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Research Article

COMPARISON OF BIOREMEDIATION EFFICIENCY OF *CAULERPA RACEMOSA* & *ULVA LACTUCA* FROM INDUSTRIAL DYE EFFLUENTS

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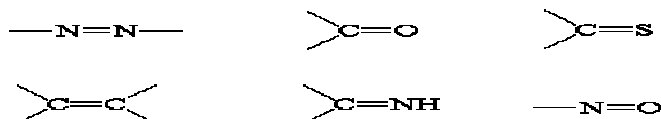
ABSTRACT

The present study reveals the potential of green macroalgae *Caulerpa racemosa* & *Ulva lactuca* in the treatment of reactive azo dyes effluent. The decolorization efficiency was measured at different concentration and pH. The pollutant removal capacity of these macro algae *Caulerpa racemosa* and *Ulva lactuca* was evaluated by physico-chemical analysis of effluent indicates potential decrease in total dissolved solids and phosphates but ammoniacal nitrogen is found increased in both the treatments. The biochemical analysis of accumulated macro algae shows declining content of protein, total sugar, chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoid with increasing days of treatment and effluent concentration. The Fourier transform infrared analysis reveals the accumulation of dye components into the algal cell functional groups which bind inside them. The *Ulva lactuca* shows significant decolorization in the present study. Thus the study reveals bioremediation potential of green macro algae which can be applicable in the industrial waste water treatment systems.

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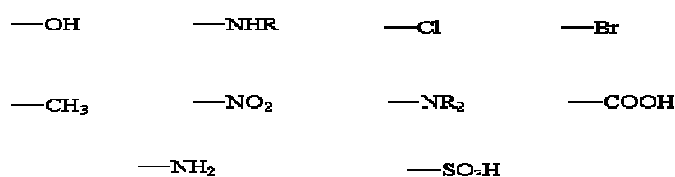
INTRODUCTION

Dyes are composed of two parts auxochromes and chromophores. The unsaturated groups in the organic compounds are responsible to produce color; such groups are called as chromophores. The compound containing the chromopheric groups are called as chromogenes by scientist Witt. For Example, Azo, Carbonyl, Thiocarbonyl, Ethlenic, Azomethine, Nitro etc.



A chromogen itself does not represent a dye but a certain groups in a chromogen leads to a depending of the color they are not chromophores and do not impart color to the compounds when present without chromophores, scientist Witt

called these group as auxochrome. They do not produce color but when present with the chromophore in a compound intensifies the color of the chromogen. Auxochrome act as functional group of atoms with non bonded electrons attached to chromophores which alters the wavelength & intensity of absorption for example, amino group, hydroxyl group, sulphonic acid, methyl group, carboxylic acid, methoxy, acetyl, acetamido. The auxochromes comes from the classes of reactive dye, azo dye, direct dye, basic dye, vat dye, sulphur dye, disperse dye (Arun and Bhaskar, 2010; Chatwal, 2009).



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Among all classes of dyes, reactive dyes are mainly used dyes in the cosmetics, textile fibers, printing. These types of dyes when released into the environment causes water pollution, because during the dyeing process 50 % of dyes are left as spent dye in its hydrolyzed form as unused dye which has no affinity towards the fabric and cannot be recycled in dyeing (Zollinger, 1987). Such kinds of dyes have toxic effects on germination rates and biomass of the plants which is helpful in an ecological functions of environment such as protection of soil erosion, providing organic matter to sustain the soil fertility (Ghodke et al, 2009a) therefore these kind of dyes are required to be treated before discharging into the environment. Various physical-chemical process such as flocculation, coagulation, adsorption, precipitation, ion exchange are implied for the treatment of such dyes but the bioremediation is eco-friendly and economically feasible clean up approach for the waste water treatment. The bacteria, fungi, algae and higher plants, enzymes are used for such treatments. They accumulated waste inside their cell biomass and tissues results biodegradation or biotransformation of the compound (Aksu, 2003; Banat et al, 1996).

Green macro algae used in the present study are *Caulerpa racemosa* entitled as A & *Ulva lactuca* as B belonging to the family Caulerpaceae and Ulvaceae respectively. It has vital role in bioremediation of heavy metals such as boron, lead, cadmium copper, chromium from the solid as well as liquid waste (Bursali et al, 2009; Hammud et al, 2014; Ghoneim et al, 2014; Ibrahim et al, 2016) and also play important role in removal of ammonia, phosphate, nitrate and nitrite from the nutrient rich aquaculture, sewage and industrial waste water and uptake them for their growth and cultivation (Pandya et al, 2017a; Chung et al, 2002; Schramm, 1991). The macro algae *Kappaphycus alvarezii* shows potential removal of phosphate from waste water and biodegradation of azo dyes (Pandya et al, 2017b; Rathod et al, 2014). The present study investigates the efficacy of pollutant removal capabilities by physico-chemical parameters for before and after treatment of dye effluents, optimization of pH and tolerance concentration of effluent on biomass and characterization study of accumulated macro algae with its biochemical response by biochemical analysis.

MATERIAL AND METHODOLOGY

Physico-chemical analysis of effluent

The dyes effluents were collected from industrial units of Gujarat, India. From the primary study of effluent analysis, the authors selected effluents of reactive red, reactive orange and reactive black dyes as E1, E4 and E6 respectively (Pandya et al, 2017a). Thus the physico-chemical parameters of effluents were analyzed by macro algae in the year of 2015-16 and 2016-17. The study was conducted on physico-chemical parameters such as total dissolved solid, total suspended solid, ammoniacal nitrogen, chemical oxygen demand, color, sulphate, phosphate and total organic carbon (Model-TOC-VCSN/ TNM-1, Make-Shimadzu Corporation, Japan) for before and after treatment by macro algae was studied followed by APHA standard manual for waste water analysis (APHA, 1998). Standard grade chemicals and reagents were used for the analysis. The ammoniacal nitrogen was studied by titration method, the chemical oxygen demand analyzed by dichromate

digestion method and color, sulphate and phosphate were studied under Uv-visible spectrophotometer (Model-1800, Make- Shimadzu).

Optimization of pH & Tolerance concentration of effluent on biomass

From the author's previous work of screening of most potential algae the macro algae *Caulerpa racemosa* and *Ulva lactuca* were selected for the bioremediation study (Pandya et al, 2017a). The optimization of environmental conditions such as potential pH for the biomass and tolerance concentration of effluent on biomass was studied. All the experiments were conducted in triplicates and standard error mean mentioned in the results. The experiment was conducted for 16 days at different pH such as pH 6 to pH 10 for E1, E4 & E6 effluent. The dried biomass of seaweed was inoculated and potential pH was optimized. Similar experiment was conducted for 24 days for the optimization of tolerance concentration of effluent. The effluent solutions were prepared in 0.2 % V/V, 0.5 % V/V & 2 % V/V. The optical density was measured at each 8 days interval in Uv-vis Spectrophotometer (Make- Shimadzu, Model- 1800) and percentage decolorization was measured by below formula:

$$(\%)\text{Decolorization} = \frac{\text{Initial absorbance} - \text{Final absorbance}}{\text{Initial absorbance}} \times 100$$

Biochemical response of accumulated macro algae

The accumulated macro algae was collected after the treatment of effluent and its effect on macro algae was studied for its biochemical response by biochemical analysis such as protein, sugar, chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoid; the method followed from the standard methods of biochemical analysis by S. R. Thimmaiah (Thimmaiah, 2004).

Fourier transform infrared analysis (FTIR) of accumulated macro algae

The Fourier transform infrared analysis of untreated and treated seaweed biomass was studied by FT-IR spectrophotometer (Make: Perkin Elmer, U.S.A., Model: Spectrum GX). The KBr disk method was applied; the macro algal samples were kept in hot air oven for 2 hours and then ground by mortar and pestle for 5-10 minutes after that 2 mg of dried green biomass were taken with 200 mg of KBr (spectroscopic grade) with extra crushing and made pellets using hydraulic pallet press and then the spectra were recorded between 4000 to 400 cm^{-1} range in ambient conditions.

