

TECHNICAL DELIVERABLE REPORT 1



OPERATIONAL AND TRAINING MANUAL

Algal-Based Tertiary Treatment in Maturation
Ponds of the Brandwacht Wastewater
Treatment Works

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Stellenbosch, South Africa

July 2017

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ACKNOWLEDGEMENT

The authors express their gratitude to the African Development Bank [ACTC-WA1] for funding the project. We would also like to thank the respective institutions for funding and in-kind contributions towards this project.

TABLE OF CONTENTS

1	EXECUTIVE SUMMARY	1
2	PURPOSE OF THE MANUAL	1
3	GLOSSARY	1
4	BACKGROUND AND LAY-OUT OF THE BRANDWACHT WASTEWATER TREATMENT WORKS	2
	4.1 Anaerobic Ponds:	2
	4.2 Facultative Ponds:	2
	4.3 Aerobic (Maturation) Ponds:	2
5	PHYCOREMEDIATION: OPERATION AND MAINTENANCE	3
	5.1 Mass Culturing, Lay-out Operation and Maintenance	3
	5.2 Algae Bioreactor Lay-out and Flow Diagram	7
6	GENERAL OPERATION AND MAINTENANCE	10
	6.1 Day-to-day Operation	10
7	DEPTH OF SLUDGE LAYER	15
8	GENERAL SANITARY ANALYSIS PROGRAM FOR PHYCOREMEDIATION TREATMENT	16
	8.1 Routine Parameters	16
9	REFERENCES	17

Tables

Table 1:	Colour as indicator of maturation ponds condition	10
Table 2:	The parameters that should be sampled on a monthly basis.	16

Figures

Figure 1:	Layout of the Brandwacht Wastewater Treatment Works consisting of three types of waste stabilisation ponds.	3
Figure 2:	Lay-out of the ponds at the Brandwacht Wastewater Treatment Works, indicating the flow of the algae from the Jo-jo tanks to the ponds.	6
Figure 3:	The step-wise procedure to follow for each algal reactor tank to maintain a healthy supply of algae.	8
Figure 4:	A colour code chart to explain the different types of colour in the algae.	9
Figure 5:	Cleaning and inspection of screening grid at plant inlet and channels.	11
Figure 6:	Water depth too low, causing rooted plants to invade pond.	11
Figure 7:	Removal of floating duckweed in the ponds, with tall plants at the water's edge.	12
Figure 8:	Cutting and cleaning tall plants on pond edges.	12
Figure 9:	Grass cutting.	13
Figure 10:	Floating debris on the pond surface.	13
Figure 11:	Borehole inspection.	14
Figure 12:	Filter cartridge inspection, rinse or replacement.	14
Figure 13:	Inspection of taps, pipes and reactor tanks for leaks, breakages or theft.	15
Figure 14:	Sludge build-up and removal from Anaerobic Pond 1A at Brandwacht WWTW.	16

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1

1 EXECUTIVE SUMMARY



Pond systems are ideally suited for use in small rural communities, because they are simple and economical to operate and maintain. The algal-based tertiary treatment (phycoremediation) used in this project utilises a specific consortium of algal species to remove nutrients and create conditions for effective solar disinfection to reduce pathogens. The intention is to implement a self-sustaining system that is independent of electricity or expensive chemicals and that can be effectively operated within financial and capacity constraints.

2 PURPOSE OF THE MANUAL

The purpose of this manual is to present operational guidelines and maintenance for phycoremediation treatment in rural wastewater treatment plants employing waste stabilisation ponds as tertiary treatment in the absence of electricity. The guideline is specifically set out for municipal plant operators and analytical services to manage an algal-based tertiary treatment system on a daily basis.

