IMPROVED QUALITY OF DISTILLERY EFFLUENT BY INTEGRATING SEQUENTIAL BIO-TREATMENT SYSTEM

Jastin Samuel., Sophia, J.D., Purusothaman, D., Poorani. D.G., Prabavathy, V.R., and Ajay Parida

International Conference
on
Innovations in Sustainable Water & Wastewater Treatment Systems

Water 4 Crops Project
M S Swaminathan Research Foundation,
Chennai

OUTLINE

- Introduction
- Objectives
- Site selection Preliminary studies
- Treatment system design
- Sequential treatment process
- Water quality changes
- Bacterial treatment
- Algal treatment & mechanism
- Reuse Study
- Summary

INTRODUCTION

Distillery effluent:

- Effluent generated from alcohol distilleries
- 8–15 L of effluent is generated for every liter of alcohol produced
- The alcohol distilleries are extensively growing due to widespread industrial applications of alcohol such as in pharmaceuticals, food, perfumery, etc.
- It is also used as an alternate fuel. There are 319 distilleries in India alone, producing 3.25 billion liters of alcohol and generating 40.4 billion liters of wastewaters annually
- Ministry of Environment and Forests (MoEF), alcohol distilleries - “Red Category” industries
- Stringent government policies on pollution - distillery industries have been forced to look for more effective treatment technologies - not only be beneficial to environment, but also be cost effective.
- In 2003, Central Pollution Control Board (CPCB), stipulated that, distilleries should achieve zero discharge in inland surface water courses by the end of 2005. Consequently, the wastewater needs to undergo extensive treatment in order to meet the stipulated environmental demands.

OBJECTIVE

Develop and demonstrate integrated treatment processes for distillery industry effluent targeted at recycling of water suitable for irrigation

