Algal technology for effective reduction of total hardness in wastewater and industrial effluents

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Abstract

Algae based remediation technology can provide an excellent solution for pollution problems. The present paper deals with application of algal technology (Phycoremediation) to reduce total hardness in waste waters and industrial effluents. Water samples from a few selected lakes and ponds of Kancheepuram district, Tamilnadu and industrial effluent samples from a soft drink manufacturing industry at Ahmedabad, textile dyeing industries from Tamilnadu and Ahmedabad were employed in the present investigation. Micro algal cultures obtained from VIAT culture collection were inoculated into the effluent samples both at laboratory scale and pilot scale level. A significant reduction in total hardness was observed in all the water samples. From the results obtained with both natural waters and industrial effluents it is evident that phycoremediation technology can effectively handle hardness and make the water reusable and industrial effluents become more suitable for R/O recycling.

Introduction

Hard water has high concentrations of Ca2+ and Mg2+ ions. Hardness is reported in terms of calcium carbonate and in units of milligrams per litre (mg/L). Hard water is generally not harmful to one's health but can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment that handles water. In domestic settings, the hardness of water is often indicated by the non-formation of suds when soap is agitated in the water sample. Hardness in water is defined as concentration of multivalent cations such as Ca^{2+} and Mg^{2+}. Hard water also forms deposits that clog plumbing. Calcium and magnesium carbonates tend to be deposited as off-white solids on the surfaces of pipes and the surfaces of heat exchangers.

The term hardness total hardness is used to describe the combination of calcium and magnesium hardness. However, hardness values are usually quoted in terms of CaCO3 because this is the most common cause of scaling. The standard classifications are given below (Droste, 1997):

- Hardness mg/L as $CaCO_3$
- Moderate 60-120
- Hard 120-180
- Very hard more than 180

Water softeners operate on the ion exchange process (specifically a cation exchange process where ions are exchanged). The hardness minerals (positively charged Calcium and Magnesium ions) attach themselves to the resin beads while sodium on the resin beads is released simultaneously into the water. Softened water is not recommended for watering plants, lawns, and gardens due to its elevated sodium content. Bioremediation can be a better alternative technology to avoid usage of chemicals.

Algae based remediation technology can provide an excellent solution for pollution problems.Vivekananda Institute of Algal technology (VIAT), Chennai, a pioneer in algae based technology to treat industrial effluents has implemented phycoremediation technology in a number of industries in India (Sivasubramanian, 2006; Kamaleswari *et al* 2007; Arti Narasimhan *et al* 2008; Sivasubramanian *et al* 2009; Hanumantha Rao *et al* 2010; Sivasubramanian *et al* 2010; 2011; Hanumantha Rao *et al* 2011; Kamaleswari and Sivasubramanian 2011).

The present paper deals with application of algal technology (Phycoremediation) to reduce total hardness in waste waters and industrial effluents.

Materials and Methods

Micro algae and Media

Micro algae employed in the present investigation were obtained from Algal Culture Collection of Vivekananda Institute of Algal Technology (VIAT), Chennai. They were grown in Bold Basal medium (Nichols and Bold, 1965) and CFTRI medium (Venkataraman, 1985).

Water samples:

Water samples from a few selected lakes and ponds of Kancheepuram district, Tamilnadu and industrial effluent samples from a soft drink manufacturing industry at

Ahmedabad, textile dyeing industries from Tamilnadu and Ahmedabad were employed in the present investigation.

Pilot tank for effluent treatment

The pilot sloping pond was constructed in RCC and was designed with a dimension of 268 cm. (Length) x 238 cm. (Width) x 64 cm. (Depth) with a sloping angle (made of GI sheet) of the evaporating surface at 150. The dimension of the sloped area was 2.53 m2. The flow rate of the effluent was maintained at 59.6 L/day (litres per day). 1 cm of water in the tank equaled 63.7 L and the plant was run during the day for about 9 hrs.

