



Low cost algae-based tertiary treatment for WWTW in rural areas of developing countries

Focus areas of presentation:

- **Water availability in Africa and climate change**
- **Self-sustainable technology requiring no chemicals or electricity**
- **Algae bio-reactors**

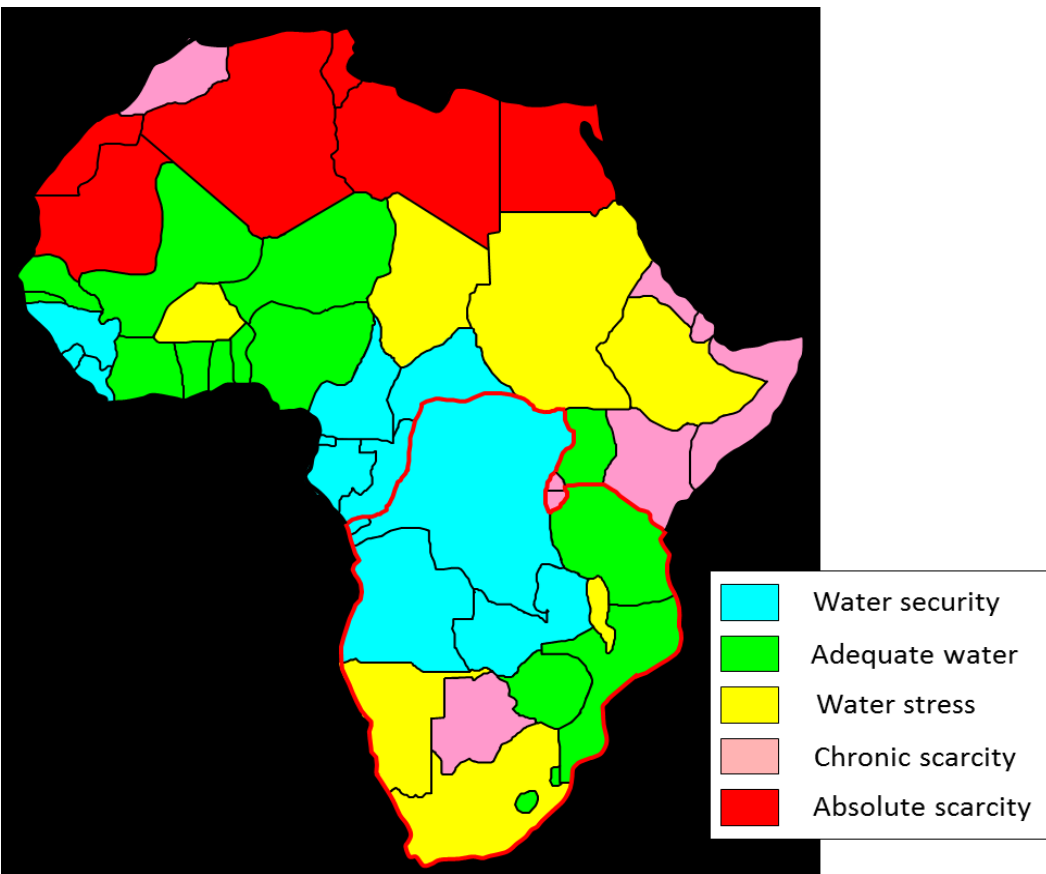
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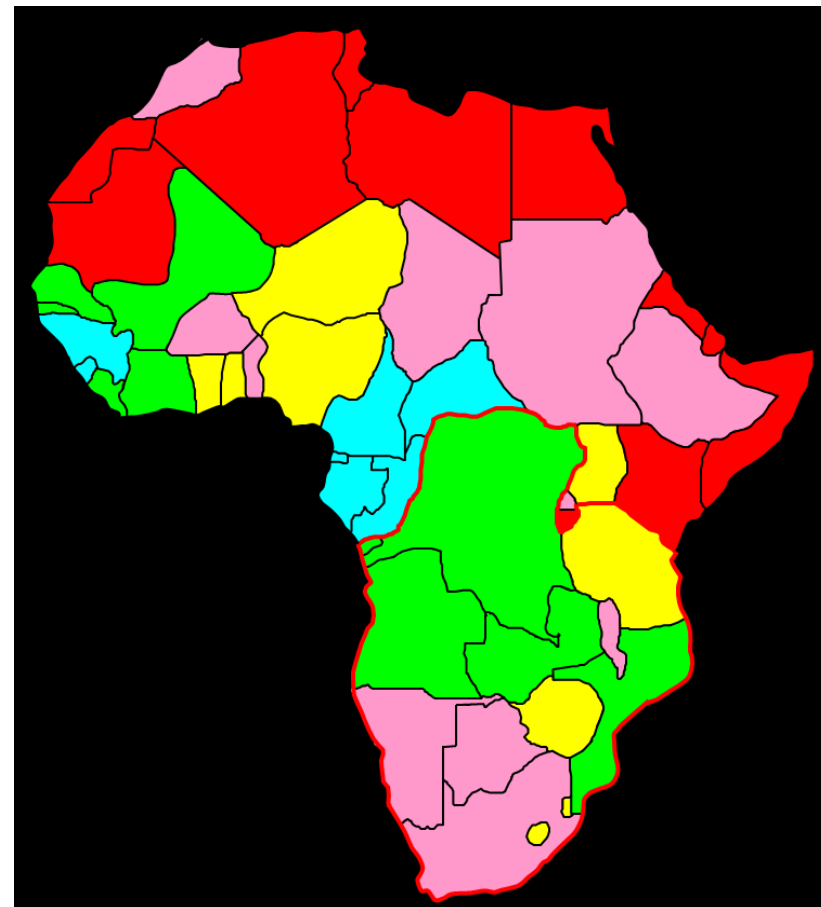
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Water availability in Africa