Site

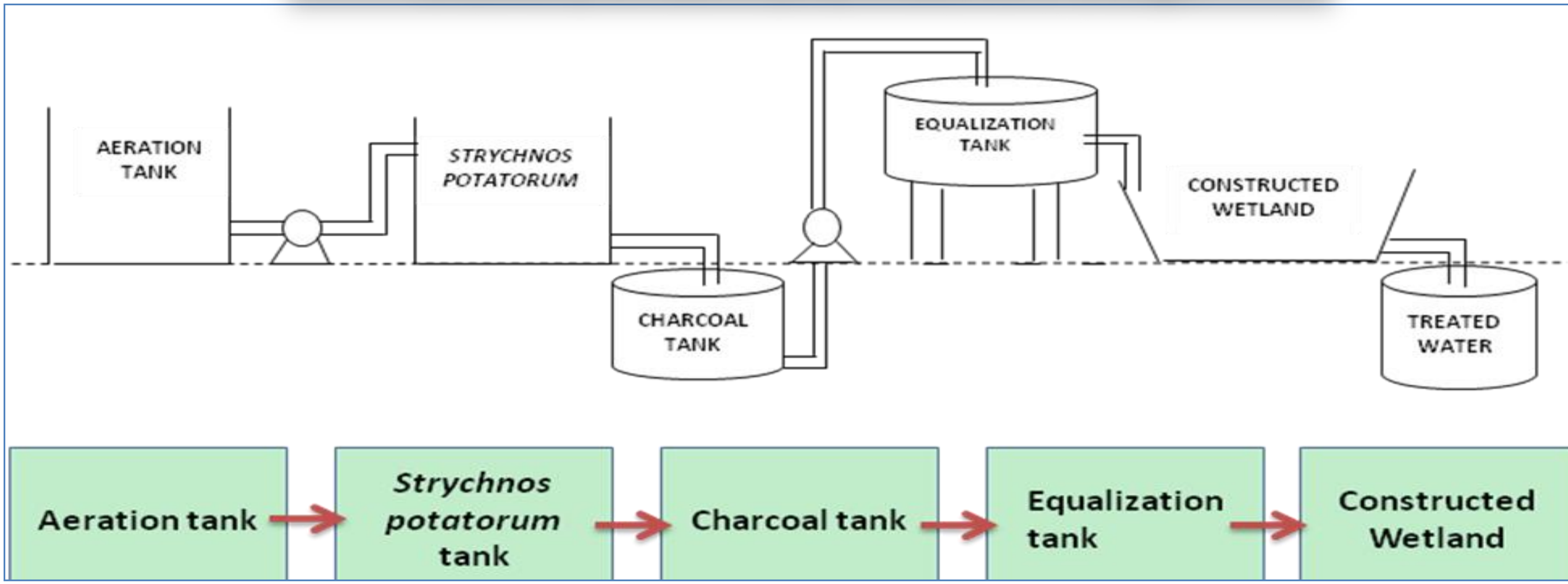
Sample Collection

Anaerobically Treated Distillery effluent Quality

Parameters	AnT DE
pH	6.6
Ec (mS/cm)	23.34
Salinity (PPT)	15.4
Temperature (°C)	35.79
COD (mg/L)	50857.14
Colour	Dark brown
BOD (mg/L)	13712.97
TDS (mg/L)	60089.82
TSS (mg/L)	14138.84
Phosphate	1222.31
Chloride	432.67
Magnesium	264.5
Sulphate	80.89
Nitrate	113.05
Calcium	126.69

AnT DE : Anaerobically treated distillery effluent

Distillery effluent (DE) treatment Design



Problems and strategies in distillery effluent (DE) treatment

Problems in existing treatment process

- Issue of melanoidin in DE
- In aeration tank bacterial growth was only 30 - 40%
- Removal of COD was only 1000mg/L in ST
- Recurring cost of *Strychnos Potatorum* seed

