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Comparative Account On Phycoremediation Of Industrial Effluent From National Thermal Power Corporation (Ntpc) Using Four Indigenous Microalgae.

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ABSTRACT

The present investigation focuses on the bioremediation of waste water by using various microalgae like Scenedesmus dimorphus, Oscillatoria willei, Chroococcus minutus and Lyngbya confervoides. For the study the industrial waste water samples and algal samples were collected from Kayamkulam Lake near NTPC, Alappuzha district, Kerala. Water samples were analysed for 12 Physico- Chemical parameters such as pH, Alkalinity, DO, Chloride, Total Hardness, Calcium, Phosphate, Sulphate, Nitrate, BOD, COD, Silicate and Heavy metals using standard methods. Algae were analysed quantitatively and qualitatively. Four most abundant and pollution tolerant taxa were isolated from the effluent and cultured in BBM and ATCC growth media. These cultures are used for the bioremediation of the above mentioned Physico-chemical parameters. The percentage reduction of each parameter was recorded from the samples treated with these algae. The percentage reduction attained with S. dimorphus was Alkalinity (46%), Phosphate (86.14%), Nitrate (77.64%), Sulphate (33.16%), Chloride (56%), Iron (42.8%), COD (71.23%) and BOD (89.72%). In case of O. willei, the percentage reduction observed was Alkalinity (49%), Phosphate (79%), Nitrate (71%), Sulphate (66.7%), Silicate (72%), Iron (53%), COD (76%) and BOD (66%). The percentage reduction with the treatment of L.confervoides was Alkalinity (43%), Phosphate (77%), Nitrate (71%), Sulphate (59.6%), COD (68%) and BOD (62%) and in case of C. minutus, the reduction noticed was Alkalinity (56%), Phosphate (92%), Nitrate (68%), Sulphate (52.9%), Silicate (89%), Chloride (52%), COD (51%) and BOD (52%) The results were discussed in the text.

KEYWORDS: Phycoremediation, Water Pollution, NTPC

INTRODUCTION

The industrial sectors and the most power plants are located near aquatic bodies to obtain large amounts of water for manufacturing processes or for cooling equipment. However unplanned industrial growth, use of out-dated technologies and lack of proper policies are usually

responsible for the ending up of both untreated and partially treated waste water in these aquatic habitats. This waste water usually contains chemicals, which contributes high Biochemical oxygen demand (BOD), and nutrient loading of water bodies [(1)]. The conventional method of chemical treatment of waste water can only reduce the concentration of pollutants to a limited extent. In this context biological treatment is more reliable as it is cost effective and economical than mechanical or chemical treatment processes. The potential of biological organisms for environmental cleanup has been studied by many researchers [(2), (3), (4), (5), (6), 7)]. The concept of Phycoremediation attained special mention as it showed great potential to complement our traditional waste water treatment processes.

Phycoremediation is nothing but the use of macro- or micro- algae for the reduction or biotransformation of pollutants including nutrients and harmful chemicals from waste water [(8)]. Microalgae usually possessed high growth rates with high biomass production and it can remove pollutants from waste water and produce bio- fuels .So it is worthy to screen and develop the efficient algae for bioremediation of contaminated water. Keeping this fact an attempt has been made to evaluate the potentiality of selected species of algae in the abatement of pollution.

MATERIALS AND METHODS

The industrial waste water and algal samples were collected from Kayamkulam Lake near NTPC Alappuzha district, Kerala. The waste water samples were analysed for 12 Physico- Chemical parameters like pH, Total Alkalinity, DO, Chloride, Total Hardness, Calcium, Phosphate, Sulphate, Nitrate, BOD, COD, Silicate and five Heavy metals viz., Iron, Lead, Zinc, Cadmium and Copper before and after algal treatment following the standard methods [(9)]. Among the algae four species viz. S.dimorphus, O. willei, L. Confervoides and C.minutes were found to be the dominant algae with good survival capacity compared to other algae. In order to evaluate and compare the potentiality of these algae in waste water treatment two experimental set up were made; one set of water samples without algae (control) and other with culture of algae. 2 ml of uniform suspension of cultured algal strains (9 days old culture) were transferred in to a flask containing 200 ml of waste water sample. The experimental setup kept under controlled environmental conditions about 20 days. Samples were periodically analysed for the above mentioned Physico- Chemical parameters

RESULT AND DISCUSSION

Physico-chemical parameters of industrial waste water were analysed. The results obtained after the treatment with algal species such as S.dimorphus, O. willei, L.confervoides and C. minutus are given in Tables- 1-4. These selected indigenous algal species were found to be effective degraders of pollutants from industrial waste water.