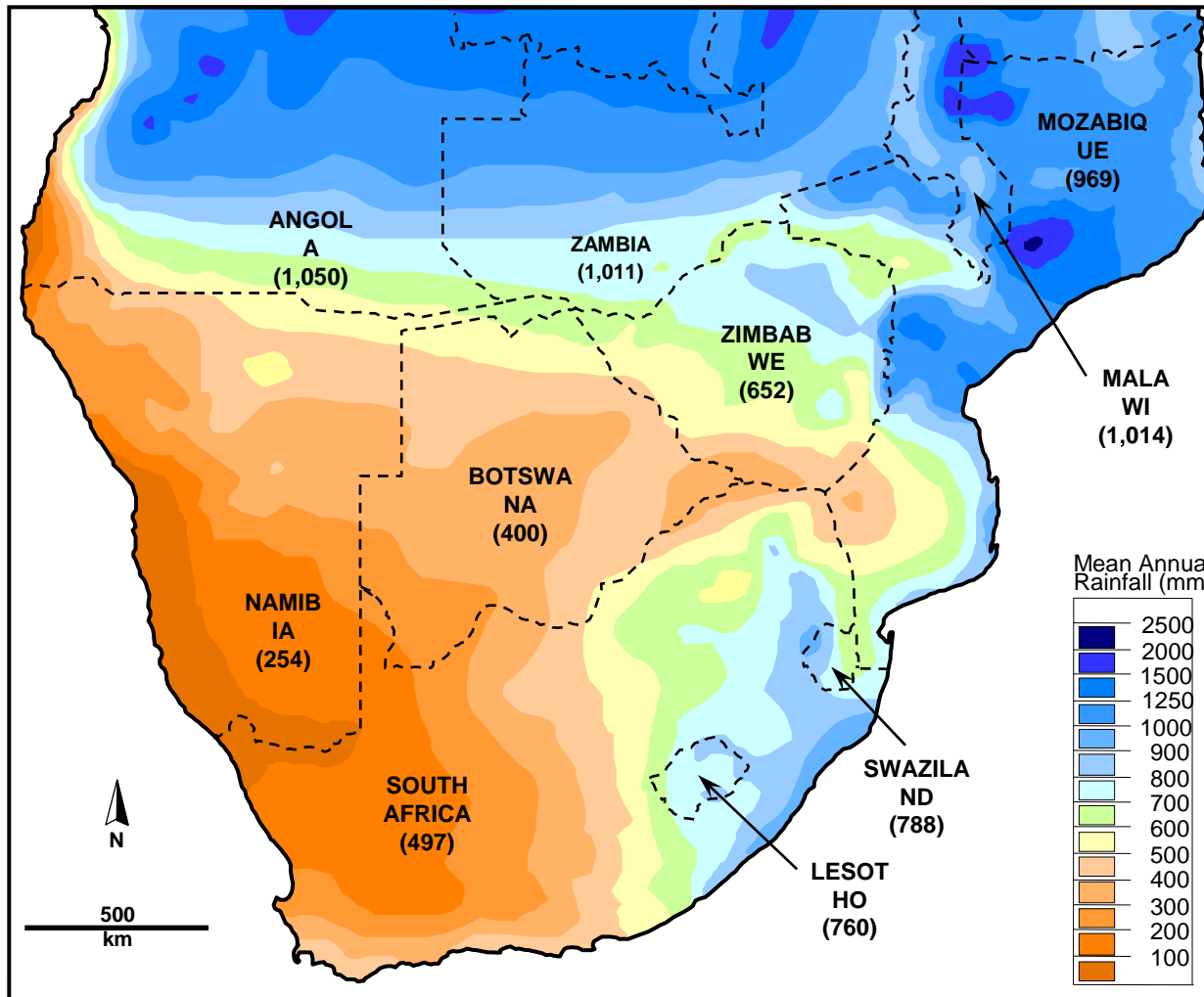
2002



2025



Mean Annual Rainfall in Southern Africa



South Africa is semi-arid with an average rainfall of 470 mm/a, well below the world's average of 840 mm/a

Water requirements already exceeded the demand in 10 out of the 19 WMA in the year 2000

Quality and quantity plays a major role in water reuse with the current climate change scenarios

Biggest challenges of WWTW in rural Africa

- 1) Inadequate sanitation is one of the leading causes of water pollution and consequently illness in many underdeveloped countries.**
- 2) Effluent not within guideline standards for water reuse**
- 3) Aging infrastructure**
- 4) Skill shortage**
- 5) Phosphorus sensitive catchments (Changing habitat conditions and reduction of ecosystem services)**



