Journal of Algal Biomass Utilization
J. Algal Biomass Utln. - Copyright © PHYCOSPECTRUM
ISSN: 2229 – 6905

Application of micro algal technology to handle effluents with high TDS: R/O reject management at a textile industry – a pilot study

Anuanandhi K, Suganya M and V Sivasubramanian

Phycospectrum Environmental Research Centre (PERC), 132 A K Block, 7th Main Road, Anna Nagar, Chennai 600040, INDIA.

Abstract

R/O reject management and handling of high TDS industrial effluents is a challenge. Phycoremediation can provide an effective alternative to MEE. The present study was done in pilot scale (5 KL) at a textile industry site in Pune, India by successfully installing an evaporation system based phycoremediation plant and the results are encouraging. The study was conducted for a period of 4 months by continuous addition of effluent into the system and monitoring evaporation rate and TDS. The system got stabilized within a period of 2 months and was stable.

Keywords: R/O reject, High TDS, micro algae, Phycoremediation, textile industry

Introduction

Phycoremediation is defined as the use of either macro-algae or micro-algae for the removal or biotransformation of pollutants, including nutrients and xeno-biotics from wastewater. Micro-Algae refer to unicellular, *green* micro-organisms, capable of growing in extremely harsh and difficult environments by taking in carbon-dioxide from the environment and giving out oxygen through photosynthesis. Their use for wastewater treatment had been largely untapped until a few years ago. Wastewater Treatment using Micro-Algae has a variety of advantages over conventional systems (Sivasubramanian, 2016). Phycospectrum Environmental Research Centre (PERC), Chennai, India, has been developing and implementing this technology in various industries in India and abroad for the past two decades (Sivasubramanian, 2015). World's First large scale Phycoremediation plant was installed in 2009 by PERC at SNAP Industry, Tamilnadu, India which is handling high TDS effluent with a zero discharge (Sivasubramanian, 2009). One of the important applications of phycoremediation technology is its role in handling high TDS effluents like R/O rejects which are conventionally treated with Multiple effect evaporators (MEE). MEEs are very expensive and energy intensive and end up in huge amount of hazardous solid waste which needs to be disposed. By implementing algae based evaporation technology we can avoid MEE and reduce opex to a great extent and above all reduce solid waste generation completely or even if a small amount of solid waste is generated it will be non-toxic and very easy to dispose (Table 1). Valuable biomass generated can be utilized as feedstock for making products (Sivasubramanian, 2019).

Table 1. Comparison between MEE and Micro-Algae based high TDS management for a 50 M3/day plant.

Particular	Algae	MEE
OPEX (Evaporation) @ 330 working days	Rs. 0.17 cr/year @ Rs. 100/m3 @330 working days	Rs. 1.15 Cr/year @Rs. 700/m3 @ 330 working days
Maintenance	Requires minor maintenance to clean up holes of inlet header.	Requires Regular maintenance.
Rain Water Harvesting	Simultaneous Rain Water Harvesting; To provide source for 5000 m3 of fresh water annually.	Not Applicable
Sludge Formed	Significant reduction in quantity. < 500 kgs per day of non-hazardous algae sludge.	1.5 tons of inorganic sludge per day. @Rs. 3/kg of disposal cost, amounts to > Rs. 15 lacs per annum.
Carbon	A 50 M3/day of micro-algae based ZLD plant will absorb CO2 equal to 70 – 80 full grown trees annually.	A 50 M3/day MEE running on firewood will consume 1200 full grown trees, 25M high and 30 cm in diameter annually.

The present study is aimed at developing an algae based evaporation technology to handle high TDS R/O reject from a textile industry at pilot scale.

Materials and Methods

Micro algae and growth medium

Micro algal strains employed in the present investigation were obtained from the Culture Collection of Phycospectrum Environmental Research Centre (PERC), Chennai, India and maintained in Bold Basal Medium (Nichols and Bold 1965).