3 GLOSSARY



TERM	DEFINITION
Aerobic	Biological process which occurs in the presence of oxygen
Algal bioreactor	A container to grow algae to high biomass concentrations
Anaerobic	Biological process which occurs in the absence of oxygen
Effluent	Treated wastewater flowing out of the wastewater treatment system
Inlet	Opening providing an entrance of untreated wastewater
Outlet	Opening providing an exit of untreated wastewater
Overload	Load exceeds the capacity of the treatment system
Ponds	Shallow bodies (<3 m) containing wastewater in an earthen basin
Screen	A device that is used to retain coarse solids found in wastewater
Sludge	Semisolid material deposited during the treatment of wastewater

4 BACKGROUND AND LAY-OUT OF THE BRANDWACHT WASTEWATER TREATMENT WORKS

Brandwacht WWTW is located close to the town of Groot Brak and is managed by the Mossel Bay Local Municipality of the Eden District in the Western Cape Province, South Africa. Brandwacht WWTW is a waste stabilisation pond system consisting of 7 earth ponds organised in series to treat domestic sewage effluent. Waste stabilisation pond systems are historically designed to allow natural overflow from one pond to another without electricity or other mechanical means. The Brandwacht WWTW is categorised as a *Micro* treatment plant treating less than 0,5 Ml of sewage effluent per day. The layout of the Brandwacht WWTW can be seen in Figure 1. It consists of three types of stabilisation ponds, namely (1) anaerobic ponds (Ponds 1A and 1B), (2) a facultative pond (Pond 2), and (3) aerobic (maturation) ponds (Ponds 3 – 7). All of these ponds have different actions and design distinctiveness as summarised below:

4.1 Anaerobic Ponds:

These ponds operate without the presence of dissolved oxygen with high organic loads. In anaerobic ponds, the biological oxygen demand (BOD) is achieved by sedimentation of solids and subsequent anaerobic digestion in the resulting sludge. A short retention time of one, to one and a half days is commonly used.

4.2 Facultative Ponds:

In these ponds aerobic conditions prevail at the water surface and below, while anaerobic conditions prevail in the bottom sediment. Facultative ponds can be differentiated into primary and secondary facultative ponds. Primary facultative ponds receive raw water and secondary facultative ponds receive particle-free wastewater. Facultative ponds are designed for BOD removal on the bases to allow for the development of a healthy algal population, since the oxygen for BOD removal by the pond bacteria is generated primarily via algal photosynthesis. The bottom layer of primary facultative ponds includes sludge deposits that are decomposed by anaerobic bacteria.

4.3 Aerobic (Maturation) Ponds:

These ponds receive their effluent from the secondary facultative ponds. Maturation ponds show less vertical stratification and are well oxygenated throughout the day. A larger algal diversity can be found in maturation ponds compared to the facultative ponds, with non-motile genera tending to be more widespread. Algae are one of the main driving forces behind treatment within maturation ponds by taking up phosphates, carbon dioxide and nitrogen compounds, while it provide oxygen for heterotrophic bacteria to degrade organic material.