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Algae-based treatment for rural municipal domestic wastewater pond systems: The South African case study



Phosphorus sensitivity index for management of rivers receiving WWTW effluent



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Article

Using modified multiple phosphorus sensitivity indices for mitigation and management of phosphorus loads on a catchment level

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With 3 figures and 3 tables

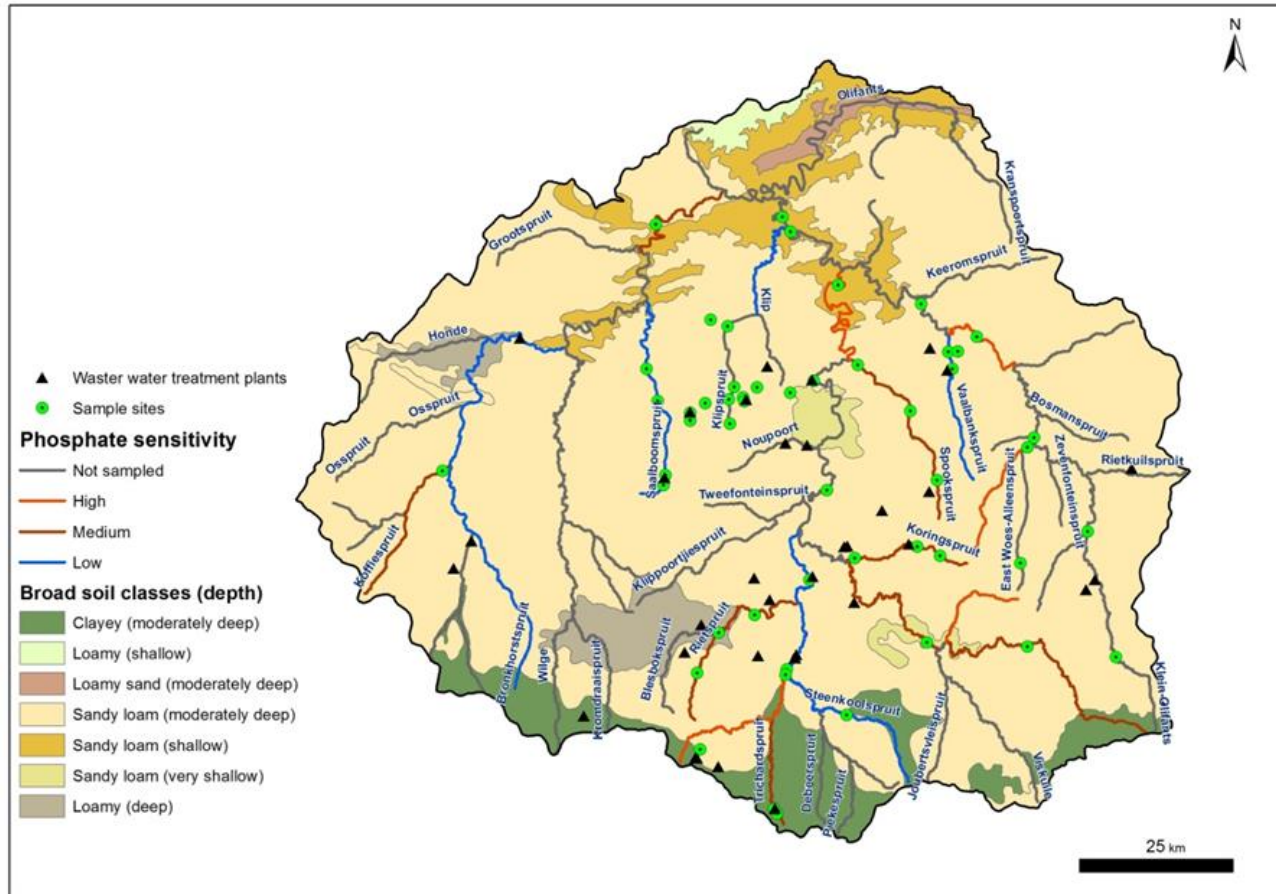
Abstract: The relationships between river and lake phosphorus sensitivity, environmental drivers and catchment characteristics within the upper Olifants River and Lake Loskop were studied over a period of four years to come up with mitigation and management strategies. Using modified indices it was evident that the best strategy for improving the trophic state of Lake Loskop was to drastically reduce the external nutrient loading coming from the upper Olifants River catchment. According to the lake phosphorus sensitivity index (LPSI) developed, Lake Loskop was phosphorus sensitive and will possibly respond to phosphorus reduction in its upper catchment. The river phosphorus sensitivity index (RPSI) developed showed that certain rivers and streams in the upper catchment of Lake Loskop were particularly sensitive to increases in phosphorus (P) loads. The substrate of these rivers and streams consisted of approximately 90 % cobbles or bedrock and showed eutrophic conditions during low flow regimes. The increase in P loads in these streams stimulates the productivity and growth of periphyton dominated by filamentous green algae mats. On the other hand, a restriction of light penetration into the water column by high concentrations of inorganic suspended solids limited the growth of both benthic and planktonic algae in > 3 order streams dominated by sand or mud bottom substrates, thus making these streams less sensitive to high P loads. Rivers and streams in the upper catchment that required mitigation of P loads were identified according to the RPSI and different P load management practices were outlined. The findings of this study are important for restoration and management purposes of increased P loads in conjunction with river characteristics and phytoplankton occurrence. The modified indices developed for P management can be a useful tool in river basins in other parts of the world with the similar environmental drivers and catchment characteristics.