RESULT AND DISCUSSION

In the present study physico-chemical analysis of effluent after treatment by *Caulerpa racemosa* and *Ulva lactuca* shows the decreasing values in total dissolved solid, total suspended solid in all effluent samples. The sulphate level was found increased; the phosphate and total organic carbon were found decreased in all effluent samples in treatment given by *Ulva lactuca*. The *Caulerpa racemosa* shows potential result to remove sulphate and chemical oxygen demand as shown in Table-1. It can be concluded from the study that due to the presence of more compounds in the effluents cause increase time period of the treatment with increase in seaweed retention time in effluent which affect the survival rate of that seaweed and it get

detoriated which results the increasing level of the total organic carbon values and ammoniacal nitrogen.

Ulva lactuca shows potential reduction in color, phosphate & total organic carbon; it means that *Ulva lactuca* utilizes the phosphate to survive and cell metabolism, reduction in total organic carbon revealed that it degrades or biotransformation of the complex organic structures into simpler forms and accumulate them into their cells therefore we found potential decolorization in the effluents. It shows potential reduction in total dissolved solid in all the samples. Highly increased amount of ammoniacal nitrogen and sulphate was observed in all the effluent this may occurred due to the breakdown of cells during the treatment of effluent with increasing time period so it can be said as sometimes this species when stored for long periods generates hydrogen disulphide and mixture of gas so the species should not store more than respective periods. In the present study *Ulva lactuca* observed most potential seaweed for the removal of total suspended solid, total dissolved solid, color and phosphate. The result indicated in Table-2.

The optimization of pH by *Caulerpa racemosa* and *Ulva lactuca* shown in Fig-1, Fig-2 and Fig-3 which indicates the most potential pH for the decolorization was found 8 to 9.5 and 7.5 to 10 for E1 effluent respectively, 6.5 to 8 and 8 to 10 for E4 effluent respectively & 8 to 9.5 by both species in E6 effluent. From the study it is found that with increasing pH the decolorization efficiency increases upto pH 9.5 to 10. Thus the waste water treatment can be conducted around pH 7 to 9.5 for best results.

Caulerpa racemosa shows increasing 88.2 % maximum decolorization on 16th day under 0.2 % v/v of E1 effluent concentration and indicates with increasing concentration the decolorization values found decreased; similar results was found in E4 & E6 effluents. The percentage decolorization was found maximum in *Ulva lactuca* as compare to *Caulerpa racemosa*.

Table 1 Effect on physico-chemical parameters by treatment of *Caulerpa racemosa*

Physico-chemical Parameter	E1 2015-16	Treated 2015-16	E4 2015-16	Treated 2015-16	E6 2015-16	Treated 2015-16	E1 2016-17	Treated 2016-17	E4 2016-17	Treated 2016-17	E6 2016-17	Treated 2016-17
TDS (mg/l)	15224	14940	19596	19500	47500	47100	12521	12180	15000	14275	14851	14234
TSS (mg/l)	1121	920	1678	1625	887	866	1242	1140	2275	2225	1345	1294
Ammoniacal Nitrogen (mg/l)	56	182	56	210	70	1120	154	392	266	686	221	342
COD (mg/l)	1036	5230	5368	7249	1927	6997	8717	6331	275.3	201	2231	1982
Color (Co.Pt. Unit)	192340	250000	57515	236030	26765.3	28708	338088	205850	1236.4	12395	46321	48632
Sulphate (mg/l)	822.5	758	643	569	3694	3180	1174	1404	4263	4068	5739	5214
Phosphate (mg/l)	1055.7	84.36	874.5	152.8	51.38	147.8	796.4	36.67	33.2	113	56.33	88.66
TOC (mg/l)	307.2	394	218.3	277	105.6	157	358.2	788	40.77	90.23	120	168

(E1: Effluent of reactive red dye, E4: Effluent of reactive yellow dye, E6: Effluent of reactive black dye)

Table 2 Effect on physico-chemical parameters by treatment of *Ulva lactuca*

Physico-chemical Parameter	E1 2015-16	Treated 2015-16	E4 2015-16	Treated 2015-16	E6 2015-16	Treated 2015-16	E1 2016-17	Treated 2016-17	E4 2016-17	Treated 2016-17	E6 2016-17	Treated 2016-17
TDS (mg/l)	17221	16940	18562	18020	17432	17080	14934	14380	16875	16120	14851	14102
TSS (mg/l)	1121	1200	1678	1588	887	1080	1242	1360	2275	2300	1345	1498
Ammoniacal Nitrogen (mg/l)	56	112	56	140	70	980	154	224	266	532	221	285
COD (mg/l)	1036	8350	5368	7019	1927	3762	8717	9864	275.3	1697	2231	2314
Color (Co.Pt. Unit)	192340	137500	57515	54160	26765.3	219082	338088	173970	1236.4	1025.7	46321	38517
Sulphate (mg/l)	822.5	1673	643	5687	3694	4577	1174	2028	4263	5359	5739	6214
Phosphate (mg/l)	1055.7	58.18	874.5	250	51.38	46.39	796.4	12.22	33.2	BDL	56.33	52.57
TOC (mg/l)	307.2	296	218.3	162	105.6	35.07	358.2	98	40.77	40.85	120	50.2

(E1: Effluent of reactive red dye, E4: Effluent of reactive yellow dye, E6: Effluent of reactive black dye)

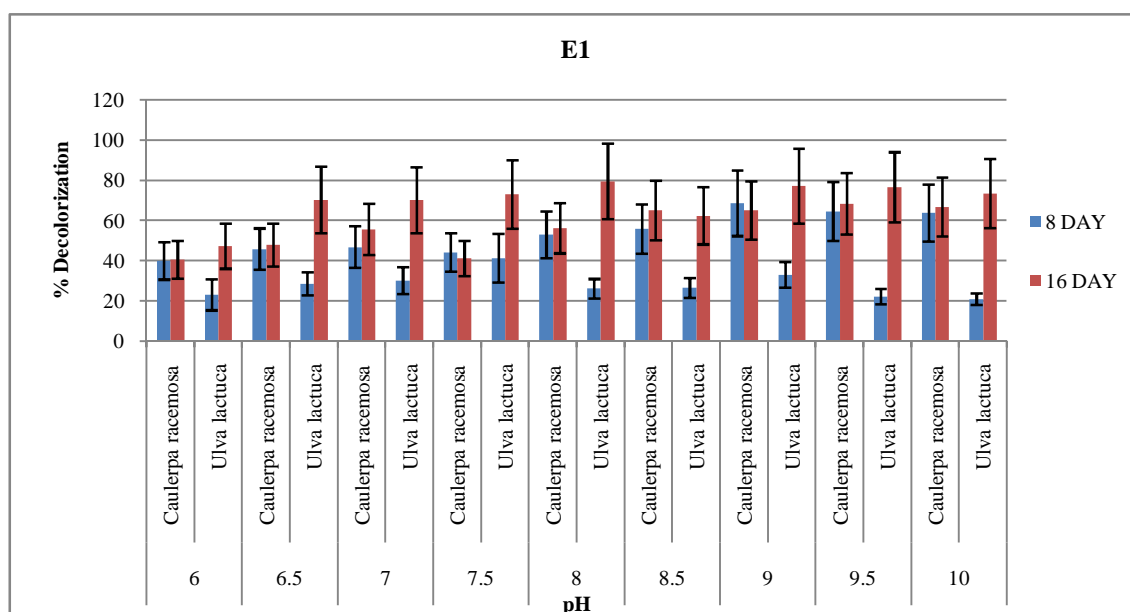


Fig 1 Optimization of pH by evaluating % decolorization using *Caulerpa racemosa* & *Ulva lactuca* in E1 effluent