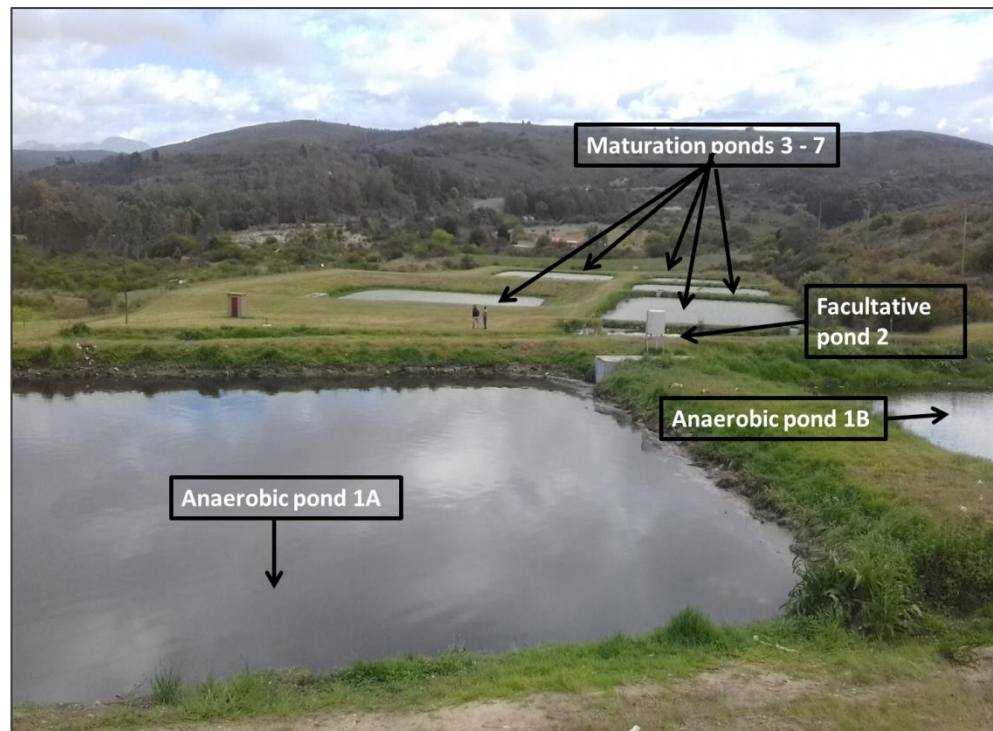


Figure 1: Layout of the Brandwacht Wastewater Treatment Works consisting of three types of waste stabilisation ponds.

5 PHYCOREMEDIATION: OPERATION AND MAINTENANCE

5.1 Mass Culturing, Lay-out Operation and Maintenance

Two species of microalgae from the phylum, *Chlorophyta*, namely *Chlorella vulgaris* and *Chlorella protothecoides*, were isolated, cultured on mass-scale in the laboratory and transported to the Brandwacht WWTW. These species are used for the phycoremediation of the pond systems. The plant operators at the WWTW will use the algal cultures to dose the selected ponds on a continuous basis by mass culturing of the algae in a step-wise procedure using onsite algal reactors.

Three reactor tanks (Jo-jo tanks with a capacity of 5 000 L each) were installed at the WWTW and numbered from 1 to 3. Clear markings to indicate the different volumes (1 000 L, 2 000 L, 3 000 L, 4 000 L and 5 000 L) were made on these tanks. In each of these tanks a total volume of 5 000 L of the two algal species was added.

For the dosing of the ponds, the steps described below need to be followed (Figure 2):

***Very Important!**

Reactor tanks 1, 2 and 3 will be used to dose Pond 3

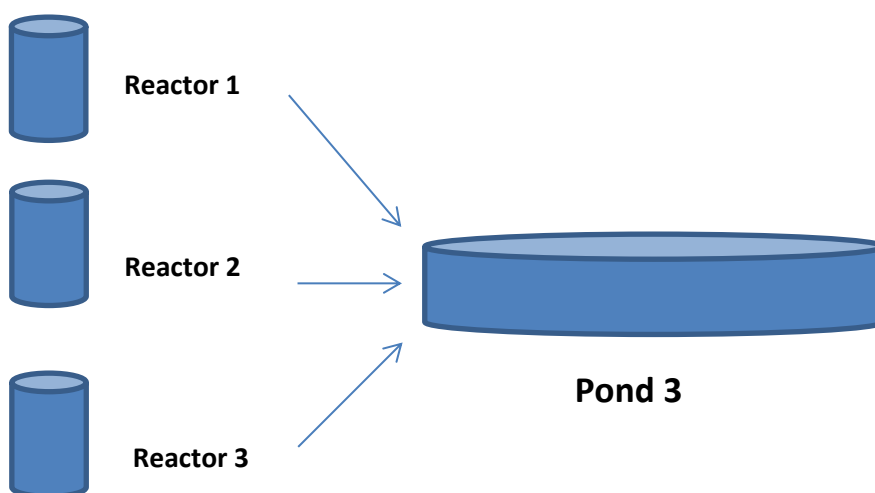
Reactor tanks 1 will be used to dose Pond 4, ± 2 weeks after dosing pond 3

Reactor tank 2 will be used to dose Pond 5, ± 2 weeks after dosing pond 3

Reactor tank 3 will be used to dose Pond 6, ± 2 weeks after dosing pond 3

1. At the start of inoculation:

Make sure that all taps are closed. Open the taps of Reactor tanks 1, 2 and 3. Then open the tap at Pond 3 (*red path*). Allow 4 000 L of algae to flow from each reactor tank into Pond 3. Close the taps for all three reactor tanks and Pond 3. Each reactor tank should now contain a volume of 1000 L of algae.