pH of the effluent has been enhanced from the initial 5.67 to 6.34 (11.81%) by S.dimorphus. pH has been changed from 5.67 to 6.39 by O. willei. L. Confervoides and C. minutus drifted pH from 5.67 to 6.19 and 6.14 respectively. Algal treatment with all the four taxa has significantly increases the pH level of waste water. Some authors have also made similar reports [(10), (11)]. The analysis of variance (ANOVA) of pH showed a significant variation between days ($P<0.01$) among all the four algae. The alkalinity of the effluent was reduced from 96 mg/l to 51.84 mg/l on 20^{th} days of treatment by S.dimorphus. Similar observation was also made by using S.obliquus [(12)]. O. willei and L. confervoides reduced the total alkalinity from 96 mg/l to 48.96 mg/l and 54.72 mg/l respectively on 20^{th} days of treatment. C. minutus showed comparatively

better performance than the other algae as it showed 56% reduction in total alkalinity. The DO of the effluent increased when treated with cultured algae. The initial level of 2.3 mg/l of the DO was increased up to 3.82 by Scenedesmus dimorphus. In the case of O. willei the DO is increased from 2.3 mg/l to 3.71mg/l. L. Confervoides and C. minutus improved the DO content from 2.3 mg/l to 3.72 and 3.60 mg/l respectively. The analysis of variance (ANOVA) of DO showed significant variation among days ($P<0.01$) in all the four algae. The Duncan's post hoc multiple comparison test among days also showed significant variation. Chloride content is regarded as one of the major pollutants in effluents and is considered difficult to be removed by our conventional biological treatment process. 50% of chloride reduction using Chroococcus turgidus was reported [(3)] .The industrial effluent had a high chloride level of 346 mg/l and it was reduced up to 152.2 mg/l by S.dimorphus. O. willei and L. confervoides reduced chloride 42% and 48% respectively on 20th days of treatment. In the case of C. minutus it reduced chloride from 346 mg/l to 166.08 mg/l. Duncan's post hoc multiple test analysis and analysis of variance (ANOVA) of chloride showed a significant variation among days ($P<0.01$) Algal treatment reduced the Total Hardness (TH) significantly. S.dimorphus reduced the initial TH of 121 mg/l to 106.1 mg/l. The initial TH of 121 mg/l of TH had reduced up to 56.8 mg/l by O. willei and 61.7 mg/l by L. confervoides. C. minutus showed 46% of hardness reduction. The analysis of variance (ANOVA) of Hardness showed significant variation among days ($P<0.01$).

The calcium content of the effluent was 96 mg/l and it had reduced to 84.1 mg/l by S.dimorphus. O. willei showed maximum reduction, as it changed the initial concentration of 96 mg/l to 59.52 mg/l. L. confervoides and C. minutus also showed marked reduction of 29% and 21% respectively on 20th days of treatment. The analysis of variance (ANOVA) of calcium showed a significant variation among days ($P<0.01$) in all the four algae. The phosphate removal by microalgae during remediation is due to the utilization of phosphorous for growth [(13)] .Here the initial phosphate concentration was 4.56 mg/l and it is much more beyond the permissible limit [(14)]. Among the four algae C. minutus showed excellent removal capacity of phosphate as it reduced up to 0.36 mg/l (92% removal) of phosphate from waste water. Species of Scenedesmus are also widely studied for the nutrient removal [(15)] .Here S. dimorphus reduced the initial phosphate level to 0.63 mg/l. O. willei and L. confervoides reduced initial level of 4.56 mg/l of phosphate to 0.95 mg/l (79%) and 1.04 mg/l (77.19%) respectively.

The concentration of sulphate has been decreased from 79 mg/l to 52.80 mg/l in the effluent when it is treated with S.dimorphus, whereas O. willei and L. confervoides reduced it from 79 mg/l to 26.3 mg/l and 31.9 mg/l respectively. C. minutus reduced the effluent sulphate from 79 mg/l to 37.20 mg/l. the analysis of variance (ANOVA) of sulphate showed significant variation among days ($p<0.01$) in all the four algae. Some algae showed superb potential for nitrogen fixation [(16)]. Here the initial nitrate level of 5.6 mg/l had reduced to 1.25 mg/l by S.dimorphus, 1.62 mg/l by O. willei, 1.51 mg/l by L. Confervoides, and 1.79 mg/l by C. minutus. The Biochemical Oxygen Demand (BOD) is the amount of oxygen required by the aerobic microorganisms present in the sample to oxidize the organic matter. Here the maximum BOD reduction was observed on 20th day of treatment at all the four samples. S.dimorphus shows higher performance of BOD reduction than the other algae used in the study. That is it reduced the BOD from 8.76 mg/l to 0.90 mg/l. O. willei had reduced the BOD from 8.76mg/l to 2.97 mg/l. L. Confervoides and C. minutus reduced 8.76 mg/l to 3.32 mg/l and 4.20 mg/l. Analysis of variance (ANOVA) of BOD showed significant variation among days ($p<0.01$) in all the four algae.