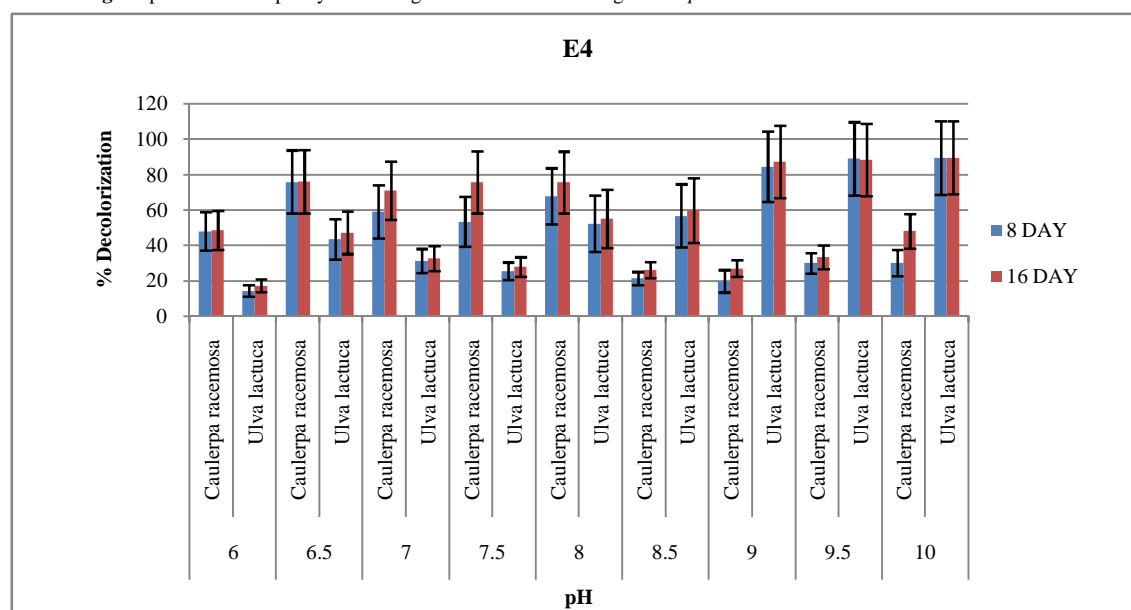


Fig 2 Optimization of pH by evaluating % decolorization using *Caulerpa racemosa* & *Ulva lactuca* in E4 effluent

In all the experiments the increasing maximum decolorization was achieved on 16th day then it becomes steady upto 24th day. From this study it was found that with increasing concentration of effluent the decolorization rate was decreased with increasing concentration of the surface of the biomass gets more accumulated with effluent uptake inside the tissues which lowers the rate of adsorption in the biomass causes decreasing rate of decolorization. After the study of tolerance concentration of effluent on biomass the accumulated biomass was studied further for its biochemical characteristics by performing biochemical analysis of protein, total sugar, chlorophyll-a, chlorophyll-b, total chlorophyll and carotenoid. Protein content of *Caulerpa racemosa* and *Ulva lactuca* get decreased with increasing concentration of effluent with increasing days intervals as highest protein content was found under 0.2 % v/v of effluent in 8th day and lowest protein

content was found on 24th day under 2 % v/v of effluent concentration as shown in Fig-7. Similar difference as protein was found in the total sugar content in *Caulerpa racemosa* and *Ulva lactuca* as the concentration of all three effluents E1, E4 & E6 were increased, the concentration of total sugar in the biomass was found decreased. The result is shown in Fig-8 which also indicates that with increasing days the total sugar level of the biomass also decreased. In this present study for *Caulerpa racemosa* and *Ulva lactuca* the maximum values of chlorophyll a, b and total chlorophyll was found on 8th day under 0.2 % v/v of each effluent concentration and lower amount was found on 24th day 2 % concentration of each effluent, it is shown in Fig-9 to Fig-11 which indicates that pigment content of the biomass decreases with increasing days and increasing effluent concentration similar result was found for carotenoid content of the biomass for *Caulerpa racemosa* and *Ulva lactuca* shown in Fig-12.

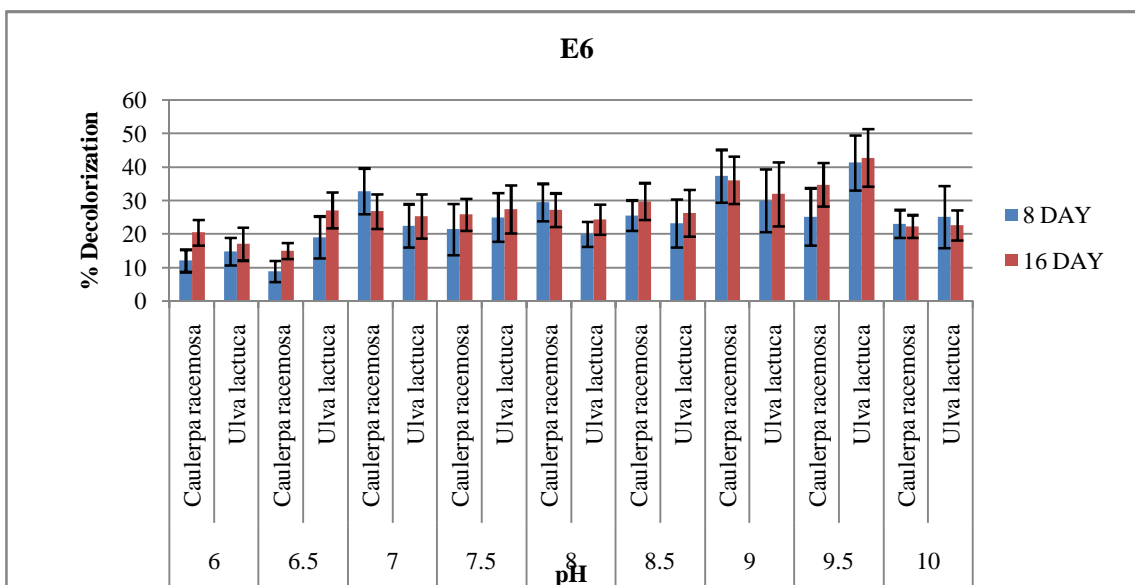


Fig 3 Optimization of pH by evaluating % decolorization using *Caulerpa racemosa* & *Ulva lactuca* in E6 effluent

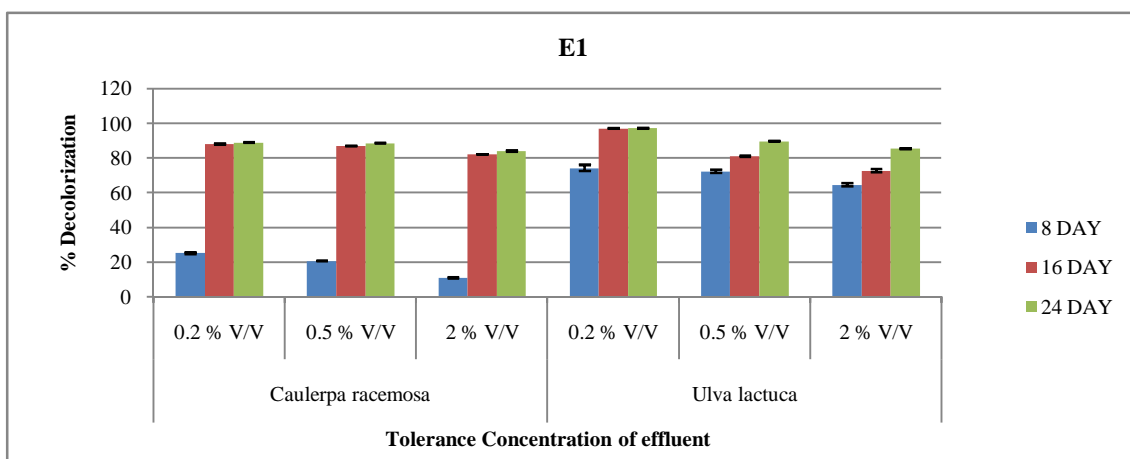


Fig 4 Tolerance concentration of E1 effluent on *Caulerpa racemosa* & *Ulva lactuca*