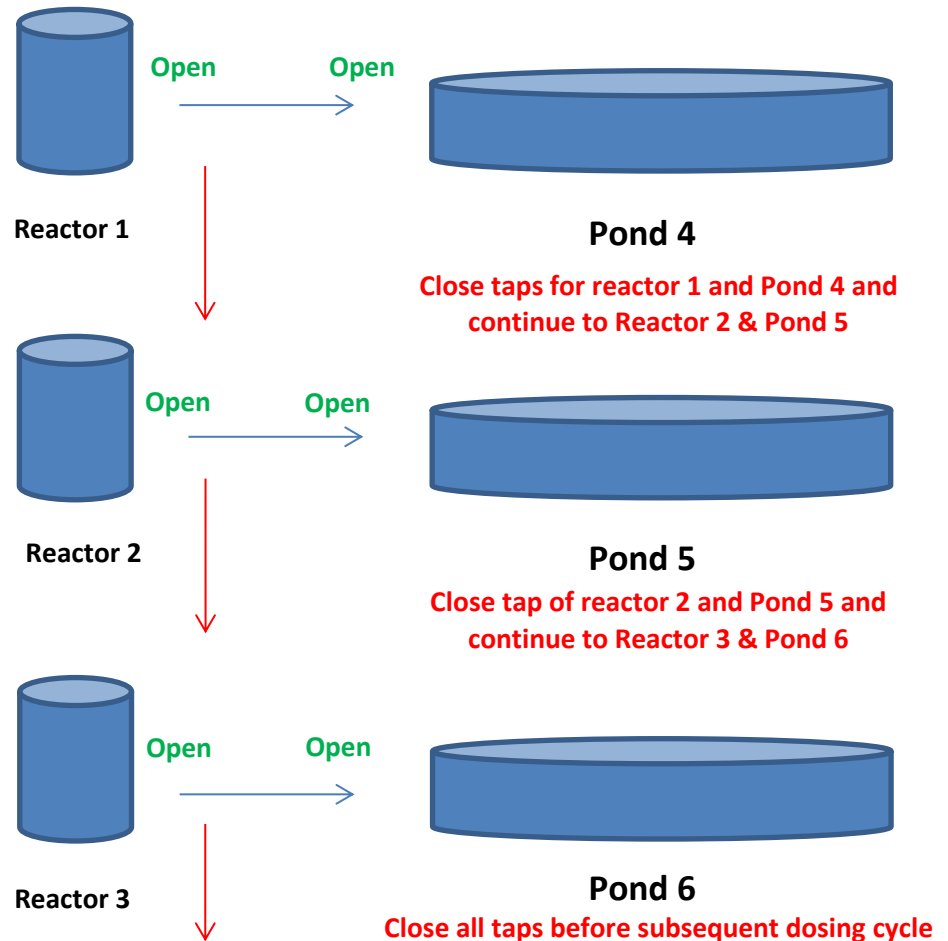


2. Two weeks later:

Since the initial dosing, Reactor tanks 1, 2 and 3 have been refilled and allowed to mature for two weeks (or more depending on the weather and level of algae maturity).

Make sure all taps are closed. Open the tap of Reactor tank 1 to allow flow. Then open the tap at Pond 4. Allow 4 000 L of algae to flow from Reactor tank 1 into Pond 4. Close the taps at Reactor tank 1 and Pond 4. Repeat the process for Reactor Tank 2 to Pond 5. Allow 4 000 L of algae to flow from Reactor tank 2 into Pond 5. Close all taps.

Similarly, repeat for dosing of Pond 6 from Reactor tank 3. Allow 4000 L of algae to flow from Reactor tank 3 to Pond 6. Close all taps.



3. After an additional two weeks:

Reactor tanks 1, 2 and 3 have been refilled and allowed to mature for another two weeks. The algae in these reactor tanks will be ready for dosing again. Thus, every two weeks the ponds will be dosed.

These steps need to be repeated to ensure the continuous dosing (and thus treatment) of the aerobic maturation ponds.

