

Biosorption and Equilibrium Study of Copper by Marine Seaweeds from North West Coast of India

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Abstract: Biosorption by algae have been an effective process for the removal of heavy metals from the aqueous solutions. The present work deals with the biosorption of Cu^{2+} by seaweeds (*Sargassum tenerrimum*, *Iyengaria stellata*, *Lobophora variegata*, *Halimeda tuna*, *Cystoseira indica*, *Sargassum cinereum* and *Ulva lactuca*) in batch system. The biosorption efficiencies of seaweeds for Cu^{2+} removal was studied at different pH (2-6), metal concentration (10-50 mg/l), time (0-24 hrs) and biomass dosage (1-10 g/l). Langmuir equilibrium study was used to obtain maximum metal uptake capacities of biomass and Freundlich equilibrium study to explain the heterogeneity of the biomass. At optimum pH (pH 5) and optimum biomass dosage (10 g/l), *U. lactuca* showed maximum Cu^{2+} metal uptakes of 60.97 mg/g. The study indicated that biosorption process was rapid and mostly completed within 3 hrs. FTIR study revealed that hydroxyl, carboxylic, amide and phosphate group contributed to Cu^{2+} metal and biomass interaction. Further, the present study demonstrated that *U. lactuca* can be considered as an effective biosorbent for the removal of Cu^{2+} from contaminated waste water and aqueous systems.

Keywords: Biosorption, FTIR & SEM, Heavy metals, Langmuir & Freundlich, Seaweeds.

I. Introduction

Rapid industrialization and recent urban trends on the world has led to increased disposal of heavy metals and other hazardous waste materials into the environment and water bodies. Heavy metal pollution is one of the major environmental problems across the globe. Thus removal and recovery of heavy metals from the waste water has become a priority for human health and environment.

Copper is one of the most important heavy metal used in electroplating industries and yields serious toxicological effects at higher concentration. It is known to have deposited in brain, skin, liver and pancreas in humans [1]. The secondary permissible standard for copper in drinking water is set as 1.0 mg/l by Environmental Protection Agency (EPA) in 2007. Therefore, it is very important to develop economically feasible processes to remove copper metal from waste water before being disposed of.

Various methods have been applied for the removal of metal ions from aqueous solutions which include physical, chemical and biological techniques. Conventional methods for removing metal ions include chemical precipitation, ion exchange, filtration, electrochemical treatment, evaporation, adsorption on activated carbon etc. Chemical precipitation and electrochemical treatment are ineffective when concentration of metal in aqueous solution is among 1 to 100 mg/l and also produce large quantity of sludge which causes many difficulties to treat [2].

Among various heavy metal removal techniques applied, biosorption is a most promising because biosorbent used have high uptake capacities and renewability. Biosorption is alternative technology which is cost effective and efficient for heavy metal removal. Biosorption utilizes the ability of biological materials to accumulate heavy metals from the aqueous solutions by metabolically mediated or purely physico-chemical pathways [3]. There are many advantages of biosorption technique such as low operating cost, easy availability, improved selectivity for specific metals of interest, less operating period, removal of heavy metals irrespective of toxicity, no production of secondary toxic compounds [4]. Many low cost adsorbent material had been used for the removal of copper like Sawdust [5], Lentil shell, Wheat shell, Rice shell [6], *Spirogyra* sp [7], *Ceratophyllum demersum*, Thyme leaves [8], Cotton boll [9], Peanut husk [10], Banana pith [11], Sugar beet pulp [12], Groundnut shells [13] and Tobacco dust [14].