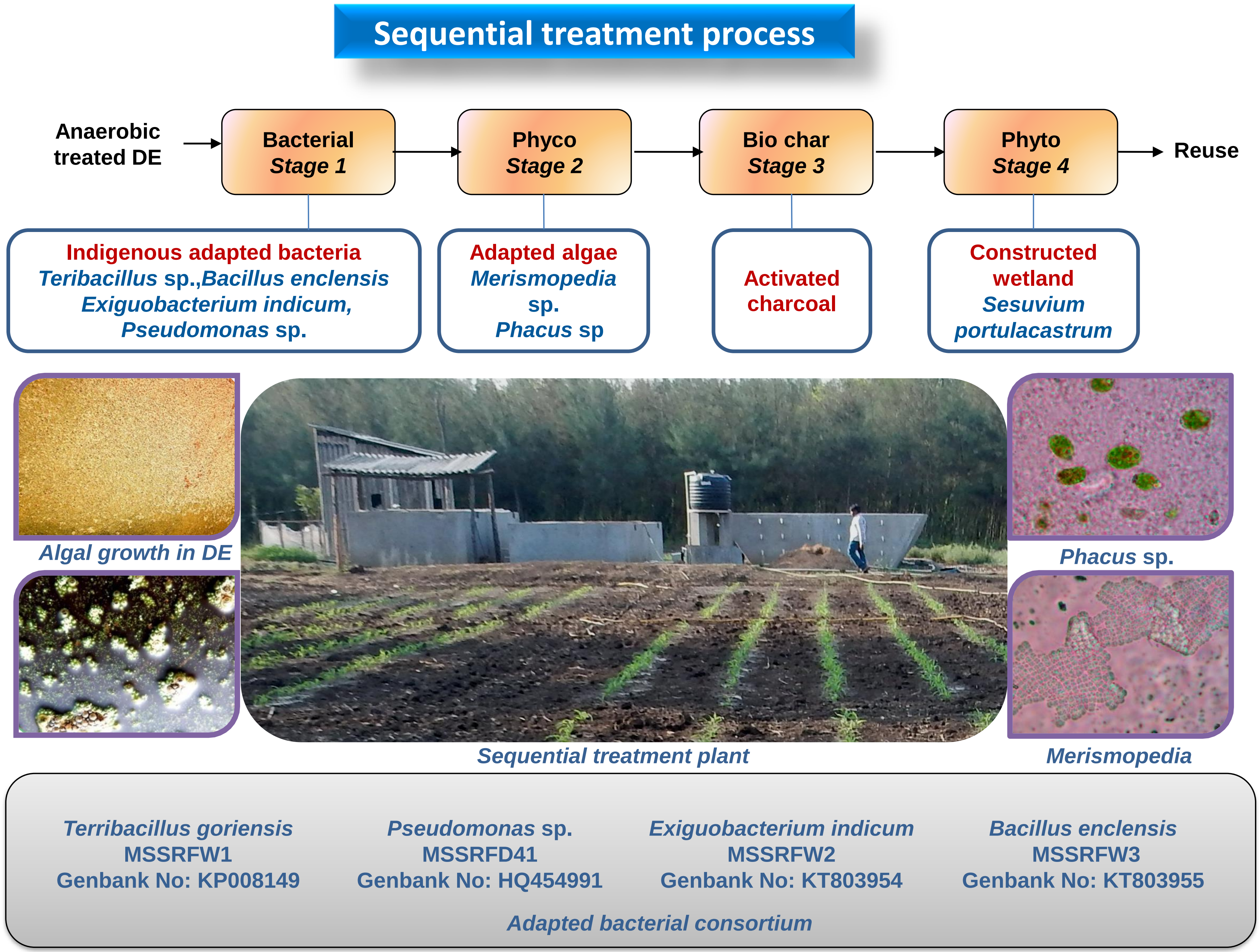
Strategies to address the problems

- Decolourisation and degradation studies
- Bacterial consortium was adapted to yield efficient results
- Microbial load of initial inoculum was increased
- Batch experiments done to choose better COD removing bio-remediant

Batch Experiments

Free cells of algae	4000 mg/L of COD was removed by free cells of algae
Growing algal cells	15066.67 mg/L of COD was removed by the growing cells of algae
Strychnos Potatorum seed	4666.67 mg/L of COD was removed by the seeds of *Strychnos potatorum*
Moringa seeds	933.33 mg/L of COD was removed by the seeds of Moringa

- The growing algal cells were selected as alternative material to reduce COD
- In addition improvement in water quality are observed



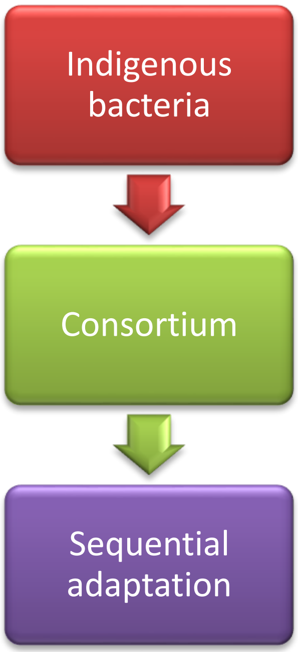
Sequential treatment process
Anaerobic treated DE
Bacterial Stage 1
Phyco Stage 2
Bio char Stage 3
Phyto Stage 4
Reuse
Indigenous adapted bacteria
Teribacillus sp.,Bacillus enclensis
Exiguobacterium indicum,
Pseudomonas sp.
Adapted algae
Merismopedia sp.
Phacus sp
Activated charcoal
Constructed wetland
Sesuvium portulacastrum
Algal growth in DE
Sequential treatment plant
Phacus sp.
Merismopedia
Terribacillus goriensis MSSRFW1 Genbank No: KP008149
Pseudomonas sp. MSSRFD41 Genbank No: HQ454991
Exiguobacterium indicum MSSRFW2 Genbank No: KT803954
Bacillus enclensis MSSRFW3 Genbank No: KT803955
Adapted bacterial consortium

Effluent Quality Changes

Parameters	AnT DE	% Removal				Treated DE
		Bacterial treatment	Algal treatment	Treatment in CWL	Total	
pH	6.60	4.6	2.4	1.2	7.1	7.10
Ec (mS/cm)	23.34	1.4	1.0	2.7	29.6	16.43
Salinity (PPT)	15.40	2.0	1.5	6.1	48.8	7.88
Temperature (°C)	35.79	0.4	2.9	5.8	14.7	30.53
COD (mg/L)	50857.14	58.9	48.6	41.0	90.0	5070.83
% Colour removal	0.00	100.0	71.6	48.8	62.0	62.02
BOD (mg/L)	13712.97	56.0	66.2	38.4	92.7	1005.83
TDS (mg/L)	60089.82	36.5	17.8	13.3	63.8	21736.75
TSS (mg/L)	14138.84	56.7	49.7	48.6	91.1	1263.88
Phosphate (me/L)	1222.31	33.4	22.1	33.4	72.4	337.91
Chloride (me/L)	432.67	32.4	24.0	5.0	60.9	169.16
Magnesium (me/L)	264.50	2.5	13.9	11.8	40.8	156.66
Sulphate (me/L)	80.89	43.0	51.5	12.9	80.7	15.58
Nitrate (me/L)	113.05	50.2	51.0	19.1	84.2	17.84
Calcium (me/L)	126.69	43.9	26.0	15.4	71.9	35.58

- DE quality enhanced significantly on reduction of COD, BOD, Colour, TSS, Sulphate, Nitrate and calcium
- Bacterial treatment enhanced pH and melanoidin degradation which enabled penetration of sunlight contributing for adaption and growth of algae
- Growing algal cells favoured degradation, adsorption and settlement of contaminants
- Halophyte *Sesuvium portulacastrum in CWL* has removed 6.1% of salinity from the distillery effluent.