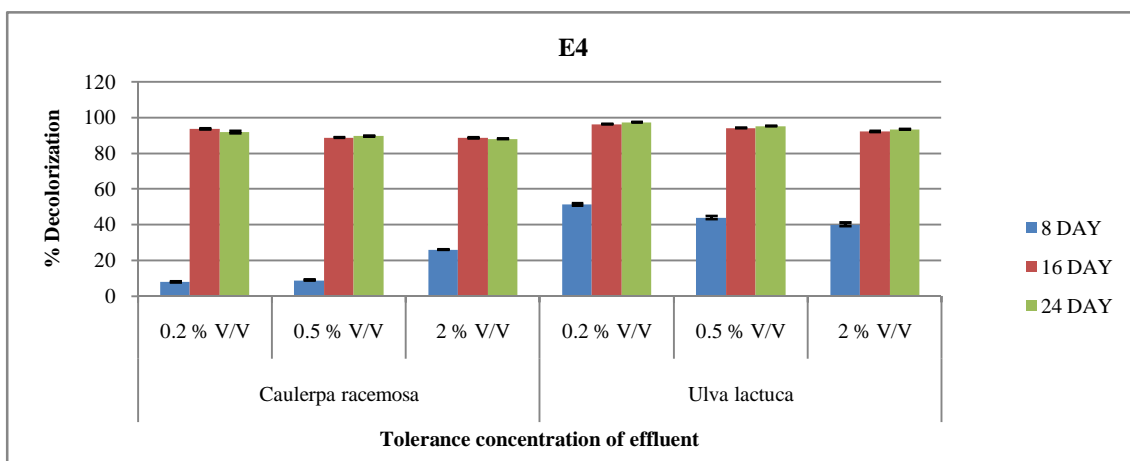


Fig 5 Tolerance concentration of E4 effluent on *Caulerpa racemosa* & *Ulva lactuca*

Fourier transform infrared analysis (FTIR) of macro algae

The recorded spectrum gives information regarding functional groups variations for before and after treatment with effluent containing heavy metals and mixture of dyes (Fig-12 to Fig-19). The Fourier transform infrared analysis spectrum of the seaweed biomass indicates distinct and various adsorption

peaks represents the existence of functional group such as O-H alcohol, N-H amino salt, C=N oxime/imine, S=O sulfate, S=O sulfonic acid, C-O aliphatic ether, C-O primary alcohol, C-O vinyl ether, O-H carboxylic acid, P-C organo-phosphorus compound, C-O alkyl aryl ether, C-H alkane, C=C alkane disubstituted (cis), C-F fluoro compound, C-O primary alcohol,

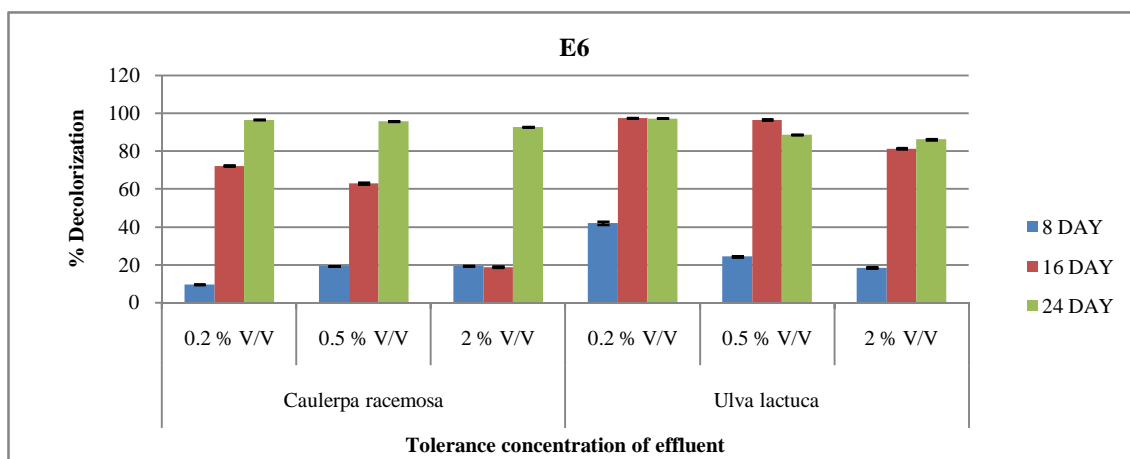


Fig 6 Tolerance concentration of E6 effluent on *Caulerpa racemosa* & *Ulva lactuca*

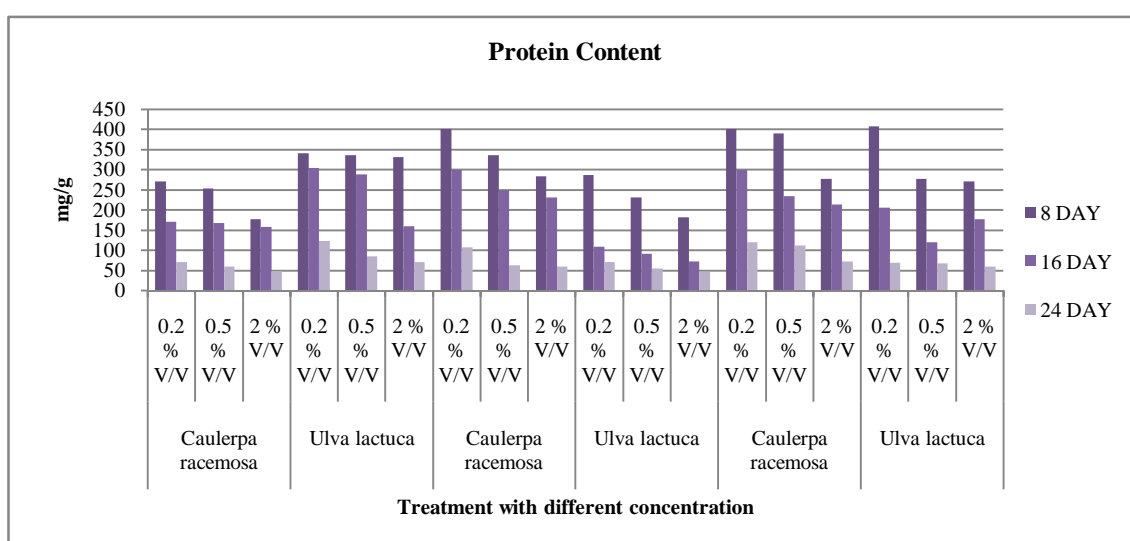


Fig 7 Protein content of *Caulerpa racemosa* & *Ulva lactuca* after treatment with different concentration of E1, E4 and E6 effluent

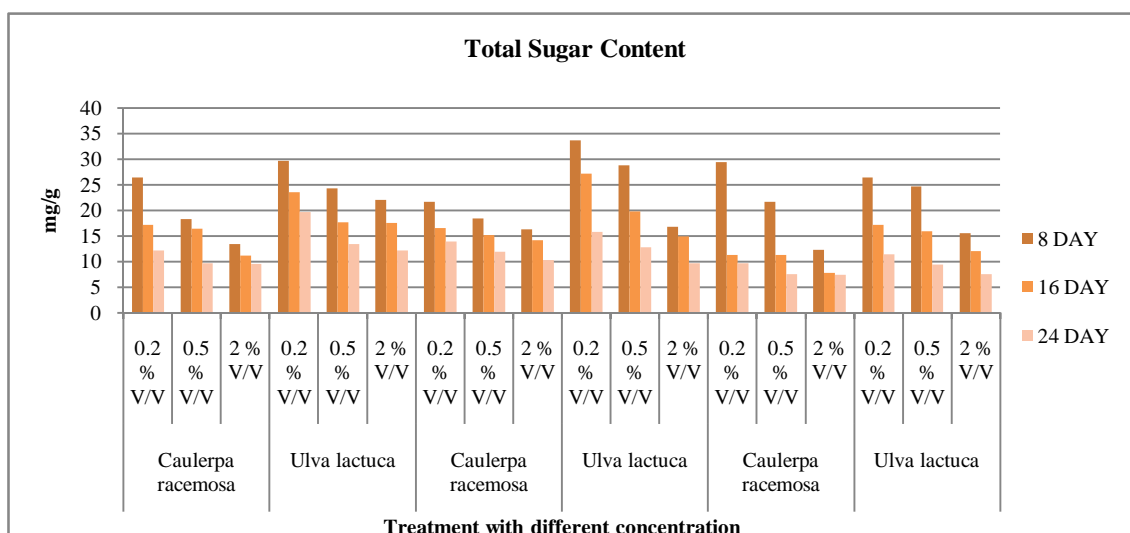


Fig 8 Total Sugar content of *Caulerpa racemosa* & *Ulva lactuca* after treatment with different concentration of E1, E4 and E6 effluent