Algae have found to be most efficient and potent biosorbent material because they have very fast growth rate and easily available worldwide. Algae contain many functional groups like amino, hydroxyl, sulphate and carboxyl which can bind with metal ions. They are associated with poly saccharides present on the cell wall surface such as fucoxanthin and alginic acid and various other proteins for binding with metal pollutants [4]. Many macroalgal species have proven to be efficient for the removal of heavy metals from waste waters. Thousands of algal species have been known even though some of the species have been investigated for

their ability to remove metals from the contaminated water. Marine algae are considered as biological resources found in many areas of world. The use of biomass of marine algae *Chaetomorpha linum* [15], *Cystoseira indica*, *Sargassum glaucescens*, *Nizimuddiniana zanardini* and *Padina australis* [16], *Corallina mediterranea*, *Galaxaura oblongata*, *Jania rubens* and *Pterocladia capillacea* [17], *Caulerpa lentilifera* [18] has been used for the removal of heavy metal ions.

In the present study investigation of the biomass of brown seaweed (*Iyengaria stellata*, *Lobophora variegata*, *S. tenerrimum*, *S. cinereum* and *C. indica*) and green seaweed (*Ulva lactuca* and *Halimeda tuna*) have been used as a biosorbent material to remove copper from the aqueous solutions.

II. Material & Methods

2.1 Biomass Preparation

Different seaweed samples (*S. tenerrimum*, *I. stellata*, *L. variegata*, *H. tuna*, *C. indica*, *S. cinereum* and *U. lactuca*) were used as a biomass material for the biosorption of copper. Seaweed samples were collected in an open container from Okha seacoast, Gujarat. Samples were brought to laboratory for experimental procedures. These samples were washed thrice with tap water and then washed twice with distilled water to remove sand and other debris from the biomass. Washed samples were then dried in an oven at 60°C for 48 hrs to remove extra moisture from the seaweed biomass. This dried biomass was then grounded to powder, sieved and meshed with a mesh size of 0.2 to 0.5 mm which was used as a biosorbent for biosorption experiment.

2.2 Batch Biosorption Experiments

The reagents and chemicals used in this work were of analytical and biological grade procured from Himedia, India. Batch biosorption experiments were conducted by introducing 1 g of algal biomass into 250 ml Erlenmeyer flasks containing 100 ml of different concentration of metal solution separately. The concentration of metal solution was in the range of 10-50 mg/l.

The flasks were kept in constant shaking condition at 120 rpm for 28°C for 24 hrs. Aliquots of metal solution was withdrawn at interval of 1 hr and centrifuged at 5000 rpm for 10 min. The concentration of the copper metal in the solution was determined spectrophotometrically by neocuprine method at 620 nm [19]. The amount of metal adsorbed q (mg/g) at equilibrium was calculated using the following equation [20].

$$q = \frac{v(C_i - C_f)}{m} \quad (1)$$

Where, C_i and C_f are initial and final metal concentration (mg/l) in the solution respectively, v is the volume of the solution (l) and m is the mass of the biosorbent (g).

The Removal Efficiency (RE %) of the metal was calculated from the equation 2

$$RE = \frac{C_i - C_f}{C_i} \times 100 \quad (2)$$

Equilibrium relationship between adsorbate and adsorbent is described equilibrium isotherm, values of which are characterized by certain constants whose values express the surface properties, maximum uptake capacity and affinity of the sorbent. Equilibrium is established which indicates whether the sorption is monolayer or multilayer on a homogenous or heterogenous surface. The monolayer sorption of the sorbate on a sorbent surface having fixed temperature is represented by the Langmuir isotherm. The Langmuir isotherm describes surface homogeneity which is described as given in equation (3)

$$\text{Langmuir Isotherm: } \frac{C_e}{Q_e} = \left[\frac{1}{K_L q_m} \right] + \left[\frac{1}{q_m} \right] C_e \quad (3)$$

Where, Q_e is the amount of Cu^{2+} sorbed at equilibrium per mass of seaweed biomass (mg/g); C_e is the concentration of the dye in aqueous phase at equilibrium (mg/L); K_L is the sorption equilibrium constant; q_m is the monolayer capacity (mg/g).