The initial COD of waste water was 216.4 mg/l and all the four algae showed comparatively better COD reduction. Algae had reduced more than 99% of silica reduction [3]. The analysis of variance (ANOVA) of COD showed a significant variation among days ($p<0.01$) in all the four algae. The industrial effluent had high initial silica and the maximum percentage reduction of 89% reduction was shown by C.minutes. It changed the initial concentration of 17.3 mg/l to 1.90 mg/l on 20th days of treatment. Other three algae also showed good performance that is S.dimorphus had changed from 17.3 mg/l to 8.44 mg/l, O. willei had reduced from 17.3 mg/l to 8.44 mg/l and L. confervoides had drifted from 17.3 mg/l to 8.44 mg/l. Iron content of the effluent was recorded 0.39 mg/l and it was reduced to 0.22 mg/l, 0.18 mg/l, 0.20 mg/l and 0.16 mg/l by S. dimorphus, O. willei, L. confervoides and C. minutus respectively. The effluent is characterized by the presence of heavy metals like Lead, Zinc Cadmium and Copper. Algae are being most successfully used micro- organism to remove the heavy metals from waste water because algal strains can survive in high concentrations of heavy metals and other toxic pollutants [17]. Here all the selected algae showed fairly good performance in heavy metal removal.

Here all the four algae showed fairly good performance in the bioremediation of most of the selected Physico chemical parameters. Hence, they can be used in the industrial sectors for the treatment of waste water.

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Table 1 Physico-chemical parameters of NTPC waste water by using Scenedesmus dimorphus

Parameters *	Mean ± SD					F-value (p-value)
	1 day	5 days	10 days	15 days	20 days	
pH	5.67[a]±0.01	5.97[b]±0.01	6.02[c]±0.01	6.03[c]±0.01	6.34[d]±0.03	840.2 (<.01)
Total Alkalinity (TA)	96.33e±0.29	87.43d±0.42	79.37c±0.15	66.57b±0.32	51.53a±0.31	9777.3 (<.01)
Dissolved Oxygen (DO)	2.33a±0.06	2.43a±0.31	2.9b±0.1	3.4c±0.26	3.86d±0.03	35.21 (<.01)
Chloride	346.33e±0.29	296.67d±0.25	231.6c±0.2	176.5b±0.2	152.53a±0.15	39402.1 (<.01)
Hardness	121.33e±0.29	119.47d±0.25	117.5c±0.36	112.5b±0.46	106.53a±0.32	909.9 (<.01)

Calcium	96.33e±0.29	94.6d±0.1	90.57c±0.42	87.5b±0.2	84.4a±0.36	832.1 (<.01)
Phosphate	4.56e±0.02	2.86d±0.02	2.28c±0.01	0.86b±0.01	0.62a±0.01	39989 (<.01)
Sulphate	79.33e±0.29	73.83d±0.21	66.5c±0.36	59.47b±0.35	52.57a±0.25	3907.5 (<.01)
Nitrate	5.65e±0.05	3.84d±0.02	2.65c±0.01	1.58b±0.01	1.25a±0.03	12121.2 (<.01)
BOD	8.76e±0.01	7.05d±0.02	5.38c±0.02	1.17b±0.12	0.93a±0.03	12284 (<.01)
COD	216.33e±0.12	134.53d±0.25	102.7c±0.2	67.87b±0.02	62.23a±0.02	50384 (<.01)
Silicate	17.34e±0.07	15.6d±0.44	11.43c±0.25	9.43b±0.35	8.47a±0.21	528.2 (<.01)
Iron	0.4c±0.01	0.35b±0.02	0.33b±0.03	0.26a±0.02	0.23a±0.02	33.1 (<.01)
Lead	0.91e±0.03	0.87d±0.02	0.76c±0.01	0.67b±0.02	0.54a±0.01	247.2 (<.01)
Zinc	0.8e±0.01	0.73d±0.02	0.64c±0.02	0.43b±0.02	0.36a±0.02	304.2 (<.01)
Cadmium	0.6e±0.006	0.56d±0.01	0.52c±0.01	0.44b±0.02	0.31a±0.01	376 (<.01)
Copper	1.61d±0.01	1.13c±0.06	0.8b±0.1	0.76b±0.02	0.57a±0.02	179.1 (<.01)

a, b ,c, d ,e are the subgroups of Duncan's post hoc multiple comparison test among days
*All the parameters except pH are expressed in mg/l

Table 2 Physico-chemical parameters of NTPC waste water by using Oscilatoria willei.