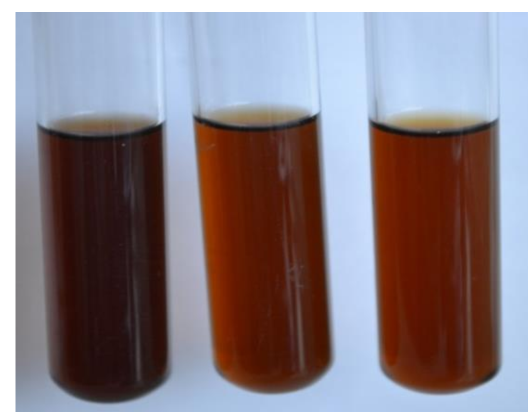
Bacterial Treatment



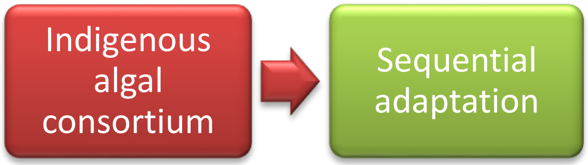
Parameters	Inlet	Outlet	% removal	Rate ($L^{-1}h^{-1}$)
pH	6.60	7.02	4.6	0.01
Ec (mS/cm)	23.34	17.07	1.4	0.1
Salinity (PPT)	15.40	8.53	2.0	0.1
Temperature (°C)	35.79	33.38	0.4	0.03
COD (mg/L)	50857.14	16720.83	58.9	474.1
% Colour removal	0.00	32.07	100.0	0.4
BOD (mg/L)	13712.97	4824.78	56.0	123.4
TDS (mg/L)	60089.82	30512.67	36.5	410.8
TSS (mg/L)	14138.84	4895.86	56.7	128.4
Phosphate (me/L)	1222.31	651.42	33.4	7.9
Chloride (me/L)	432.67	234.11	32.4	2.8
Magnesium (me/L)	264.50	206.36	2.5	0.8
Sulphate (me/L)	80.89	36.91	43.0	0.6
Nitrate (me/L)	113.05	45.03	50.2	0.9
Calcium (me/L)	126.69	56.85	43.9	1.0

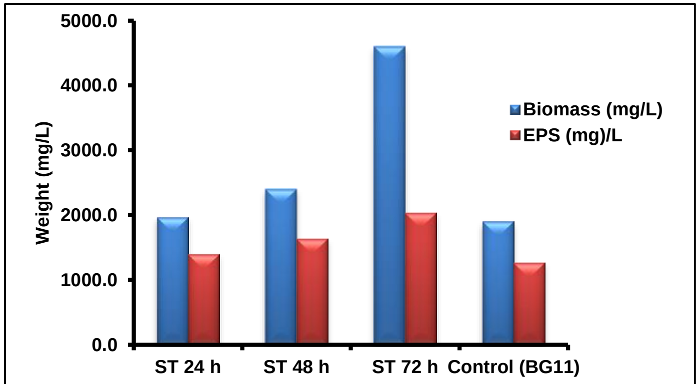
Increased removal capacity is due to,

- Using indigenous adapted bacterial consortium
- Optimum retention time
- Aeration and continuous mixing of the effluent
- Degradation of melanoidin