C-O secondary alcohol, C-O tertiary alcohol, N-O nitro compound, C-O aromatic ester, S=O sulfonamide, S=O sulfoxide found in *Caulerpa racemosa* and *Ulva lactuca*. These bands are resulted due to the participation of functional groups of seaweed biomass in the adsorption of dyes effluent and

heavy metals such as Pb, Cr & Cu. The comparison of the each spectrum with its original spectrum before treatment indicates decrease in intensity of bands and band shifts which is reported in Table-3 and Table-4 for *Caulerpa racemosa* & *Ulva lactuca* respectively.

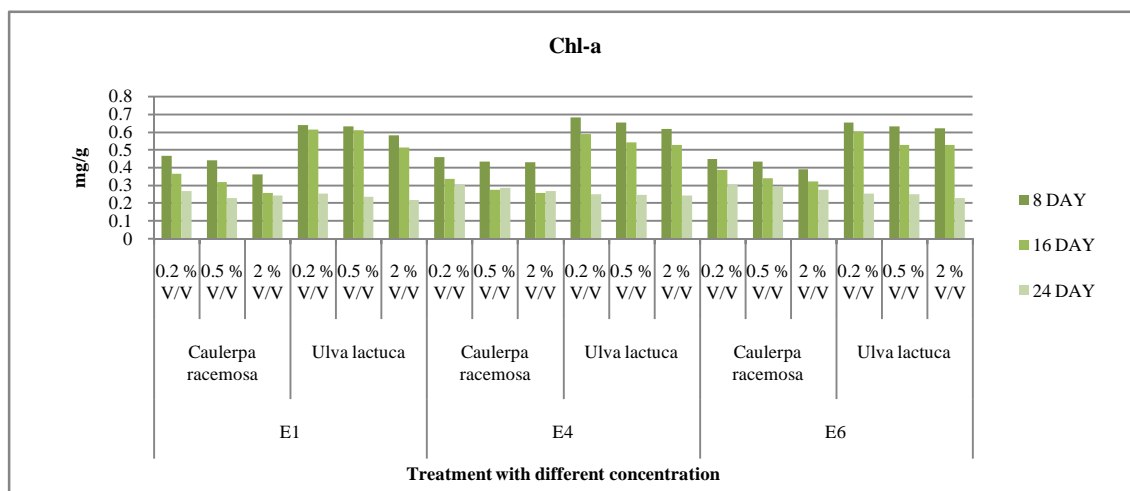


Fig 9 Chlorophyll-a content of *Caulerpa racemosa* & *Ulva lactuca* after treatment with different concentration of E1, E4 and E6 effluent

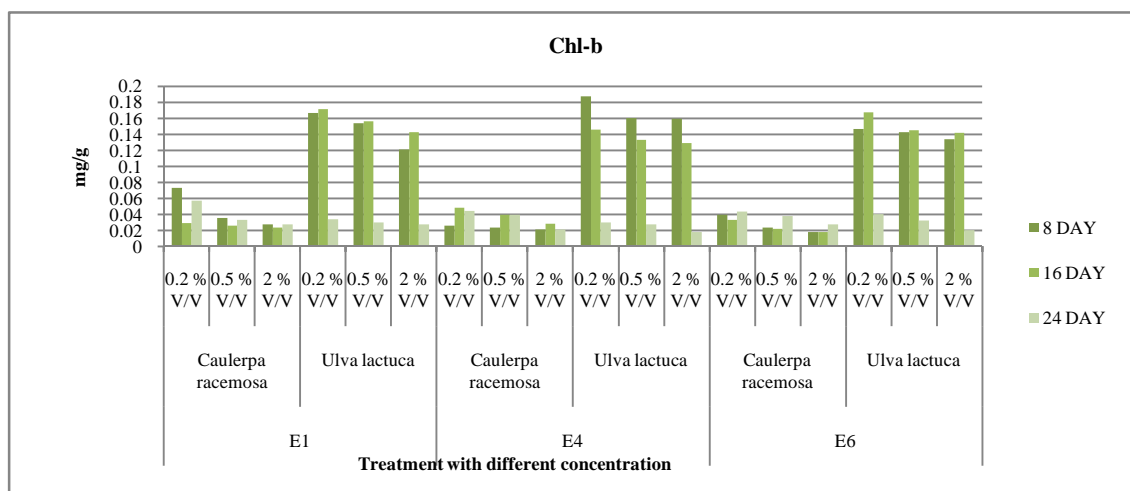


Fig-10 Chlorophyll-b content of *Caulerpa racemosa* & *Ulva lactuca* after treatment with different concentration of E1, E4 and E6 effluent

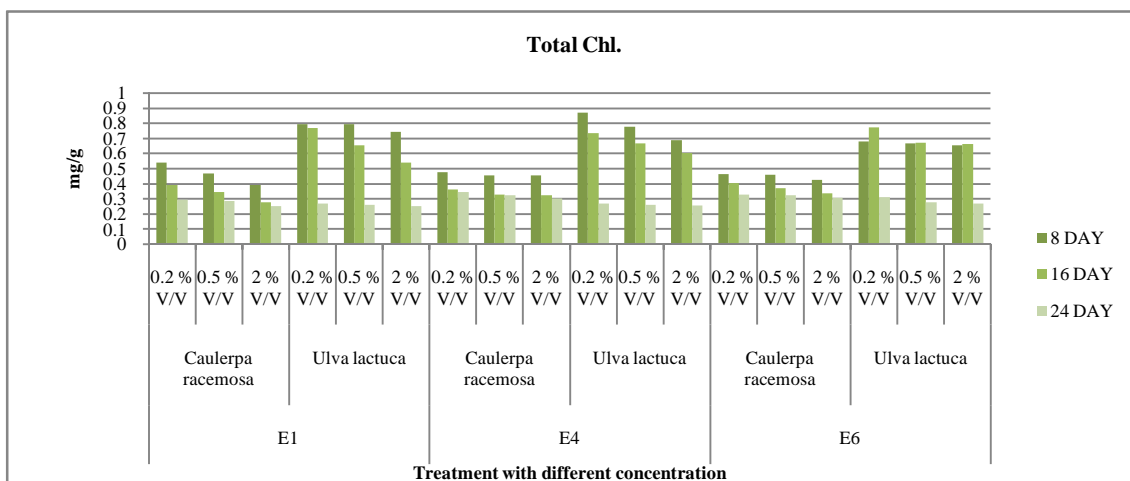


Fig 11 Total Chlorophyll content of *Caulerpa racemosa* & *Ulva lactuca* after treatment with different concentration of E1, E4 and E6 effluent

The IR spectra of *Caulerpa racemosa* & *Ulva lactuca* indicates minor changes in the peaks frequencies because of the binding with heavy metals & dyes effluent functional groups resulted in decline in adsorption frequencies. These binding taken place due to presence of active sites in the seaweed biomass. Thus the analytical study of Fourier transform infrared analysis indicates the presence of ionizable functional groups inside the

seaweed biomass which has ability to interact with cations and other functional groups (Bueno *et al.*, 2008; Sun *et al.*, 2008; Ertugay and Bayhan, 2008; Uluozlu *et al.*, 2008). Thus it can be concluded that functional groups play very important role in the removal of cations and breakdown or transformation of the molecules of the dyes effluent.