Industrial Effluent

R/O reject from a textile industry, situated in Pune which manufactures carpets, was obtained. This industry has a dye house, which uses water to dye the yarn. After dyeing this colored water is treated in an in-house 'Effluent Treatment plant', which removes all the harmful dyes and chemicals from the water. The outlet goes into their R/O system to recycle the water. But after treating with R.O system, a significant amount of high TDS R/O reject is generated. To dispose this high TDS water is a major problem for the company. The company has contemplated setting up a MEE, but because of several disadvantages associated with a MEE has refrained from doing so. The R/O reject has a pH of 6 – 8.5 and a TDS of around 20,000 ppm.

Results and Discussion

Lab screening

Laboratory screening of the R/O reject from the textile industry was done by inoculating micro algae cultures (*Chlorococcum vitiosum Chlorococcum humicola, Chroococcus turgidus, Dactylococcopsis raphioides, Desmococcus olivaceus, Scenedesmus dimorphus, Scenedesmus incrassatulus, Oocystis borgei* and

Chlorella vulgaris) into raw effluent and incubated under light. Cell counts were done and division rates were calculated. The results are given in Fig 1.

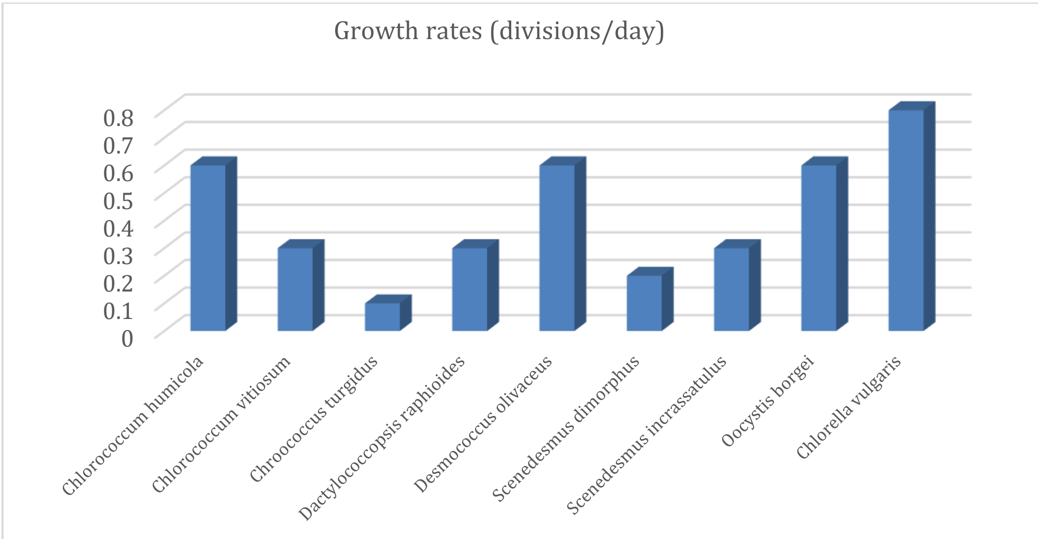


Fig 1. Growth rates of various micro algae grown in R/O reject from a textile industry

The best performing micro algae were selected and made into a consortium and taken to the filed for pilot trials