Key words: river phosphorus sensitivity index (RPSI), lake phosphorus sensitivity index (LPSI), periphyton, river substrate, lake A/C diatom ratio, eutrophication.



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WWTW in Phosphorus sensitive Olifants River catchment



Objectives

- 1) The principal objectives of the study was to facilitate the effective and efficient removal of nutrients (specific phosphorus) and pathogens in rural Wastewater Treatment Works (WWTWs) effluent through algae based treatment (phycoremediation).**
- 2) To established in the final polishing ponds an aquaculture (fish) or phosphorus harvesting (fertilizer) venture for job creation.**
- 3) Using existing infrastructure with no electricity.**



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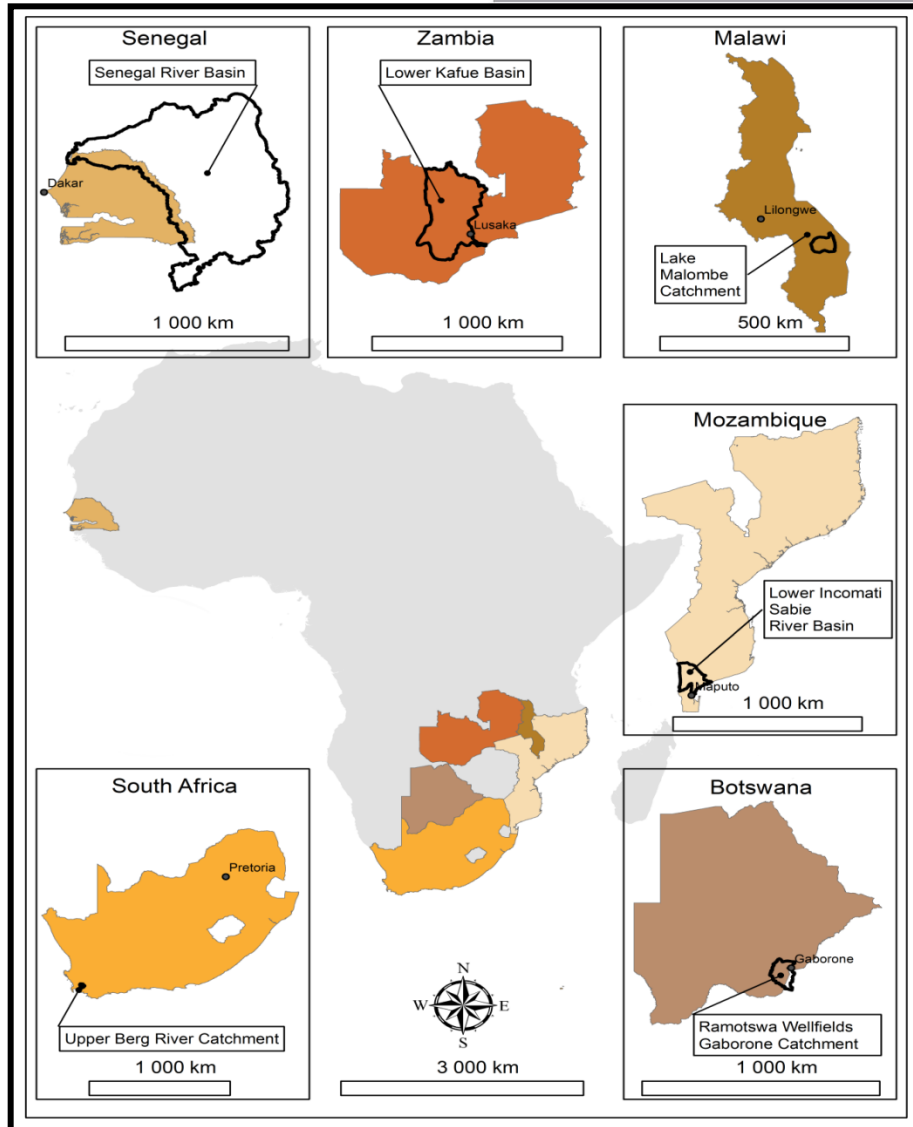


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Collection of micro algae



Different WWTP algae species were collected from different countries in Africa, with a variation in climate conditions in mind