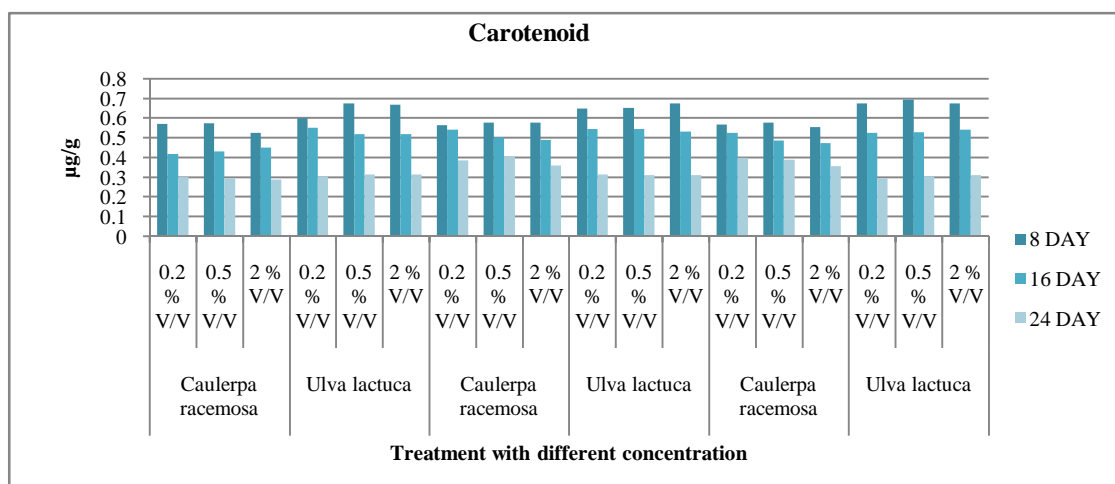


Fig 12 Carotenoid content of *Caulerpa racemosa* & *Ulva lactuca* after treatment with different concentration of E1, E4 and E6 effluent

Table 3 Fourier transform infrared analysis (FTIR) Interpretation of *Caulerpa racemosa*

<i>Caulerpa racemosa</i>	Adsorption bands (cm ⁻¹)			Assignment
	Initial	Final	Difference	
E1-effluent	3426.95	3426.83	0.12	O-H stretching alcohol, bonded, N-H Primary aliphatic amine
	2924.16	2923.50	0.66	N-H stretching amine salt bonded, C-H alkane-methylene strong bonded
	1651.27	1644.96	5.63	C=N imine/oxime, associated
	1651.27	1644.96	6.31	C=N imine/oxime, associated, C=C alkene disubstituted (cis), C=C disubstituted, C=C conjugated, C=C vinylidene,
	1543.79	1545.84	(-2.05)	N-O stretching nitro compound
	1455.14	1415.99	39.15	P-C aromatic organo-phosphorus compound, S=O stretching sulfate, S=O stretching sulfate, O-H bending alcohol, O-H bending carboxylic acid
	1245.26	1246.26	(-1)	C-N amine stretching, C-O aromatic ester strong, C-O alkyl aryl ether strong, P-O phosphorus oxide strong
	1166.82	1139.71	27.11	S=O sulfonic acid anhydrous hydrate, C-O stretching eliphatic ether
	1029.11	1030.03	(-0.92)	C-O strctching vinyl ether, C-X fluoroalkanes, C-N aliphatic amine, S=O sulfoxide, C-O alkyl aryl ether
	3426.95	3428.58	(-1.63)	O-H stretching alcohol bonded, N-H Primary amine strong
E4-effluent	2923.50	2925.75	(-2.25)	N-H stretching amine salt bonded, C-H methylene medium to strong bonded, O-H Carboxylic acid strong, O-H alcohol weak
	1651.27	1642.70	8.57	C=N imine/oxime, associated, C=C alkane disubstituted cis, alkene vinylidene, C=C conjugated, C=C monosubstituted
	1543.79	1551.03	(-7.24)	N-O stretching nitro compound
	1455.14	1410.94	44.2	P-C aromatic organo-phosphorus compound, O-H bending carboxylic acid, O-H bending alcohol, S=O stretching sulfate, S=O stretching sulfonyl chloride
	1245.26	1247.59	(-2.33)	C-N amine stretching, C-O aromatic ester, C-O alkyl aryl ether strong
	1166.82	1080.45	86.37	S=O sulfonic acid anhydrous hydrate, C-O stretching eliphatic ether
E6-effluent	1029.11	1029.48	(-0.17)	C-O stretching vinyl ether, C-O stretching alkyl aryl ether, C-X Fluoroalkanes, C-N aliphatic amines, S=O sulfoxide
	3426.95	3428.02	(-1.07)	O-H stretching alcohol, bonded, N-H Primary amine
	2923.50	2925.75	(-2.25)	N-H stretching amine salt bonded, O-H alcohol weak, O-H carboxylic acid, C-H methylene medium to strong
	1651.27	1641.42	9.85	C=N imine/oxime, associated, C=C alkane disubstituted cis, alkene vinylidene, C=C conjugated, C=C monosubstituted
	1455.14	1407.74	47.4	P-C aromatic organo-phosphorus compound, O-H bending carboxylic acid, O-H bending alcohol, S=O stretching sulfate, S=O stretching sulfonyl chloride,
	1245.26	1244.35	0.91	C-N amine stretching, C-O aromatic ester, C-O alkyl aryl ether strong
	1166.82	1205.06	(-38.24)	S=O sulfonic acid anhydrous hydrate, C-O stretching eliphatic ether
	1029.11	1029.29	(-0.18)	C-O stretching vinyl ether, C-O stretching alkyl aryl ether, C-X Fluoroalkanes, C-N aliphatic amines, S=O sulfoxide

Table 4 Fourier transform infrared analysis (FTIR) Interpretation of *Ulva lactuca*

<i>Ulva lactuca</i>	Adsorption bands (cm ⁻¹)			Assignment
	Initial	Final	Difference	
E1-effluent	3415.81	3428.28	-12.47	O-H alcohol stretching free
	2926.48	2925.39	1.09	O-H carboxylic acid stretching, N-H stretching amine salt, C-H alkane stretching
	1643.81	1635.39	8.42	C=N imine/oxime stretching, C=C alkane disubstituted (cis)
	1442.51	1422.84	19.67	O-H bending carboxylic acid, C-F fluoro compound
	1101.62	1055.64	45.98	C-O aliphatic ether stretching, C-O secondary alcohol stretching, C-O alkyl aryl ether stretching, C-N amine stretching, C-O vinyl ether stretching

	3415.81	3427.31	(-11.5)	O-H alcohol stretching free
	2926.48	2925.21	1.27	O-H carboxylic acid stretching, N-H stretching amine salt, C-H alkane stretching
E4-effluent	1643.81	1633.52	10.29	C=N imine/oxime stretching, C=C alkane disubstuted (cis)
	1442.51	1421.37	21.14	O-H bending carbocyclic acid, C-F fluoro compound
	1101.62	1055.99	45.63	C-O aliphatic ether stretching, C-O secondary alcohol stretching, C-O alkyl aryl ether stretching, C-N amine stretching, C-O vinyl ether stretching
	3415.81	3426.24	(-10.43)	O-H alcohol stretching free
	2926.48	2928.03	(-1.55)	O-H carboxylic acid stretching, N-H stretching amine salt, C-H alkane stretching
E6-effluent	1643.81	1631.97	11.84	C=N imine/oxime stretching, C=C alkane disubstuted (cis)
	1442.51	1422.31	20.2	O-H bending carbocyclic acid, C-F fluoro compound
	1101.62	1055.63	45.99	C-O aliphatic ether stretching, C-O secondary alcohol stretching, C-O alkyl aryl ether stretching, C-N amine stretching, C-O vinyl ether stretching