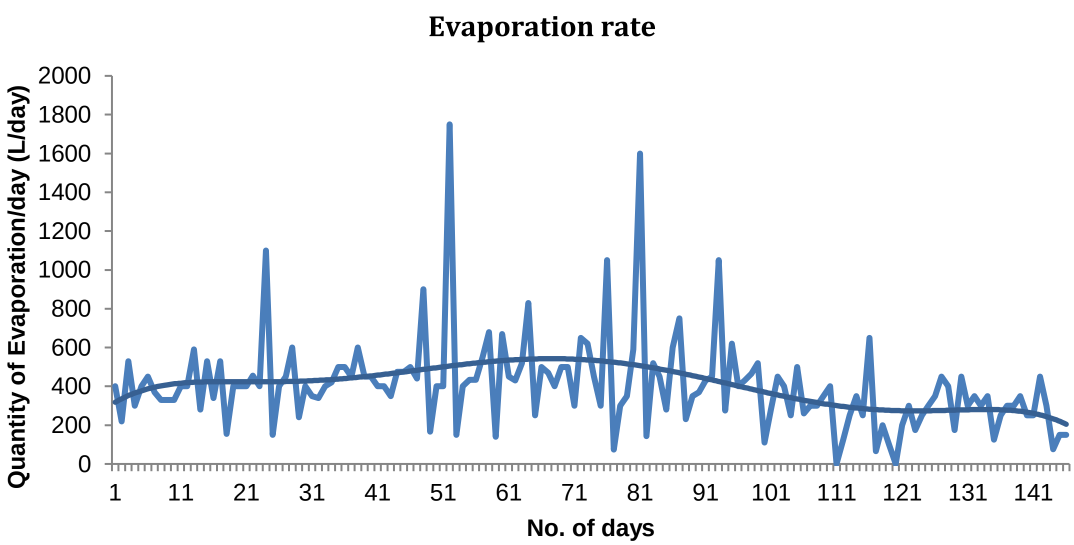
Field trial: Pilot tank

An erect tank system with an evaporation surface which also functions as illumination panel was installed at the factory site. A 60 M^2 corrugated cement sheet was erected and was covered by plastic sheet to prevent leakages. A tank of 5000 L was used to store the algae buffer culture. A recirculation pump of 2.5 M^3/h was used to re-circulate the algal culture onto the corrugated surface. Harvesting of the algae was manual and no external harvesting mechanism was present. Fig 2 shows the slope tank consisting of reservoir and evaporation surface.

Fig 2 Slope tank system for evaporation of R/O reject

Fig 3 The surface of the slope showing luxuriant growth of algae

The effluent loaded with micro algae consortium was circulated over the slope surface with a pump and evaporation rate and TDS were monitored. The results a given in Fig 4 and 5. The results show that an average of 400 L per day was observed for a period of four months for an evaporating surface of 60 M^2 totally 6.5 mm which included 2 months of rain fall. This efficiency is good. The system did not produce any solid wastes and the biomass when analyzed showed 20% salts. The biomass analysis showed no toxic property and can be used as a feedstock for composting and production of bio-fertilizer (Table 2).

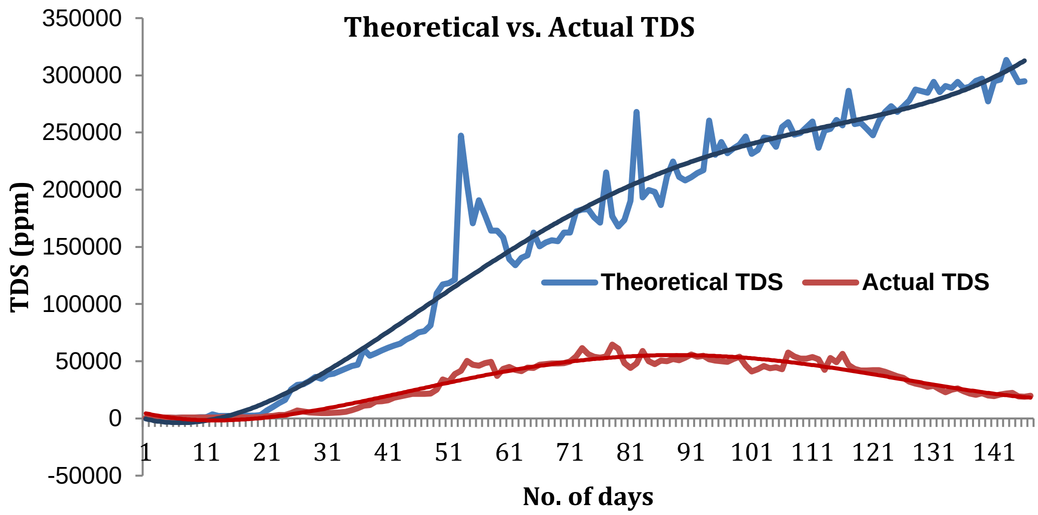


Average evapo-transpiration rate recorded over 4 months	: 405 L/day
Total Surface Area Used	: 60 M2
Average evaporation (including 2 months rainfall)	: 6.75 MM