Analysis of physic – chemical parameters was done following APHA Standard Methods (APHA. 1985)

Results and Discussion

Industrial effluents

Water samples were inoculated with micro algae obtained from VIAT, Chennai. Analysis of total hardness was done after 7 days incubation. Table 1 and Fig 1 show results of laboratory level treatment of effluent samples (1 and 2) from a soft drink manufacturing industry, Ahmedabad by employing *Chlorococcum humicola*. Algal treatment has reduced total hardness to about 71 % in both the samples. Ca^{2+} and Mg^{2+} were also reduced significantly. Table 2 and Fig 2 show Table 1 and Fig 1 show results of laboratory level treatment of effluent samples (1 and 2) from a soft drink manufacturing industry, Ahmedabad by employing *Chlorella conglomerata*. There was 63 to 74% reduction in total hardness. Ca^{2+} and Mg^{2+} were also reduced effectively by *Chlorella sp.*

Table 1 Effect of algal treatment on total hardness of effluent from soft drink manufacturing industry at Ahmedabad – Lab study using *Chlorococcum humicola*

Parameters	Effluent 1			Effluent 2		
	Initial	**Final**	**% reduction**	**Initial**	**final**	**% reduction**
Total Hardness (as Ca CO_3) mg/L	1220	360	**70.5**	1460	420	**71.2**
Calcium (as Ca) mg/L	320	81	**74.7**	368	96	**73.9**
Magnesium (as Mg) mg/L	101	36	**64.4**	129	43	**66.6**

Fig 1. Effect of algal treatment on total hardness of effluent from soft drink manufacturing industry at Ahmedebad – Lab study using *Chlorococcum humicola*

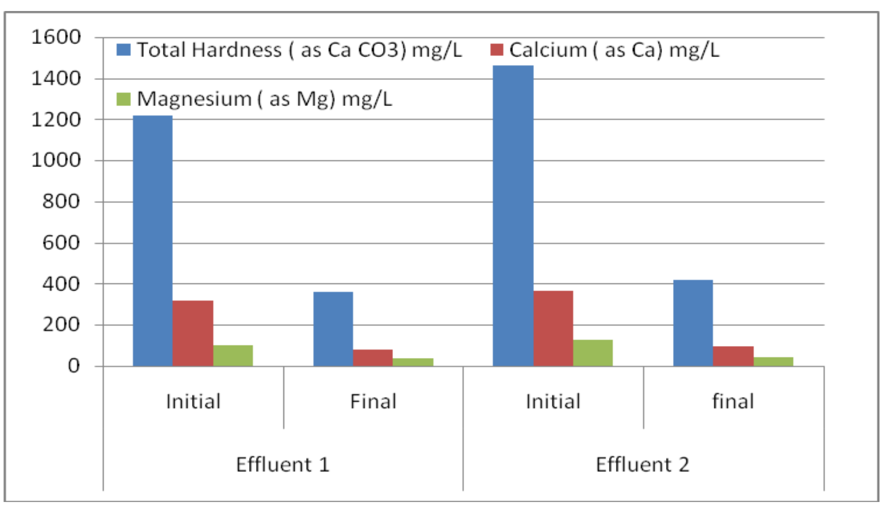
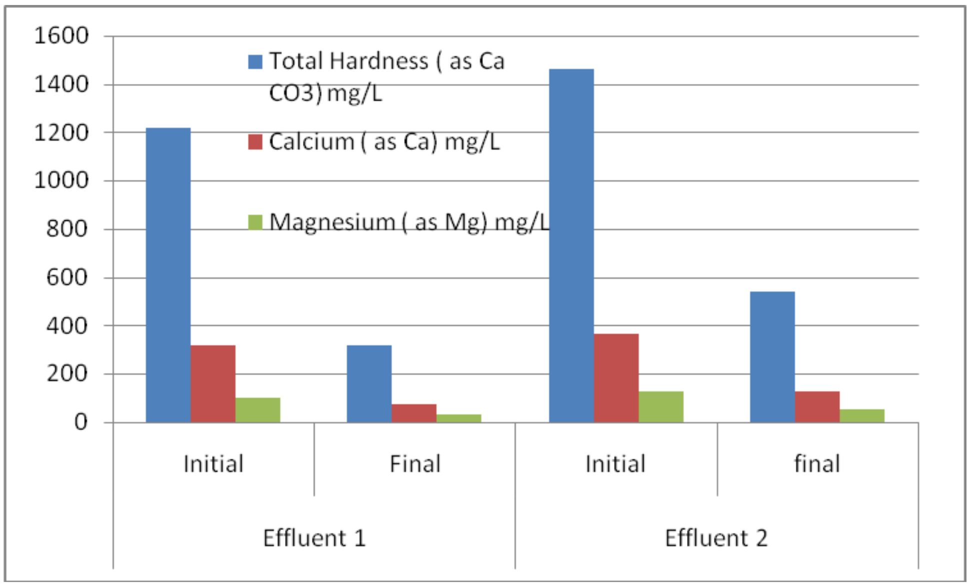