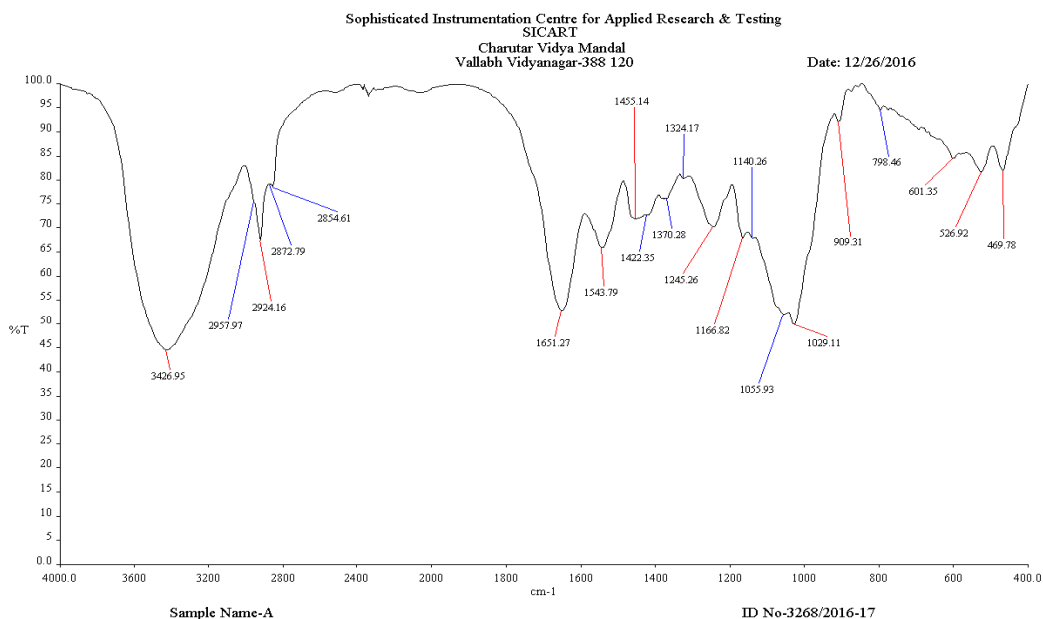


Fig 13 Fourier transform infrared analysis (FTIR) of *Caulerpa racemosa*

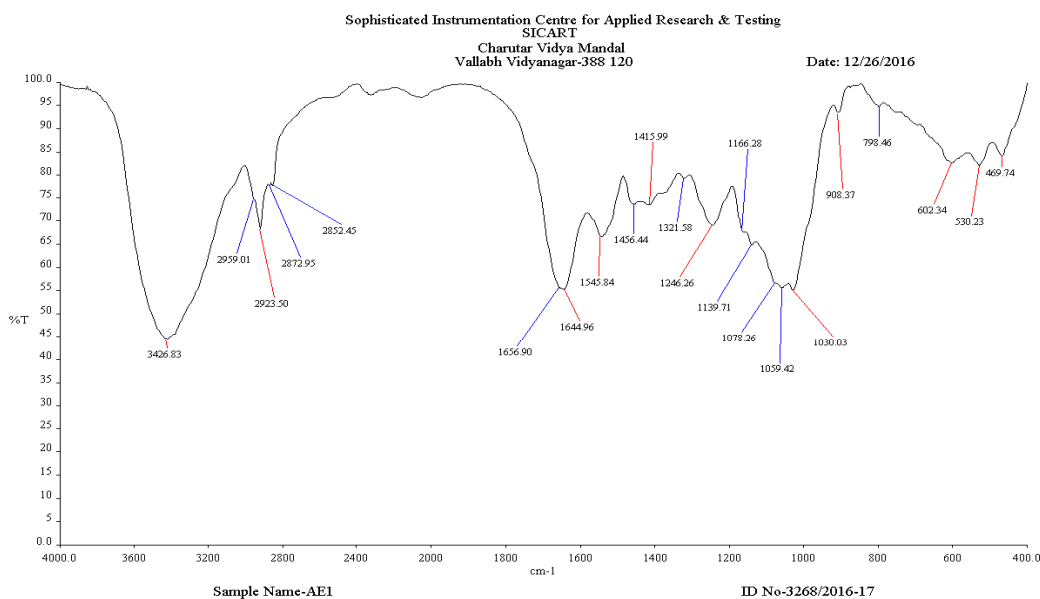


Fig 14 Fourier transform infrared analysis (FTIR) of *Caulerpa racemosa* treatment with E1 effluent

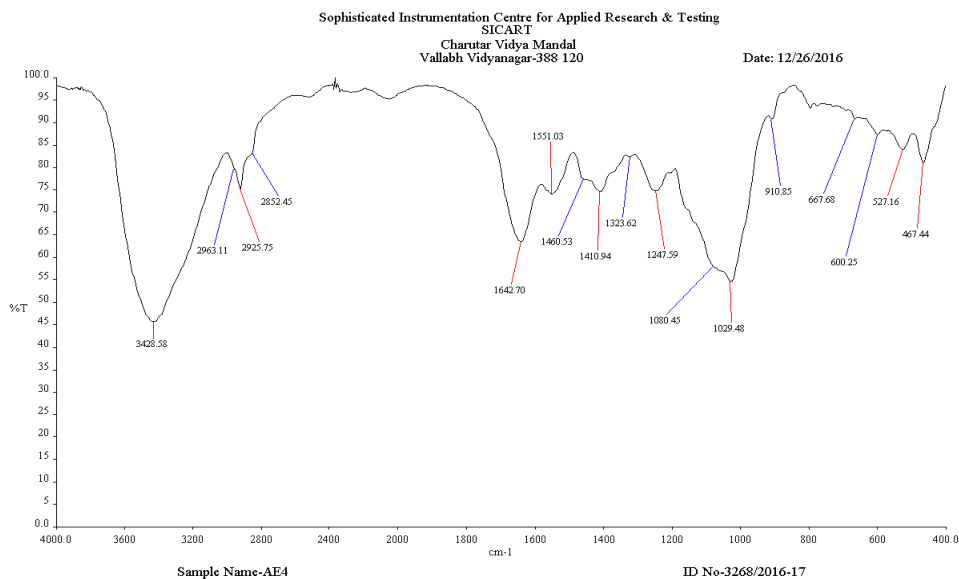


Fig 15 Fourier transform infrared analysis (FTIR) of *Caulerpa racemosa* treatment with E4 effluent

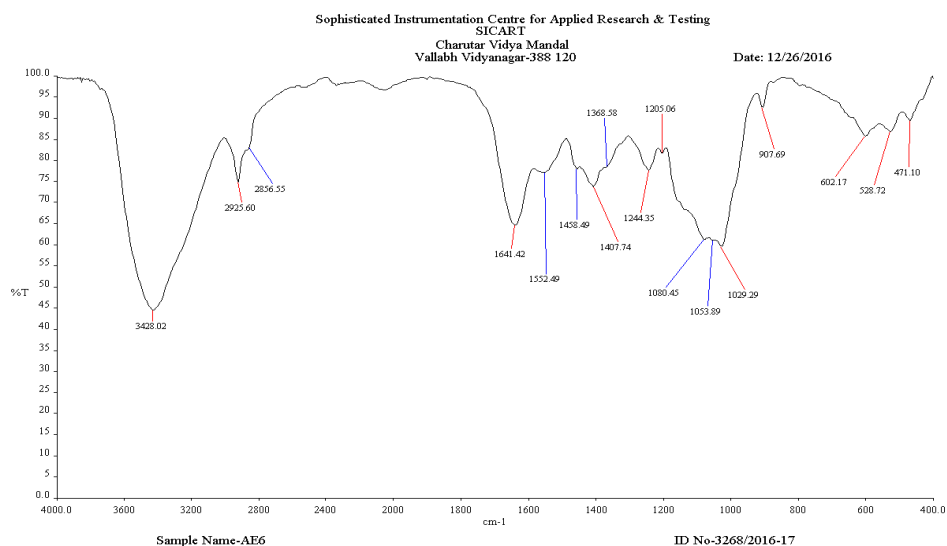


Fig 16 Fourier transform infrared analysis (FTIR) of *Caulerpa racemosa* treatment with E6 effluent