***Please Note!**

It is important to dose only the designated pond at a time and to use only the specified Reactor tanks for each pond, so as to ensure a constant supply of healthy algae at all times.

Figure 2: Lay-out of the ponds at the Brandwacht Wastewater Treatment Works, indicating the flow of the algae from the Jo-jo tanks to the ponds.



The steps described below need to be followed for each Reactor tank in order to maintain a healthy supply of live algae to dose the ponds (Figure 3):

1. Pour off 4 000 L of mature algae from the Reactor tank into the pond.
2. Add 1 000 L of water into the Reactor tank (thus, a total volume of 2 000 L in the Reactor tank), together with 20 g fertiliser.
3. Allow the algae in the Reactor tank to grow and become more green (Figure 4). This may take more or less one week, depending on the climate.
4. Once the algae have reached the desired colour, add another 1 000 L water into the Reactor tank (thus, a total volume of 3 000 L in the Reactor tank), together with 20 g fertiliser.
5. Allow the algae in the Reactor tank to grow and become more green (Figure 4). This may take more or less one week, depending on the climate.
6. Once the algae have reached the desired colour, add another 1 000 L water to the Reactor tank (thus, a total volume of 4 000 L in the Reactor tank), together with 20 g fertiliser.
7. Allow the algae in the Reactor tank to grow and become more green (Figure 4). This may take more or less one week, depending on the climate.
8. Once the algae have reached the desired colour, add another 1 000 L water to the Reactor tank (thus, a total volume of 5 000 L in the Reactor tank), together with 20 g fertiliser.
9. Allow the algae in the Reactor tank to grow and become more green (Figure 4). This may take more or less one week, depending on the climate. The algae are now ready to be dosed again into the pond.
10. Repeat steps 1 to 9 to ensure a continuous supply of algae.