Table 2 Effect of algal treatment on total hardness of effluent from soft drink manufacturing industry at Ahmedabad – Lab study using *Chlorella conglomerata*

Parameters	Effluent 1			Effluent 2		
	Initial	Final	% reduction	Initial	final	% reduction
Total Hardness (as Ca CO_3) mg/L	1220	320	**73.8**	1460	540	**63**
Calcium (as Ca) mg/L	320	72	**77.5**	368	128	**65.2**
Magnesium (as Mg) mg/L	101	34	**66.3**	129	53	**58.9**

Fig 2. Effect of algal treatment on total hardness of effluent from soft drink manufacturing industry at Ahmedebad – Lab study using *Chlorella conglomerate*



Textile dyeing effluent from an industry from Tamilnadu and Ahmedabad were treated with micro algae at laboratory level as well as pilot scale level in the industry itself. The resutls are given in Tables 3 to 7 and Fig 3 to 6. Combined effluent from textile dyeing industry fromTamilnadu when treated with algae at laboratory total hardness was reduced to only 25%. But when the same effluent was treated with algae at pilot scale field level there was 87% reduction in total hardness. Similarly the dye bath effluent from this industry when treated at the field in pilot plant exhibited significant reduction in total hardness (84%).

Table 3. Effect of algal treatment on total hardness of combined effluent from textile dyeing industry at Tamilnadu – Lab study using *Chlorococcum humicola*

Parameters	Effluent (Combined)	Effluent treated with alga	% reduction
Total Hardness (as Ca CO_3) mg/L	875	650	25.71
Calcium (as Ca) mg/L	190	160	15.78
Magnesium (as Mg) mg/L	96	60	37.5

Fig 3. Effect of algal treatment on total hardness of combined effluent from textile dyeing industry at Tamilnadu – Lab study using *Chlorococcum humicola*