Algal Treatment

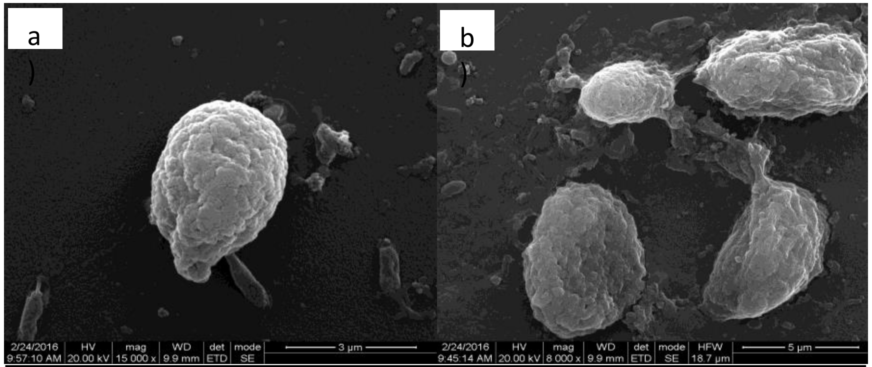




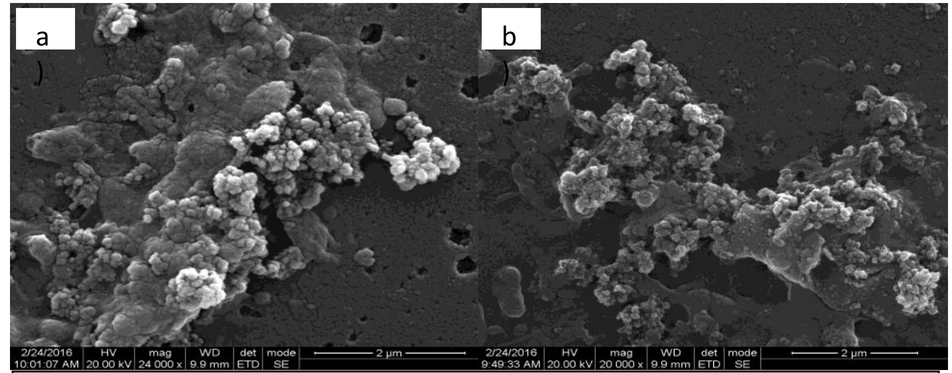
Biomass and EPS concentration of adapted algal consortium at 24, 48 and 72 h interval compared to control un-interacted)

Parameters	Inlet	Outlet	% removal	Rate ($L^{-1}h^{-1}$)
pH	7.02	7.19	2.36	0.002
Ec (mS/cm)	17.07	16.90	1.03	0.002
Salinity (PPT)	8.53	8.40	1.49	0.002
Temperature (°C)	33.38	32.40	2.93	0.014
COD (mg/L)	16720.83	8591.88	48.62	112.90
% Colour removal	32.07	62.64	71.56	0.42
BOD (mg/L)	4824.78	1632.85	66.16	44.33
TDS (mg/L)	30512.67	25075.58	17.82	75.52
TSS (mg/L)	4895.86	2461.29	49.73	33.81
Phosphate (me/L)	651.42	507.62	22.07	2.00
Chloride (me/L)	234.11	178.00	23.97	0.78
Magnesium (me/L)	206.36	177.61	13.93	0.40
Sulphate (me/L)	36.91	17.90	51.52	0.26
Nitrate (me/L)	45.03	22.06	51.02	0.32
Calcium (me/L)	56.85	42.05	26.03	0.21

- High production of EPS in distillery effluent indicates the involvement of EPS in protecting the algal cells against highly adverse conditions.
- The EPS production of the adapted algal consortium in distillery effluent is significantly high compared to that of the un-interacted cells.
- Very significant correlation between the increase in algal growth, EPS production and the reduction of different parameters.

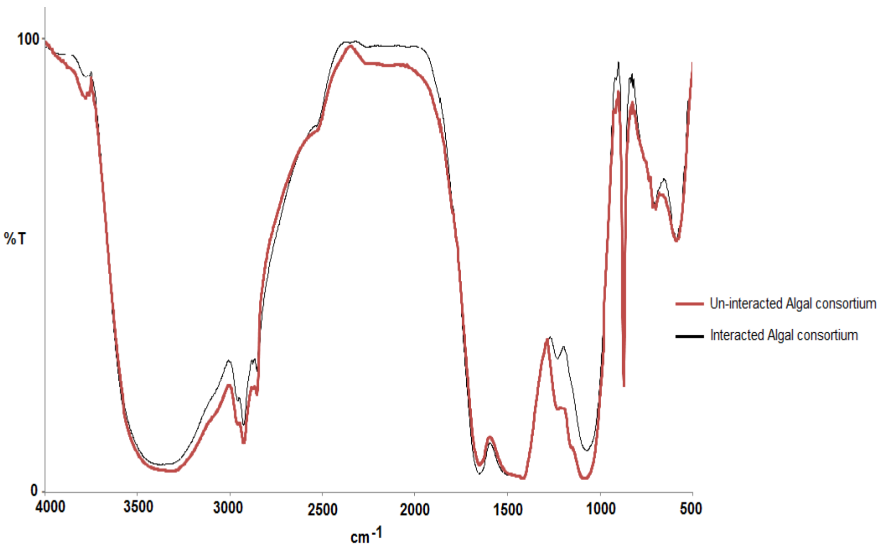


HR-SEM images of *Phacus* sp. a) un-interacted b) interacted with DE



HR-SEM images of *Merismopedia* sp. a) un-interacted b) interacted with DE

- Significantly increases in the diameter of *Phacus* sp. cells on interaction with the effluent due to the surface adsorption of contaminants & changed from smooth to rough with shrinkages on interaction with distillery effluent
- Exopolysaccharide can be seen around the cells interacted with distillery effluent compared to the un-interacted ones
- Algal cells have adapted themselves to survive and thrive in the distillery effluent