Parameters *	Mean ± SD					F-value (p-value)
	1 day	5 days	10 days	15 days	20 days	
pH	5.67^{a}±0.01	6.02^{b}±0.02	6.04^{b}±0.03	6.13^{c}±0.03	6.37^{d}±0.02	444.9 (<.01)
Total Alkalinity (TA)	96.33e±0.29	85.4d±0.44	73.37c±0.25	59.5b±0.36	48.95a±0.04	11678.5 (<.01)
Dissolved Oxygen (DO)	2.33a±0.06	2.43a±0.21	2.8b±0.1	3.4c±0.36	3.75c±0.03	30.1 (<.01)

Chloride	346.33e±0.29	312.63d±0.21	279.43c±0.35	250.6b±0.3	200.8a±0.2	4968.8 (<.01)
Hardness	121.33e±0.29	103.67d±0.25	92.67c±0.25	66.47b±0.25	56.4a±0.3	29317.3 (<.01)
Calcium	96.33e±0.29	89.5d±0.2	73.43c±0.31	66.67b±0.25	59.56a±0.04	12696.2 (<.01)
Phosphate	4.56e±0.02	2.96d±0.01	2.44c±0.02	1.12b±0.02	0.96a±0.01	30610 (<.01)
Sulphate	79.33e±0.29	63.23d±1.08	58.6c±0.36	39.37b±0.31	26.63a±0.31	4100 (<.01)
Nitrate	5.65e±0.05	3.14d±0.03	2.97c±0.01	1.93b±0.02	1.64a±0.02	8474.6 (<.01)
BOD	8.76e±0.01	7.33d±0.21	5.46c±0.03	3.96b±0.04	2.97a±0.01	1856.6 (<.01)
COD	216.33e±0.12	129.27d±0.25	96.5c±0.44	62.6b±0.26	51.95a±0.03	19396 (<.01)
Silicate	17.34e±0.07	13.77d±0.32	9.5c±0.17	6.43b±0.35	4.85a±0.04	1523.4 (<.01)
Iron	0.4±0.01	0.28±0.02	0.25±0.01	0.22±0.02	0.5±0.59	0.58 (0.684)
Lead	0.91e±0.03	0.84d±0.03	0.66c±0.03	0.48b±0.01	0.35a±0.01	383.4 (<.01)
Zinc	0.8e±0.01	0.77d±0.02	0.68c±0.01	0.48b±0.01	0.38a±0.02	735.9 (<.01)
Cadmium	0.6e±0.01	0.48d±0.01	0.37c±0.01	0.32b±0.02	0.24a±0.01	383 (<.01)
Copper	1.61e±0.01	1.45d±0.02	1.24c±0.03	0.95b±0.02	0.77a±0.02	795.7 (<.01)

a, b, c ,d ,e are the subgroups of Duncan's post hoc multiple comparison test among days
*All the parameters except pH are expressed in mg/l

Table 3 - Physico-chemical parameters of NTPC waste water by using Lyngbya confervoides

Parameters*	Mean ± SD					F-value (p-value)
	1 day	5 days	10 days	15 days	20 days	
pH	5.67^{a}±0.01	5.92^{b}±0.01	5.97^{c}±0.01	6.02^{d}±0.02	6.18^{e}±0.01	816.7 (<.01)
TotalAlkalinity (TA)	96.33e±0.29	89.67d±0.35	74.23c±0.15	69.47b±0.25	54.72a±0.18	12605.7 (<.01)