Screening of micro algae

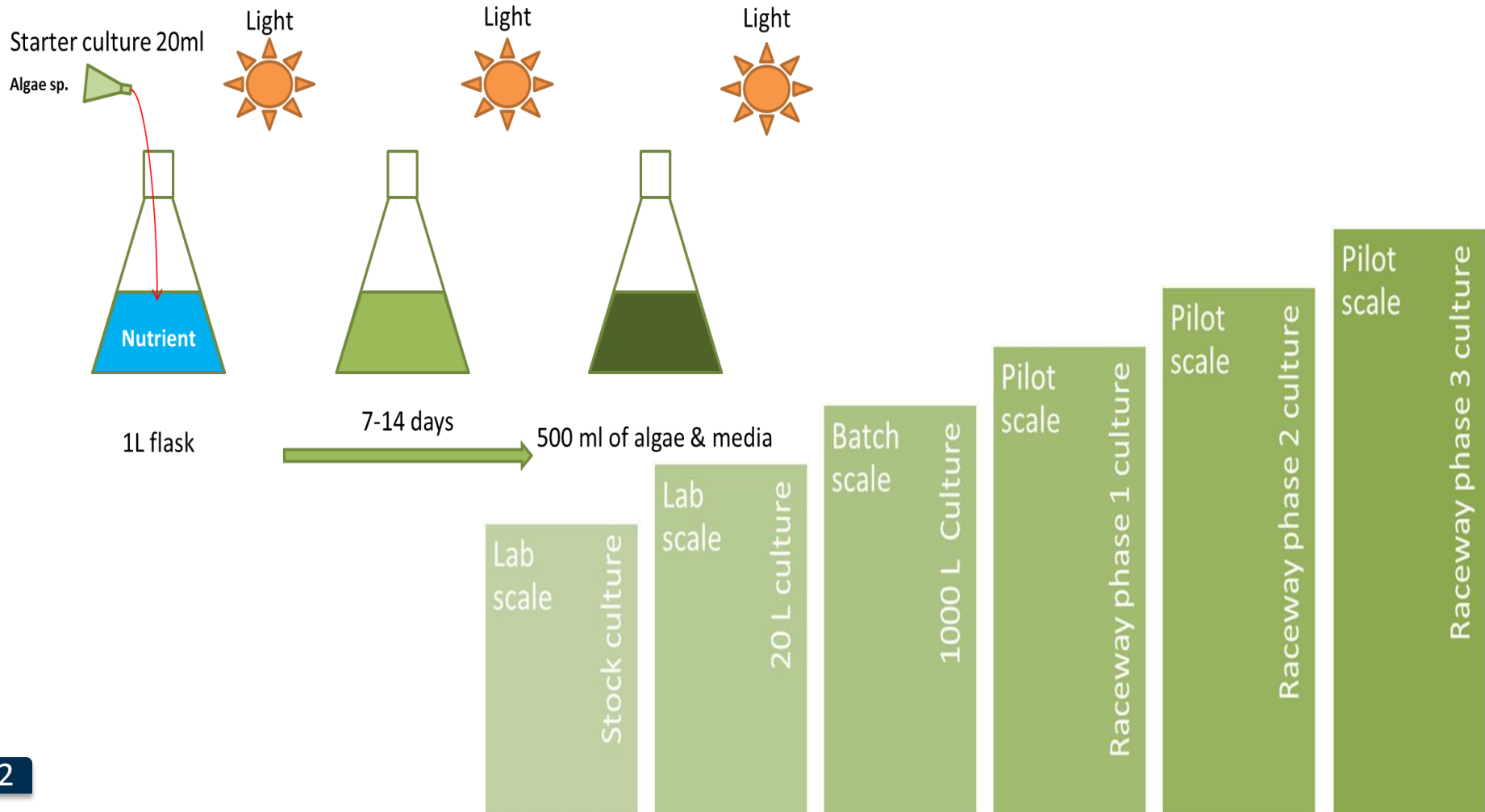


Collected algae were screen for the following characteristics:

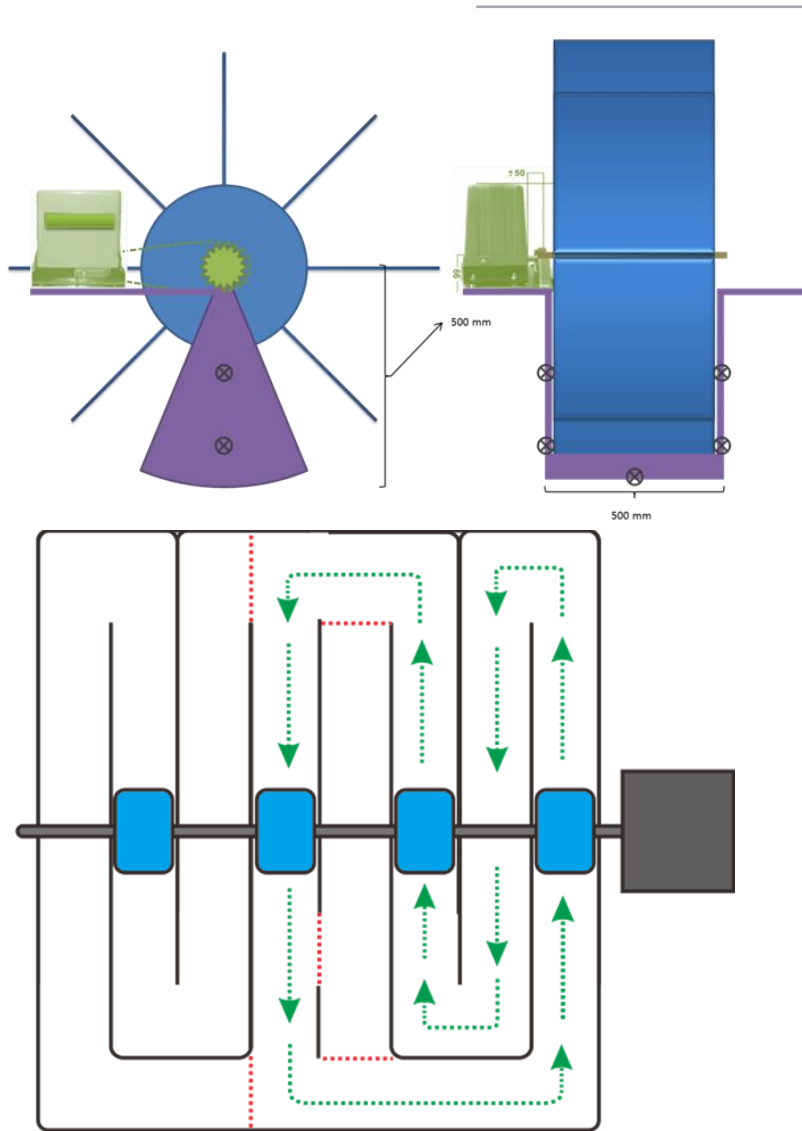
- **Maximum uptake of phosphates, since most Southern African rivers are phosphate sensitive.**
- **Tolerance to temperature changes**
- **Exponential growth to out compete other algae**