FT-IR spectrum of adapted algal consortium interacted and un-interacted with distillery effluent

- The algal cell wall and exopolysaccharide have different functional groups N–H, O–H, CH_3, C=O, COO−, CH_2 and P=0 which on interaction with cations (Ca^{2+}, Na^{2+}, Mg^{2+} and etc.) in distillery effluent are able to remove them.
- A large number of hydrogen group bonds the C or N of algae with hydroxyl, carboxyl and phenol groups of melanoidin which additionally favors sorption.
- The multilayered adsorption increases the density of algal cells enabling it to sediment with the contaminants.

Treatment in Constructed wetland

Parameters	Inlet	Outlet	% removal
pH	7.19	7.10	1.2
Ec (mS/cm)	16.90	16.43	2.7
Salinity (PPT)	8.40	7.88	6.1
Temperature (°C)	32.40	30.53	5.8
COD (mg/L)	8591.88	5070.83	41.0
% Colour removal	62.64	62.02	48.8
BOD (mg/L)	1632.85	1005.83	38.4
TDS (mg/L)	25075.58	21736.75	13.3
TSS (mg/L)	2461.29	1263.88	48.6
Phosphate (me/L)	507.62	337.91	33.4
Chloride (me/L)	178.00	169.16	5.0
Magnesium (me/L)	177.61	156.66	11.8
Sulphate (me/L)	17.90	15.58	12.9
Nitrate (me/L)	22.06	17.84	19.1
Calcium (me/L)	42.05	35.58	15.4