Fig 4. Evaporation trend over a period of 4 months

TDS trend and stabilization of the evaporation system

Every day an average of 400 L of raw R/O reject with a TDS of around 20,000 was added and evaporated into a buffer volume of 5 KL. The TDS increased to about 48000 and stabilized and later showed a decrease and dropped below 20000 which shows the efficiency of the system. The blue line in Fig 5 shows the theoritical TDS which varied beween 20000 initially and about 350000 at the end of 4 months of evaporation which means more than 300000 of TDS disappeared and we could do a mass balance taking into consideration of dry biomass harvested plus the 30% of salt remaining in the agae biomass (Table 3).



Actual TDS in tank varies between 20000 ppm to 60000 ppm. Theoretical TDS based on actual TDS load is around 350000 ppm.

Fig 5. TDS trend and stabilization of the system over a period of 4 months

Table 2. Analysis of biomass harvested from the treatment tank

Parameters	Results	Units
Energy value	195	Kcal/100g
Protein	20.1	g/100g
Carbohydrate	25.7	g/100g
Fat	1.3	g/100g
Moisture	4.3	g/100g
Total ammoniacal nitrogen	3.2	g/100g
Sulphate	29660	mg/Kg
Calcium	12025	mg/100g
Magnesium	1359	mg/100g
Sodium	8704	mg/100g
Potassium	1078	mg/100g
Copper	1.0	mg/100g
Zinc	5.1	mg/100g
Iron	100	mg/100g
Chromium	3.62	mg/100g

Table 3. Summary of Algae Biomass Compositional Analysis

Components	March	April	May	June	Average
Sodium	9.1%	8.7%	6.2%	10.3%	8.6%
Potassium	7.2%	1.1%	1.2%	1.5%	2.7%
Calcium	10.9%	12.0%	9.4%	8.1%	10.1%
Magnesium	2.0%	1.4%	0.7%	0.6%	1.1%
Sulphate	4.0%	3.0%	11.4%	10.8%	7.3%
Total Salts	**33.2%**	**26.1%**	**28.9%**	**31.4%**	**29.9%**

Mass Balance

Based on the evaporation volume and volume of raw effluent added every day and the total volume of effluent maintained in the reaction tank and the biomass generated we could arrive at a mass balance. The average amount of salts remaining in the biomass (30%) plus the amount disappeared shows a balance and it also confirms the efficiency of the system. .

How the technology works?

1. Depending on the nature of the effluent, the consortium of species which can adapt, grow and remediate the RO Reject effluent was selected.
2. Along with the species, the micro-nutrients and organic hormones which were found to be necessary for the growth of the algae was identified.
3. Algal consortium was grown separately in 20 L bottles and then transferred into the 5000 L tank where it was cultured for a month.
4. Once the algal population had reached the desired cell count, fresh RO reject was gradually added.
5. Since no outlet is present, only the amount which is evaporated is added daily into the tank.
6. The theoretical TDS is calculated based on the actual TDS going into the tank.
7. Algae performs the following functions:
   a) Neutralizes acidic or alkaline pH in the inlet effluent.
   b) Facilitates better evaporation of water.
   c) Algae do not allow the TDS to move beyond a certain limit. This is quite evident from the fact that whereas the theoretical TDS keeps on increasing, the actual tank TDS reaches almost a steady state after some time.
8. Fresh algae with a 30% salt content is harvested from the system. When diluted with irrigation water this could be an efficient bio-fertilizer.

Conclusion

Algae evaporation technology to handle high TDS water without generating any solid waste is a boon to industries to reduce operation costs and reduce sludge formation and to avoid the most expensive and energy intensive MEE. Industries which reuse the water through R/O process can also depend on this technology to manage the R/O reject very effectively. Perc, Chennai has been improving this process by integrating PMF enclosure technology which is ecofriendly and very effective.

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eISSN: 2229 – 6905

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