Algae cultivation

After selecting an specific consortium of algae a step wise approach was followed



Algae raceway for mass culturing



Selection of pilot area



Motetema WWTW is situated at the small town of Elias Motsoaledi, Sekhukhune District of the Limpopo province, South Africa. Due to the lack of proper WWTW infrastructure and electricity, a series of ponds are employed at the Motetema WWTW to treat sewage effluent. The WWTW consist of 12 earth ponds organised in two series of six each parallel to one another

Characteristics of the Motetema WWTW



Six ponds are operated at a time, while the other 6 ponds are dried to remove sludge. The pond system is based on natural overflow from one pond to another. The average total effluent that needs to be treated (for a population of 11 400) by the Motetema WWTW is ~ 2.5 MI/ day. Wastewater from the Motetema WWTW flows into the Elephant River. The Elephant River is known as the most polluted river system in southern Africa. The River is also classified as a phosphate sensitive river

Transporting algae to pilot area



**20 000 litres of cultured algae was transported to the pilot area on a monthly bases to determine:
Phosphorus uptake**

Setting up algae bioreactors



Algae bioreactors

Five semi transparent containers of 5000 litres

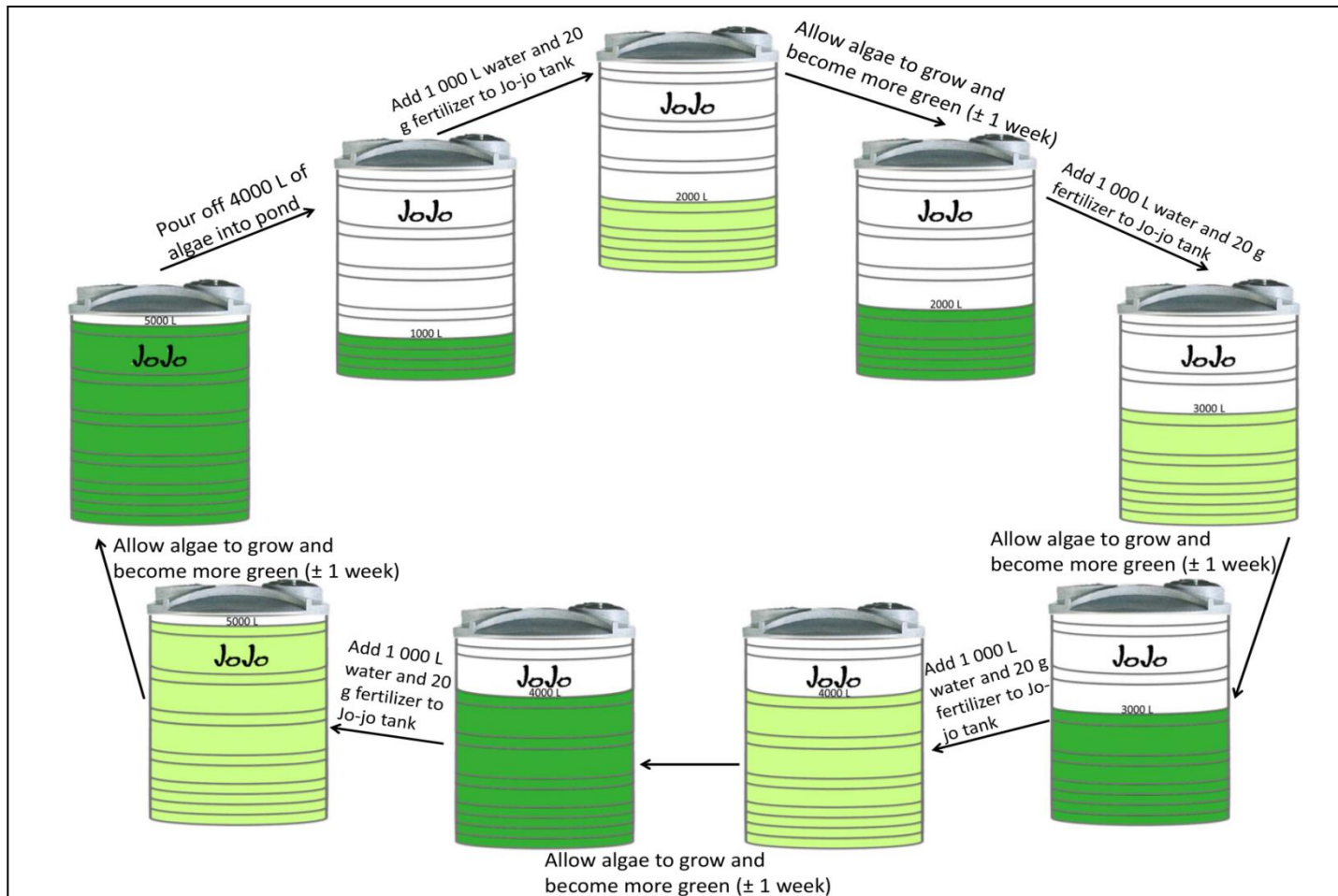


Algae culturing steps



- 1) Inoculation time (3 to 4 weeks) of algae in the different pond systems depend on season
- 2) Algae has been stirred manually every 4 days
- 3) Average cells for inoculation 10 000/ml

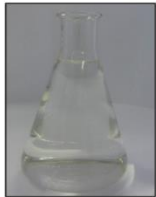
Algae culturing steps



Colour codes for WWTP operator

When are the algae the right colour?

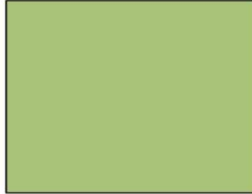
Use colour codes described below



A transparent colour indicates that algae have not started to grow yet.



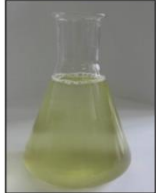
A light green colour indicates that algae are starting to grow.



A medium green colour indicates that algae are growing well.



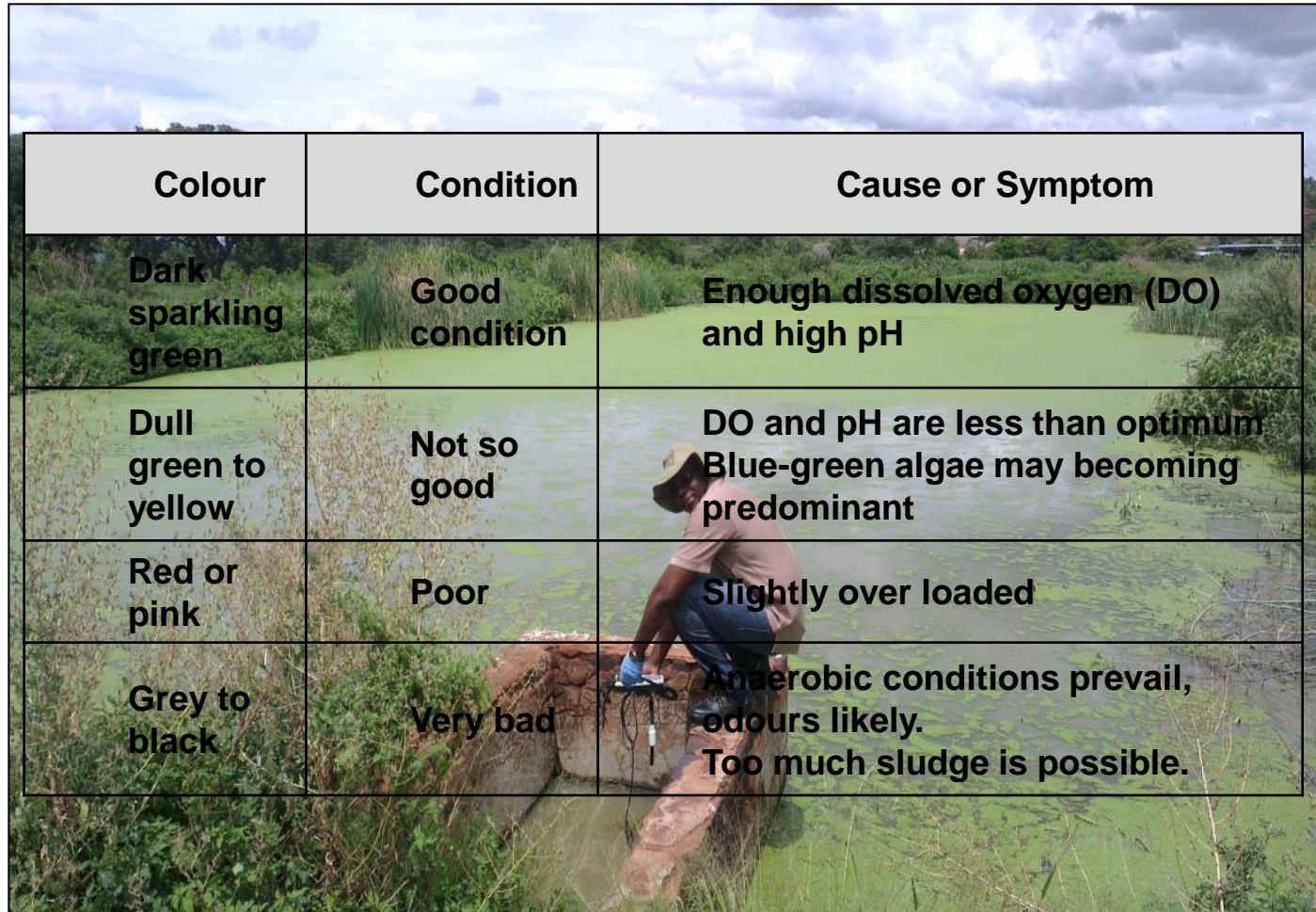
A dark / rich green colour indicates that algae have reached maximum growth. Please dose ponds now.