Experiments to demonstrate reuse of treated water

Sweet corn cultivation using bio-treated wastewater

Crop: Sweet corn

Variety: F1 HY Sweet Gold 95

Soil: Clay soil

Cycles studied: 3 seasons & 4 on going

Treatment: T1 bio-treated distillery effluent

T2 Anaerobic treated distillery effluent

T3 - fresh water as control

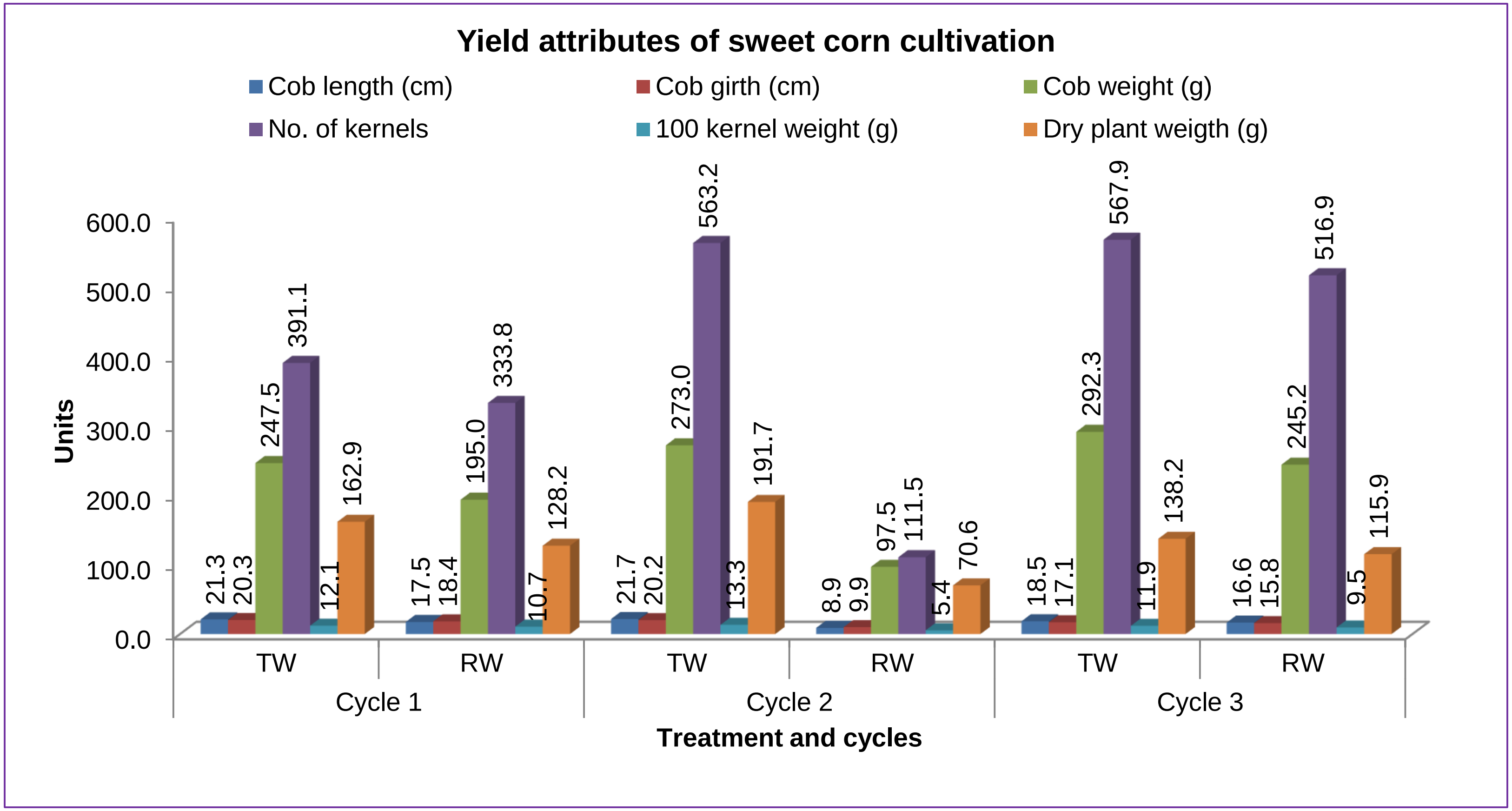
Area: 1512 m^2

Irrigation: Localised irrigation method

Frequency: Alternate day irrigation

RBD of sweet corn trials

T1	T2	T3
R3	R7	R2
R2	R3	R7
R1	R5	R4
R5	R6	R3
R7	R1	R6
R6	R2	R5
R4	R4	R1



Biometric monitoring

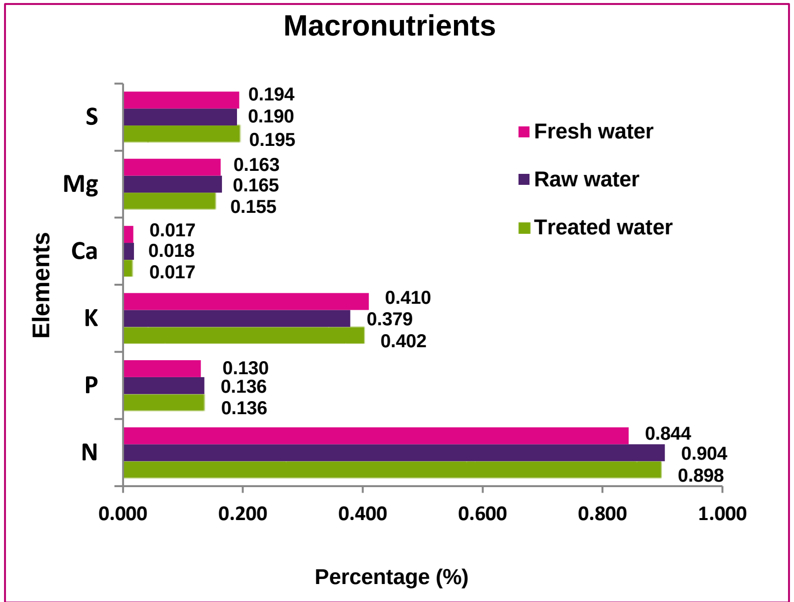
T1- cobs

T2- cob

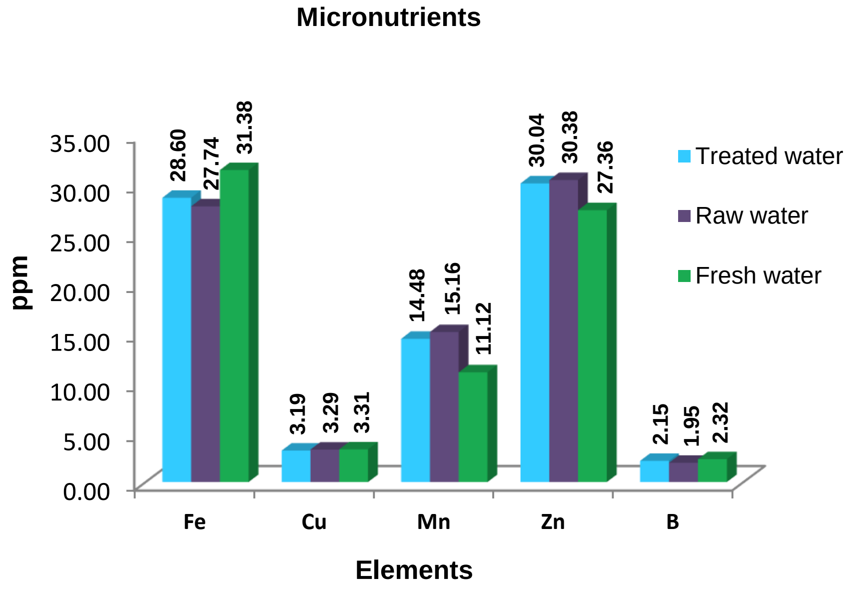
T3- cob

Damaged cobs

Sweet corn crop analysis



Uptake (%) of macronutrients by sweet corn in different treatments



Uptake (ppm) of micronutrients by sweet corn in different treatments

- Post harvest, the corn kernels from cobs of each treatment were separated and the samples were dried, ground and sieved.
- The samples were analyzed for N, P, K, Ca, Mg, S, Fe, Mn, Zn, and Cu on dry weight basis using auto-analyzer, atomic absorption spectrometer and ICP-AES with respect to the parameters.
- Irrigating sweet corn with the bio-treated, anaerobic treated distillery effluent and fresh water showed no significant difference in the uptake of macro and micronutrients.
- However, the crop analysis of corn kernels showed that the %uptake of elements was lower than the sufficiency range which conveys that it won’t be harmful or toxic to itself, animals or human.

Experiments to demonstrate reuse of treated water

Halophyte cultivation using bio-treated wastewater

Crop: Halophyte

Species: ***Sesuvium portulacastrum* & *Suaeda maritima***

Plantation: 23 Sept 2014

Soil: Clay soil

Treatment: T1 bio-treated distillery effluent

T2 Anaerobic treated distillery effluent

Area: 200 m^2

Irrigation: Localised irrigation method