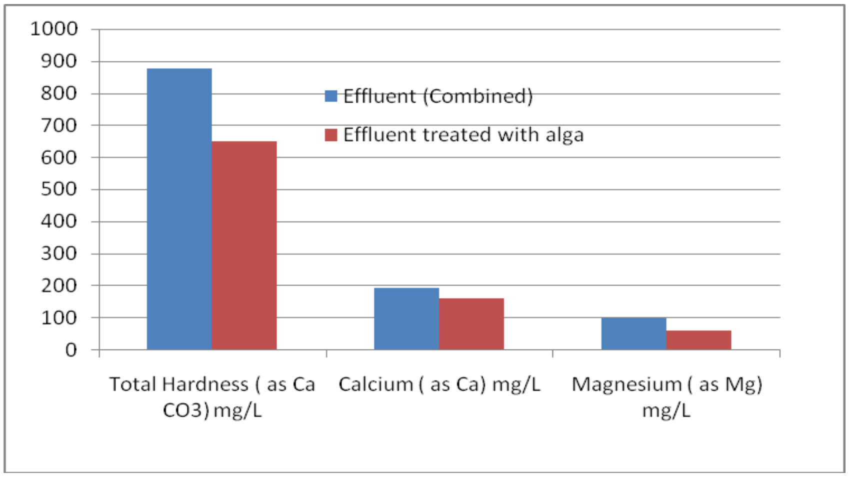


Table 4 Effect of algal treatment on total hardness of combined effluent from textile dyeing industry at Tamilnadu – Pilot field study using *Chlorococcum humicola*

Parameters	Raw combined effluent	Effluent treated with alga	% reduction
Total Hardness (as Ca CO_3) mg/L	875	110	**87.42**
Calcium (as Ca) mg/L	190	24	**87.36**
Magnesium (as Mg) mg/L	96	12	**87.5**

Fig 4. Effect of algal treatment on total hardness of combined effluent from textile dyeing industry at Tamilnadu – Pilot field study using *Chlorococcum humicola*

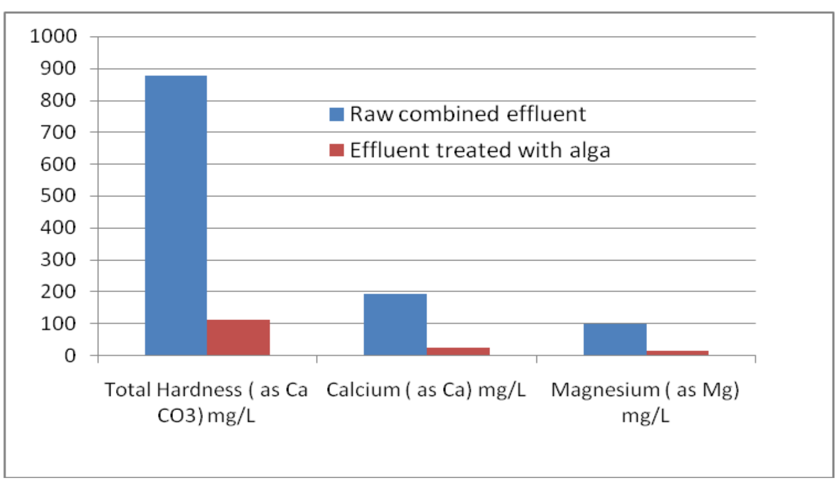


Table 5. A comparsion of laboratory treatment and field level pilot scale treatment on the reduction of hardness in combined effluent from textile dyeing industry at Tamilnadu

Parameters	Raw combined effluent	Effluent treated with alga (lab)	Effluent treated with alga (field)	% Reduction (lab)	% Reduction (field)
Total Hardness (as Ca CO_3) mg/L	875	650	110	25.71	**87.42**
Calcium (as Ca) mg/L	190	160	24	15.78	**87.36**
Magnesium (as Mg) mg/L	96	60	12	37.5	**87.5**

Table 6. Effect of algal treatment on total hardness of dye bath effluent from textile dyeing industry at Tamilnadu – Pilot scale study employing *Chlorococcum humicola*.

Parameters	Dye bath effluent	Dye bath Effluent treated with alga (field)	% reduction
Total Hardness (as Ca CO_3) mg/L	800	575	**83.75**
Calcium (as Ca) mg/L	180	130	**27.77**
Magnesium (as Mg) mg/L	84	60	30

Fig 6 . Effect of algal treatment on total hardness of dye bath effluent from textile dyeing industry at Tamilnadu – Pilot scale study employing *Chlorococcum humicola*.