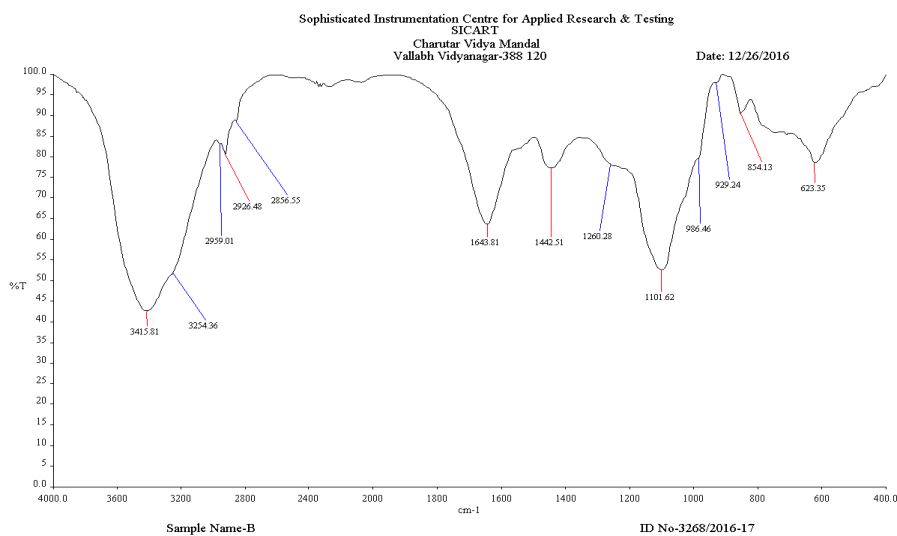


Fig 17 Fourier transform infrared analysis (FTIR) of *Ulva lactuca*

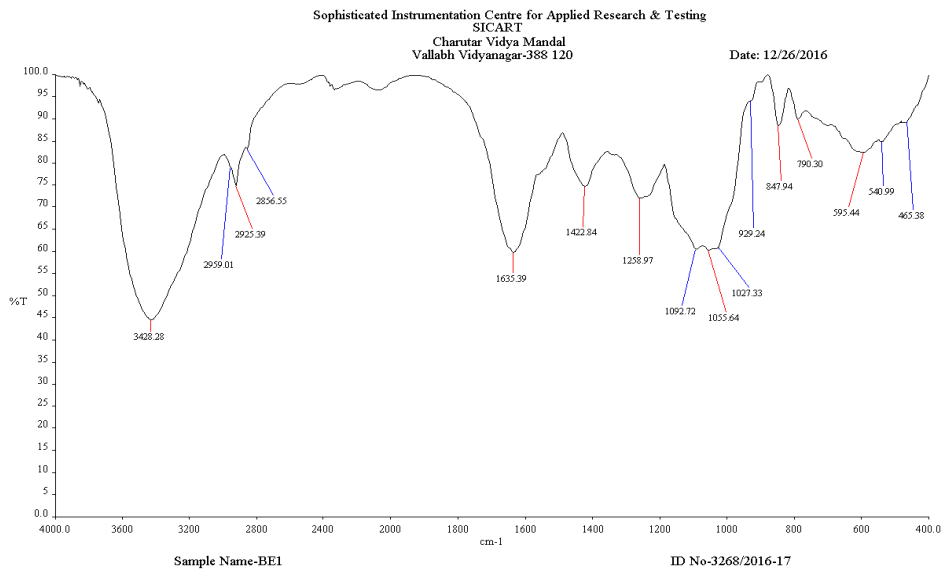


Fig 18 Fourier transform infrared analysis (FTIR) of *Ulva lactuca* treatment with E1 effluent

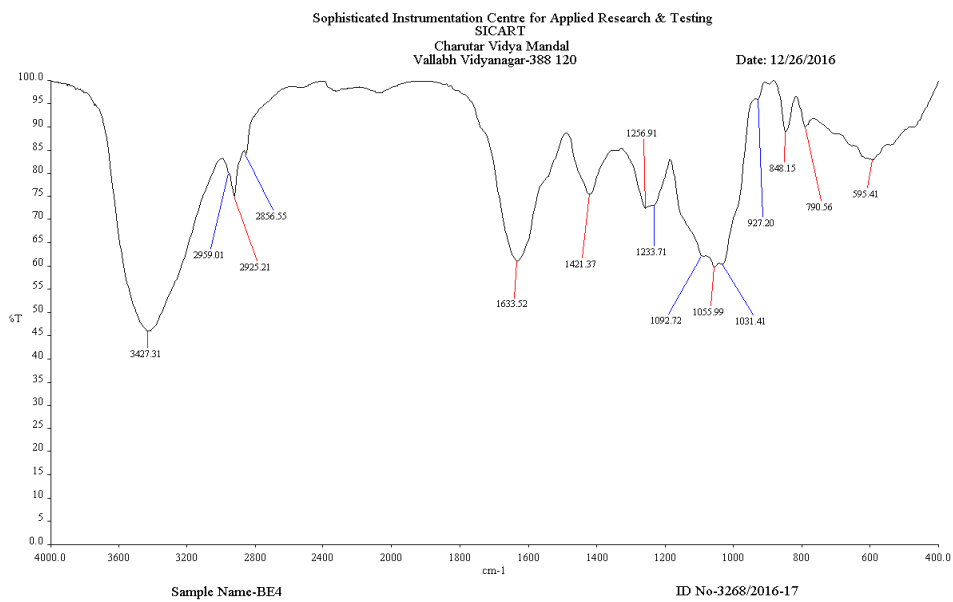


Fig 19 Fourier transform infrared analysis (FTIR) of *Ulva lactuca* treatment with E4 effluent

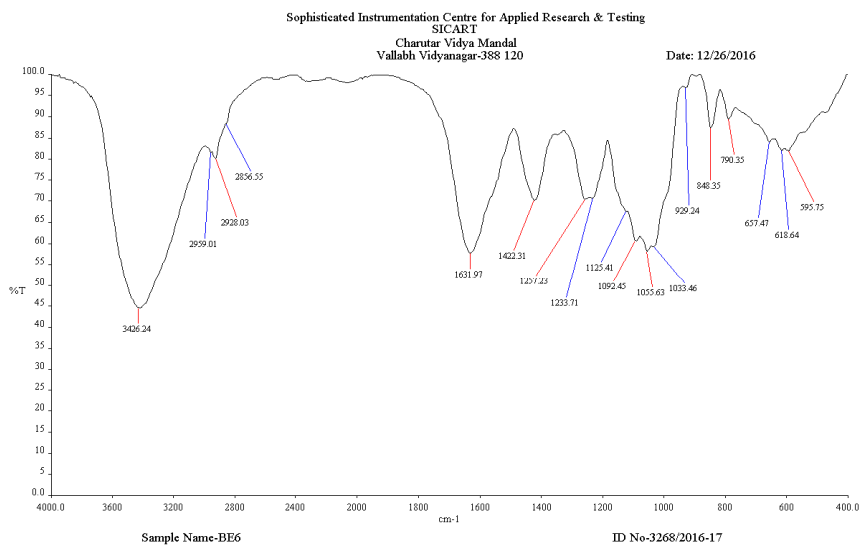


Fig-20 Fourier transform infrared analysis (FTIR) of *Ulva lactuca* treatment with E6 effluent

CONCLUSION

Physico-chemical analysis of the effluents in *Caulerpa racemosa* indicates potential decrease in total dissolved solids, total suspended solid, sulphate and phosphate in E1 effluent. In *Ulva lactuca* it shows potential decrease in total dissolved solid, color, phosphate and total organic carbon in all effluent samples. The optimum pH was found 7 to 9.5 for best results. In the study of tolerance concentration of effluent on biomass revealed that with increasing concentration the rate of adsorption decreases which causes decreasing rate of decolorization. The biochemical response of accumulated algae indicates with increasing effluent concentration the biochemical content of seaweed decreases. The Fourier transform infrared study reveals the accumulation of dye effluents component inside the algal cells functional groups. Thus, this study represents the macro algae having potential capabilities for dye decolorization and these accumulated algae are applicable as source of energy generation in future.

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