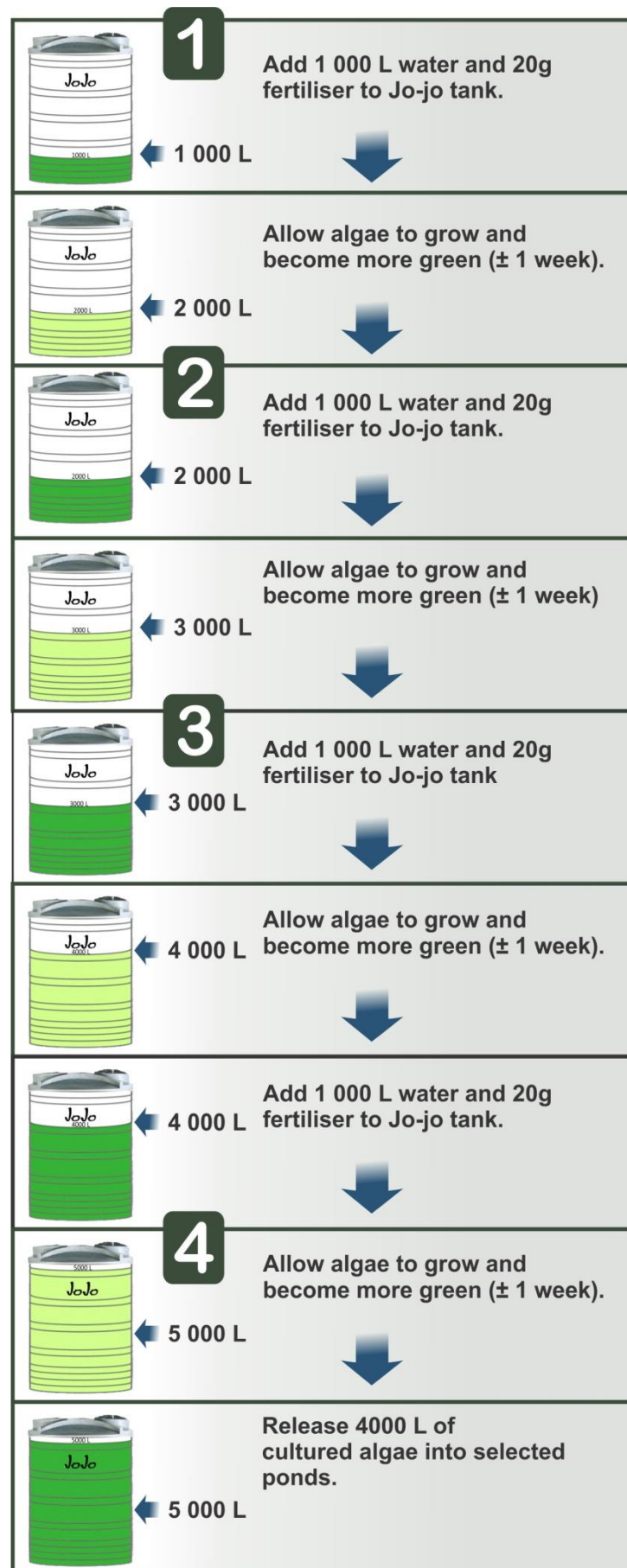
***Very Important**

The time frames given are only an indication. The growth of the algae will depend on various factors (e.g., temperature, light, etc.) that may increase or decrease the time it takes to grow and become greener. Thus, the colour codes indicated in Figure 4 need to be used.

5.2 Algae Bioreactor Lay-out and Flow Diagram

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Figure 3: The step-wise procedure to follow for each algal reactor tank to maintain a healthy supply of algae.



When are the algae the right colour?

Use colour codes described below

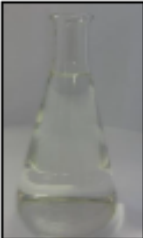
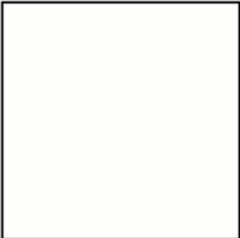
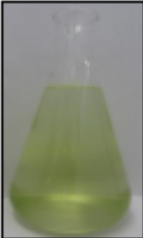
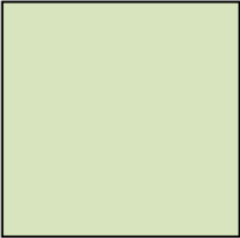

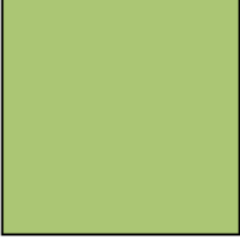

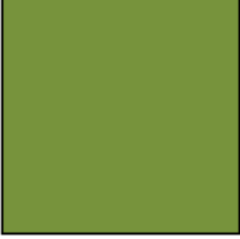
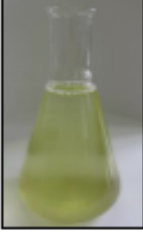
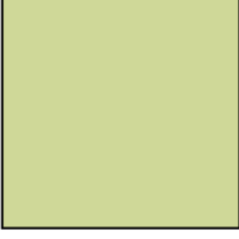
		A transparent colour indicates that alga have not started to grow yet.
		A light green colour indicates that algae are starting to grow.
		A medium green colour indicates that algae are growing well.
		A dark / rich green colour indicates that algae have reached maximum growth. Please dose ponds now.
		Yellowish / brownish colour indicates that algae are starting to die off. They need nutrients. Add fertiliser.

Figure 4: A colour code chart to explain the different types of colour in the algae.

6 GENERAL OPERATION AND MAINTENANCE

6.1 Day-to-day Operation

The following needs to be attended to on a day-to-day basis:

1. Attend to the screen and detritus channel (Figure 5).
2. Keep the minimum desired water depth to help control rooted plants like, for example *Typha* sp. (Figure 6).
3. Keep the embankments free of vegetation, especially at the verges. Remove floating plants on the water or tall plants at the water's edges or that droop into the water. Rooted plants in the water promote mosquito breeding and add to sludge. Bacteria are essential for good treatment in secondary facultative and matured ponds and they require oxygen. Sunlight must penetrate the water and reach the algae to produce the oxygen. Floating plants like duck weed intercept the light, causing the oxygen levels to drop and then change the pond's colour from green to brown (Figure 7).
4. Look out for leakage from rat and crab holes and close them. Inspect the berm slopes for erosion or damaged spots, especially after intense rain periods.
5. Mow vigorous and dense perennial grass cover growth on embankments every two weeks (Figure 8 and Figure 9).
6. Clear floating debris from pond surfaces and clean overflows if necessary (Figure 10).
7. Routine inspection and quarterly groundwater monitoring of boreholes (Figure 11).
8. Weekly inspection of integrity of pipes, reactor tanks, and taps. Also check the filter cartridge, rinse and replace filter routinely (Figure 12 and Figure 13).
9. Inspect on a daily bases the conditions of the series of maturation ponds by using Table 1 as guideline:

Table 1: Colour as indicator of maturation ponds condition

Colour	Condition	Cause or Symptom
Dark sparkling green	Good condition	Enough dissolved oxygen (DO) and high pH
Dull green to yellow	Not so good	DO and pH are less than optimum Blue-green algae may becoming predominant
Red or pink	Poor	Slightly over loaded
Grey to black	Very bad	Anaerobic conditions prevail, odours likely. Too much sludge is possible.



Figure 5: Cleaning and inspection of screening grid at plant inlet and channels.



Figure 6: Water depth too low, causing rooted plants to invade pond.



Figure 7: Removal of floating duckweed in the ponds, with tall plants at the water's edge.



Figure 8: Cutting and cleaning tall plants on pond edges.



Figure 9: Grass cutting.



Figure 10: Floating debris on the pond surface.



Figure 11: Borehole inspection.



Figure 12: Filter cartridge inspection, rinse or replacement.



Figure 13: Inspection of taps, pipes and reactor tanks for leaks, breakages or theft.

7 DEPTH OF SLUDGE LAYER

The depth of the sludge layer in the anaerobic, primary and secondary facultative ponds needs to be tested on a six-month basis using the 'white towel test'. The white towelling material is wrapped around one end of a wooden pole which must be 1 m longer than the pond depth. The pole must be lowered in the pond vertically with the towel end first, until it reaches the bottom of the pond at inlet and outlet points. The pole must be slowly and carefully withdrawn to measure the sludge-liquid interface layer. This layer will be clearly visible since some sludge particles will be entrapped in the towelling material. Measurement of sludge depth is essential and important for the successful performance of the system, because the build-up of sludge at the outlets of the anaerobic pond and in- and outlets of the primary and secondary facultative ponds can block or reduce wastewater flowing from one pond to another.



Figure 14: Sludge build-up and removal from Anaerobic Pond 1A at Brandwacht WWTW.



8 GENERAL SANITARY ANALYSIS PROGRAM FOR PHYCOREMEDIATION TREATMENT

8.1 Routine Parameters

Table 2 is a list of the parameters should be routinely monitored on a monthly basis. Samples must be taken by a grab sampler.

Table 2: The parameters that should be sampled on a monthly basis.

Parameters	DWA Guidelines for Effluent	Ideal Phycoremediation Treatment Conditions	Location of Sampling
5 days, 20°C, biological oxygen demand		< 12 mg/l	Maturation ponds
Chemical oxygen demand	75 mg/l		Effluent
Suspended solids	25 mg/l		Effluent
Faecal coliform	1000 / 100ml		Effluent
Nitrogen: Nitrate/Nitrite	15 mg/l		Effluent
Ortho- phosphate	1 mg/l		Effluent
pH	5.5 - 9.5 (effluent)	7.5 - 10.5	
Electrical conductivity	70 mS/m		Effluent
Oxygen (mg/l) for aquaculture conditions		>2 mg/l	Final maturation pond
Temperature		30	Maturation ponds
Suspended chlorophyll a		>500 µg/l	Excluding final maturation pond
Algal speciation * (disruption of algae speciation)			Not final maturation pond

9 REFERENCES

Environmental Protection Agency (EPA). (1997). *Operations Manual: Stabilization Ponds*. MO-15, 430/9-77-012.

Oberholster, PJ., Cheng, P., Claassen, M., De Klerk, AR., De Klerk, LP., McMillan, P., and Naidoo, M. (2017). Operational and Training Manual for Algal-Based Tertiary Treatment in Maturation Ponds of the Motetema Wastewater Treatment Works. WRC Report No. TT707/16

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