Yellowish / brownish colour indicates that algae are starting to die off. They need nutrients. Add fertilizer.

Colour codes are used, due to the lack of testing equipment to determine cell counts or Chl-a.

Management of pond systems



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.

Data analyses

Table 1: Average selected parameters for monitoring the efficiency of algae for remediation in Motetema wastewater treatment works (n=5).

PARAMETERS	BEFORE (UNFILTERED)							AFTER (UNFILTERED)							REMOVAL EFFICIENCY (%)		
	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7	Pond 1	Pond 2	Pond 3	Pond 4	Pond 5	Pond 6	Pond 7	Pond 5	Pond 6	Pond 7
Total Nitrogen water (mg/L)	34	30	27	23	58	31	26	47	33	36	36	33	20	18	43.1	35.1	30.7
Total Organic Carbon (mg/L)	99	61	57	47	181	45	37	117	58	77	67	55	35	31	69.6	22.1	16.4
Total Chemical Oxygen Demand (mg/L)	378	238	224	157	567	142	103	479	228	276	272	230	92	93	59.4	35.2	2.0
Total Phosphorus (mg/L)	34	30	27	23	58	20	18	4.6	3.2	3.6	3.3	3.3	3.1	2.8	94.3	84.5	84.4
Suspended Solids (mg/L)	229	117	115	65	224	54	76	259	118	76	120	123	82	89			
Sulphate as SO ₄ Dissolved (mg/L)	87	89	106	109	71	167	153	210	150	155	159	103	122	117	39.7	63.3	23.5
Chloride as Cl (mg/L)	60	61	62	60	76	76	74	89	83	82	84	66	61	60	13.1	19.7	18.9
ortho Phosphate as P (mg/L)	0.07	0.14	0.14	1.1	5.8	3.4	2	1.5	0.28	1.7	1.8	1.1	0.44	0.28	81.0	87.1	86.0
Ammonia as N (mg/L)	20	17	19	18	37	24	27	33	22	21	22	21	20	18	43.2	16.6	33.3
Electrical Conductivity (mS/m)	104	102	102	98	112	100	116	132	116	120	115	120	116	94			
pH (Lab) (20°C)	8.1	8.1	8.1	8.1	7.8	8.1	8	8	8.3	8	8.7	8.9	8.6	8.2			

***E-coli* was reduce in the effluent of Pond 7 within DWS guideline range: General limit for *E coli* WW 1,000/100ml**

Data analyses

Table 2: Zooming on Pond 5-7 after algae is removed through filtering (n=5) to determine algae uptake of phosphorus

PARAMETERS	BEFORE (FILTERED)			AFTER (FILTERED)			% REMOVAL		
	Pond 5	Pond 6	Pond 7	Pond 5	Pond 6	Pond 7	Pond 5	Pond 6	Pond 7
Total Nitrogen water (mg/L)	32	20	20	20	14	13	37.5	30.0	35.0
Total Organic Carbon (mg/L)	83	27	25	20	27	19	75.9	7.4	24.0
Chemical Oxygen Demand (mg/L)	282	72	68	52	71	49	81.6	1.4	27.9
Total Phosphorus (mg/L)	7.0	0.3	0.6	0.1	0.1	0.1	99.0	72.1	88.3

Aquaculture



Currently experiments are ongoing to make use of ornamental fish to reduce algae biomass in last matured pond

Conclusion

1) In phosphorus sensitive catchment of under developing countries the selected algae species can be use to reduce nutrients and E-coli in the treated waste water effluent.

2) The proposed waste water treatment system is ideal as a adaptation response to climate change in areas where dilution capacity of receiving water bodies will be much lower due to less rainfall in the future, since it will directly reduce the health risk to communities and improve aquatic ecosystem health. Improved knowledge and increased local municipalities' capacity as well as reducing poverty by creating job opportunities for communities. By improving rural sewage pond systems to be self-sufficient there will be a reduction of operator responsibilities to manage treatment, a reduction in labour costs, reduction in energy requirements and an increase in the potential fiscal returns from the tangible products generated by the treatment unit.



The end