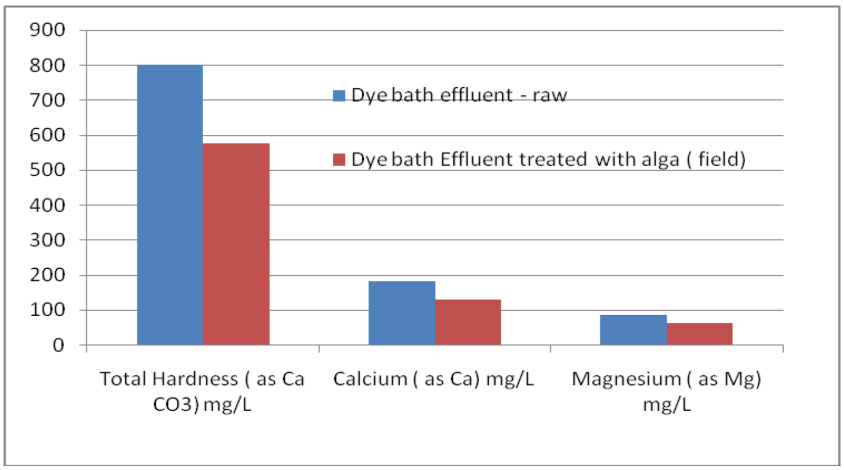


Table 7. A comparsion of laboratory treatment and field level pilot scale treatment on the reduction of hardness in dye bath effluent from textile dyeing industry at Tamilnadu

Parameters	Dye bath effluent	Dye bath Effluent treated with algae (lab)	Dye bath Effluent treated with algae (field)	% reduction in lab	% reduction from field
Total Hardness (as Ca CO_3) mg/L	800	1325	575	0	**83.75**
Calcium (as Ca) mg/L	180	290	130	0	27.77
Magnesium (as Mg) mg/L	84	144	60	0	30

Water samples from lakes and ponds

Water samples collected from selected lakes (with hardness above 2000 mg/L) and ponds of Kancheepuram district, Tamilnadu were inoculated with a mixture of micro algae, *Chroococcus turgidus, Cylindrospermum majus, Nostoc muscorum, Chlamydomonas elegans, Scenedemus bijugatus, and Tetraedron caudatum.* After 7 days incubation total hardness, calcium and magnesium were analyzed and the results are presented in Tables 8 and 9 and Figs 8 and 9. In all the treatments there was significant reduction in total hardness. The lakes and ponds with higher total hardness exhibited correspondingly higher reduction of hardness. Lakes showed very high total hardness values well above the permissible limits. Algal remediation has brought the values down to permissible levels (<600). There was a significant reduction in Mg2+ values when treated with algae (37 to 90% in lake water samples). Although the pond water samples did not exhibit higher total hardness values algal treatment has reduced the values to 2 digits. This technology will yield much better results at the large scale treatment systems.

From the results obtained with both natural waters and industrial effluents it is evident that phycoremediation technology can effectively handle hardness and make the water reusable and industrial effluents become more suitable for R/O recycling. Algal technology can be an ecofriendly, cost effective alternative to chemical technology which is too expensive and results in pollution.

Table 8. Effect on algal treatment on total hardness of water samples from selected lakes of Kancheepuram District, Tamilnadu – Lab study

Parameter (mg/L)	Lake 1		Lake 2		Lake 3		Lake 4	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Total Hardness (mg/L)	1900	540 **(71.5%)**	4100	540 **(86.8%)**	6500	400 **(93.8%)**	1440	479 **(66.7%)**
Calcium (mg/L)	472	406 (14%)	164	128 (22%)	1820	112 (93.8&)	336	266 (21%)
Magnesium (mg/L)	173	75 (56.6%)	346	53 (85%)	468	48 (90%)	144	91(37%)

Fig 8. Effect on algal treatment on total hardness of water samples from selected lakes of Kancheepuram District, Tamilnadu – Lab study