Frequency: Alternate day irrigation

Biometrics	*Sesuvium portulacastrum*		*Suaeda maritima*	
	T1	T2	T1	T2
Height/ length (cm)	200	60	112	90
Circumference (m)	9.5	1.14	5.2	4

- Field trials indicate both species survive and grow luxuriantly in bio-treated distillery effluent
- Proposed to conduct detailed studies to explore phyto-remediation potential through CWL
- Soil reclamation and phyto-remediation
- Futuristic research is on going across the globe
- Economic values: Food, fodder, bio-fuel, edible oil, bio-salt
- MSSRF is establishing genetic garden of halophytes

Summary

- The whole treatment set up has a cumulative role in treating distillery effluent when they are integrated sequentially
- Bacterial treatment enhanced pH and melanoidin degradation which enabled penetration of sunlight contributing for adaption and growth of algae
- Active uptake mechanism of algae helps in the removal of inorganic contaminants such as SO_4^{2-} (sulphate), $NH^+{}_4$ (ammonia), $NO^-{}_2$ (nitrite), $NO^-{}_3$ (nitrate), PO_4^{2-} (phosphate) and Na^+ (sodium) ions.
- The available of sunlight for algal growth is an indicator of the reduction of melanoidin.
- Since the algal treatment is after the bacterial treatment, the electrons from bacterial metabolism are taken up by algae for photosynthesis and carbon fixation which ultimately pumps out oxygen.
- Hence, removal of organic, inorganic contaminants by adsorption, uptake, sedimentation and supply of oxygen by algae reduces the TDS, TSS, COD, and BOD in the effluent.
- Constructed wetland with halophytes play an important role in the removal of salinity which has to be studied in detail
- Using treated effluent in sweet corn cultivation with better yield shows a promising potential for reuse
- Luxuriant growth of halophytes in treated water suggests that the halophytes can be used to reclaim saline lands


Thank you