="list-style-type: none"> <li>• pH = 6 – 9</li> <li>• TSS <math>\leq 10</math> mg/l</li> <li>• Turb <math>\leq 5</math> TNU</li> <li>• BOD <math>\leq 10</math> mg/l</li> <li>• COD <math>\leq 30</math> mg/l</li> <li>• TN <math>\leq 10</math> mg/l</li> <li>• TP <math>\leq 2</math> mg/l</li> <li>• FC <math>\leq 0</math></li> <li>• TC <math>\leq 0</math></li> <li>• <math>CL_2</math> residual <math>\leq 1</math> mg/l</li> </ul>	<ul style="list-style-type: none"> <li>• pH – weekly</li> <li>• BOD – weekly</li> <li>• TSS – weekly</li> <li>• Turbidity - continuous</li> <li>• <math>CL_2</math> residual - continuous</li> <li>• Coliforms – daily</li> <li>• Nutrient, toxicant and salinity – regularly</li> </ul>
Industrial uses ( <i>system cooling, boiler feed and process water</i> )	<ul style="list-style-type: none"> <li>• pH = 6 – 9</li> <li>• TSS <math>\leq 10</math> mg/l</li> <li>• Turb <math>\leq 5</math> TNU</li> <li>• BOD <math>\leq 20</math> mg/l</li> <li>• COD <math>\leq 10</math> mg/l</li> <li>• TN <math>\leq 5</math> mg/l</li> <li>• TP <math>\leq 0.2</math> mg/l</li> <li>• FC <math>\leq 200</math> cfu/100ml</li> <li>• TC <math>\leq 200</math> cfu/100ml</li> <li>• <math>CL_2</math> residual <math>\leq 1</math> mg/l</li> </ul>	<ul style="list-style-type: none"> <li>• pH – weekly</li> <li>• BOD – weekly</li> <li>• TSS – weekly</li> <li>• Turbidity - continuous</li> <li>• <math>CL_2</math> residual - continuous</li> <li>• Coliforms – weekly</li> <li>• Nutrient, toxicant and salinity – regularly</li> </ul>
Other activities ( <i>construction works, street cleaning, fire protection and groundwater recharge</i> ).	<ul style="list-style-type: none"> <li>• pH = 6 – 9</li> <li>• TSS <math>\leq 10</math> mg/l</li> <li>• Turb <math>\leq 10</math> TNU</li> <li>• BOD <math>\leq 20</math> mg/l</li> <li>• COD <math>\leq 70</math> mg/l</li> <li>• TN <math>\leq 10</math> mg/l</li> <li>• TP <math>\leq 0.2</math> mg/l</li> <li>• FC <math>\leq 200</math> cfu/100ml</li> <li>• TC <math>\leq 200</math> cfu/100ml</li> <li>• <math>CL_2</math> residual <math>\leq 1</math></li> </ul>	<ul style="list-style-type: none"> <li>• pH – weekly</li> <li>• BOD – weekly</li> <li>• TSS – weekly</li> <li>• Turbidity - continuous</li> <li>• <math>CL_2</math> residual - continuous</li> <li>• Coliforms – weekly</li> <li>• Nutrient, toxicant and salinity – regularly</li> </ul>

Types of reuse	Reclaimed water quality	Reclaimed water monitoring
	mg/l	

In addition to the recommended guidelines in Table 4, the recommended guidelines for the maximum concentration of trace elements in soils under natural conditions are presented in Table 5. It suggested that for monitoring purposes, the soil and vegetation is sampled and analysed. The only satisfactory safeguard is the sampling and analysis of soil and vegetation before irrigation commences and regular monitoring during the life of the irrigation scheme.

**Table 5: Recommended Maximum Concentrations of Metals in Irrigation Waters (Dettrick and Gallagher, 2002)**

Elements	Suggested soil CCL <sup>1</sup> (kg/ha)	LTV <sup>2</sup> over 100 years mg/L	STV <sup>3</sup> over 20 years mg/L	Plant effects
Aluminium (Al)	ND <sup>4</sup>	5	20	Toxic at pH < 5.5
Arsenic (As)	20	0.1	2	toxicity varies depending on species
Beryllium (Be)	ND	0.1	0.5	toxicity varies depending on species
Boron (B)	ND	0.5	<0.5 - 15	toxicity varies depending on species
Cadmium (Cd)	2	0.01	0.05	toxic at low conc. bio-accumulation issues
Chromium (CrVI)	ND	0.1	1	low toxicity
Cobalt (Co)	ND	0.05	0.1	toxic at high concentration
Copper (Cu)	140	0.2	5	toxic at high concentration
Fluoride (F)	ND	1	2	not active in neutral to alkaline soils
Iron (Fe)	ND	0.2	10	not toxic in aerated soils.
Lead (Pb)	260	5	2	low toxicity, inhibits growth at high conc.
Lithium (Li)	ND	2.5	2.5	0.075 mg/L if used on citrus crops
Manganese (Mn)	ND	0.2	10	toxicity depends on Fe/Mn ration and soil pH
Mercury (Hg)	2	0.002	0.002	No guideline at the time
Molybdenum (Mo)	ND	0.01	0.05	low toxicity to plants, toxic to animals fed crops grown on high avail. Mo
Nickel (Ni)	85	0.2	2	toxicity increases with soil pH < 7
Selenium (Se)	10	0.02	0.05	toxic to plants. Toxic to animals fed on high Se pasture
Uranium (U)	ND	0.01	0.1	
Vanadium (Vn)	ND	0.1	0.5	toxic to plants

Elements	Suggested soil CCL <sup>1</sup> (kg/ha)	LTV <sup>2</sup> over 100 years (mg/L)	STV <sup>3</sup> over 20 years (mg/L)	Plant effects
Zinc (Zn)	300	2	5	pH dependant. Higher level on pH 7 +

*CCL<sup>1</sup> = Cumulative contaminant loading limit – is the maximum contaminant loading in soil, defined in kg/ha, above which site specific risk assessment is required if contaminant addition is planned (assuming application rate of 1000mm / year, inorganic contaminants in top 150 mm of soil profile & soil bulk density is 1300 kg/m<sup>3</sup>).*

*LTV<sup>2</sup> = long term trigger value – is the maximum concentration (mg/L) of contaminant in irrigation water which can be tolerated given 100 years of irrigation.*

*STV<sup>3</sup> = short term trigger value – is the maximum concentration of contaminant that can be tolerated over 20 years assuming same annual irrigation loading assumptions as LTV*

*ND<sup>4</sup> = Not determined insufficient background data to calculate CCL*

## 6. Conclusion

Conventional water resources have been seriously depleted due to increase in water demand in various sectors. As a result, wastewater reclamation and reuse is increasingly being integrated in the planning and development of sustainable water resources. For any reuse project to be successful and well embraced by all users, it must operate within a regulated framework. This paper provides suggested guidelines for the operation, inspection and regulation of reuse water facilities in South Africa. This will minimise potential human risks and environmental pollution of reuse project.

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