Dissolved Oxygen (DO)	2.33a±0.06	2.8b±0.1	3.57c±0.42	3.67c±0.15	3.76c±0.04	27.9 (<.01)
Chloride	346.33e±0.29	306.73d±0.38	236.4c±0.44	196.57b±0.42	179.5a±0.36	10657 (<.01)
Hardness	121.33e±0.29	109.37d±0.31	96.6c±0.26	79.53b±0.32	61.57a±0.15	22607.5 (<.01)
Calcium	96.33e±0.29	90.37d±0.25	82.8c±0.1	75.6b±0.3	68.22a±0.07	7514.8 (<.01)
Phosphate	4.56e±0.02	3.43d±0.03	2.95c±0.02	1.33b±0.02	1.04a±0.02	17163.5 (<.01)
Sulphate	79.33e±0.29	66.4d±0.96	57.5c±0.36	48.47b±0.4	31.77a±0.12	3683.1 (<.01)
Nitrate	5.65e±0.05	3.66d±0.02	2.75c±0.02	1.67b±0.02	1.54a±0.04	8327.6 (<.01)
BOD	8.76e±0.01	7.44d±0.03	5.83c±0.02	4.24b±0.02	3.35a±0.03	30120.3 (<.01)
COD	216.33e±0.12	147.47d±0.45	119.20c±0.2	76.27b±0.25	69.25a±0.02	168162.4 (<.01)
Silicate	17.34e±0.07	14.53d±0.35	12.53c±0.25	8.47b±0.32	6.15a±0.03	1035.6 (<.01)
Iron	0.4c±0.01	0.33b±0.02	0.34b±0.03	0.26a±0.03	0.23a±0.03	29.6 (<.01)
Lead	0.91e±0.03	0.85d±0.01	0.68c±0.02	0.53b±0.02	0.37a±0.01	488.2 (<.01)
Zinc	0.8d±0.01	0.79d±0.01	0.72c±0.01	0.58b±0.01	0.41a±0.01	865.8 (<.01)
Cadmium	0.6e±0.01	0.52d±0.01	0.44c±0.02	0.38b±0.01	0.26a±0.01	514.2 (<.01)
Copper	1.61d±0.01	1.46c,d±0.03	1.35b,c±0.03	1.23b±0.23	0.83a±0.02	23.3 (<.01)

a, b ,c ,d ,e are the subgroups of Duncan's post hoc multiple comparison test among days
*All the parameters except pH are expressed in mg/l

Table 4 Physico-chemical parameters of NTPC waste water by using Chroococcus minutus

Parameters*	Mean ± SD					F-value (p-value)
	1 day	5 days	10 days	15 days	20 days	
pH	5.67^{a}±0.01	6.03^{b}±0.02	6.07^{c}±0.02	6.13^{d}±0.01	6.17^{e}±0.01	781.7 (<.01)

Total Alkalinity(TA)	96.33e±0.29	73.53d±0.38	62.53c±0.38	56.57b±0.31	42.6a±0.36	10267 (<.01)
Dissolved Oxygen (DO)	2.33a±0.06	2.63a±0.15	3.37b±0.35	3.63b±0.21	3.57b±0.15	23.9 (<.01)
Chloride	346.33e±0.29	317.6d±0.26	232.47c±0.4	212.63b±0.25	166.47a±0.35	16689.3 (<.01)
Hardness	121.33e±0.29	112.63d±0.25	98.5c±0.17	86.6b±0.44	65.37a±0.31	15876.6 (<.01)
Calcium	96.33e±0.29	91.53d±0.21	86.73c±0.21	79.57b±0.31	75.84a±0.04	4003.9 (<.01)
Phosphate	4.56e±0.02	1.86d±0.02	0.95c±0.02	0.47b±0.02	0.36a±0.01	39960.6 (<.01)
Sulphate	79.33e±0.29	63.5d±0.36	58.4c±0.26	51.47b±0.32	37.57a±0.35	6953.8 (<.01)
Nitrate	5.65e±0.05	4.4d±0.26	3.17c±0.01	2.25b±0.04	1.77a±0.03	507.9 (<.01)
BOD	8.76e±0.01	8.15d±0.02	6.45c±0.02	5.14b±0.02	4.23a±0.03	26462.2 (<.01)
COD	216.33e±0.12	186.27d±0.25	143.47c±0.25	118.37b±0.15	106.57a±0.31	12502.9 (<.01)
Silicate	17.34e±0.07	11.57d±0.31	8.63c±0.21	4.67b±0.25	1.88a±0.07	2607.6 (<.01)
Iron	0.4d±0.01	0.27c±0.01	0.24b±0.03	0.17a±0.02	0.16a±0.02	90.1 (<.01)
Lead	0.91e±0.03	0.77d±0.02	0.57c±0.02	0.43b±0.02	0.34a±0.03	316.8 (<.01)
Zinc	0.8e±0.01	0.62d±0.01	0.53c±0.02	0.45b±0.01	0.33a±0.03	400.6 (<.01)
Cadmium	0.6e±0.01	0.52d±0.02	0.43c±0.02	0.34b±0.01	0.24a±0.03	215.4 (<.01)
Copper	1.61e±0.01	1.54d±0.01	1.44c±0.02	1.27b±0.01	0.95a±0.01	1658.2 (<.01)

a,b ,c, d, e are the subgroups of Duncan's post hoc multiple comparison test among days
*All the parameters except pH are expressed in mg/l.