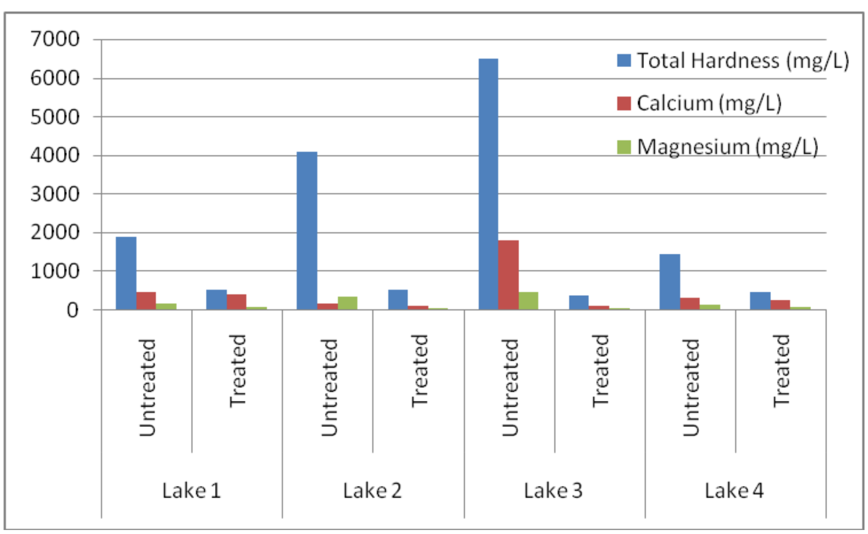
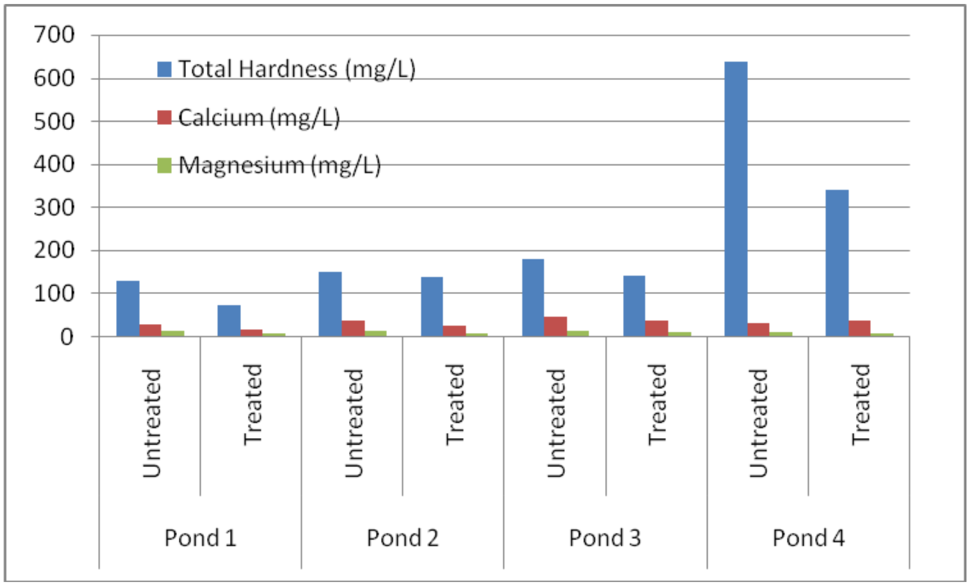


Table 9. Effect on algal treatment on total hardness of water samples from selected ponds of Kancheepuram District, Tamilnadu – Lab study

Parameters	Pond 1		Pond 2		Pond 3		Pond 4	
	Untreated	Treated	Untreated	Treated	Untreated	Treated	Untreated	Treated
Total Hardness (mg/L)	130	75	152	138	180	142	638	341
Calcium (mg/L)	29	19	38	26	48	39	33	38
Magnesium (mg/L)	14	10	14	10	14	12	13	10

Fig.9. Effect on algal treatment on total hardness of waster samples from selected ponds of Kancheepuram District, Tamilnadu – Lab study



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