The monolayer coverage is obtained from a plot of C_e/Q_e versus C_e . The slope and the intercept of the linear graph obtained from this plot give the value of q_m and K .

$$\text{Freundlich Isotherm: } Q_e = K_f C_e^n \quad (4)$$

The Freundlich equation is an empirical model that considers heterogeneous adsorptive energies on the adsorbent surface which is described by Equation (4). The Freundlich coefficients n and K_f are obtained from the plots of $\ln Q_e$ versus $\ln C_e$.

III. Results & Discussions

3.1 Effect of pH

Experiments were conducted with all seven seaweed samples for the copper biosorption in batch process. Heavy metal biosorption is pH dependent as it affects biosorbent surface charge, degree of ionization and species of biosorbent [21]. It was found that pH of the metal solution is an important parameter that affect the biosorption. Metal binding site on the cell surface and chemistry of the metal solution are both influenced by pH of the solution [22]. For pH determination, 1 g of algal biomass was added to 100 ml metal solution containing different pH range (2-6) and effect of pH on the metal was studied (Fig. 1). An experiment with different pH range concluded that maximum metal uptake was observed at pH 5 for all the seaweeds. A maximum metal uptake was observed in *U. lactuca* among all the seaweeds studied for different pH of the metal solution.

It was observed that as the pH of the solution increases the biosorption of copper metal increases. It is because at lower pH i.e. in acidic condition, there is competition between metal cations and positive ions (H^+) which inhibit the binding of metal biosorption [18, 23-26]. At low pH, the concentrations of positive ions (H^+) increases in the metal solution which binds on the ligands (active sites) on the surface of the seaweed biomass which restricts the metal cations binding on the cell surface saturating the cell surface with hydrogen ions and leave the metal ions free in the solution. At higher pH, the concentration of protons (positive charge hydrogen ions) becomes gradually low and so there is less competition between protons and metal ions in the solution. As a result more metal ions bind to the free binding sites on the cell surface of the seaweed biomass and hence increase the biosorption or metal removal efficiency. A decrease in the adsorption capacity was observed at higher pH values (pH 6 to 9). This reduction in the absorption capacity could be due to the copper precipitation beyond pH 6. The similar kind of results has also been suggested by several researchers [27-29]. Hence, the range for the pH optimization study was selected between pH 2 to 6.

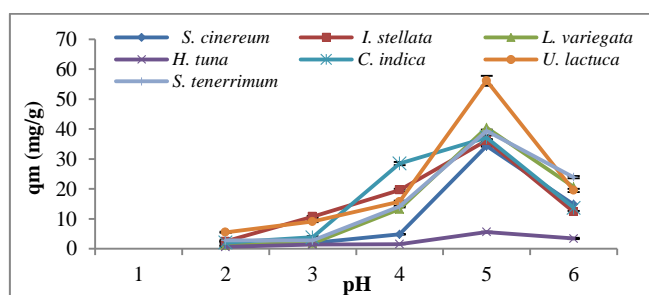


Fig. 1 Effect of pH on removal efficiency by seaweeds (biosorbent dosage = 10 g/l; initial metal concentration = 50 mg/l; agitation speed = 120 rpm and contact time = 24 hrs)

3.2 Effect of biosorbent dosage

Biosorbent dosage has a great influence on the biosorption process. The potential of biomass is determined as number of available binding sites present on the biomass surface to remove metal ions in the solution. The effect of biomass dosage in biosorption on heavy metal ions was studied in the range of 1 to 10 g/l. The effect of biomass dosage on Cu^{2+} was studied for all the seaweeds. The study showed that as the biomass dosage increases the efficiency of the biosorbent to remove metal ions also increases (Fig. 2). It is because of the available exchangeable active sites for the binding of the metal ions in the solution. The efficiency of the biosorbent was almost constant after the biomass dosage of 10 g/l. This specific activity or behaviour of the biosorption could be explained by the formation of partial aggregates of the biomass at the higher dosage which reduces the effective surface area for the biosorption [30-31].

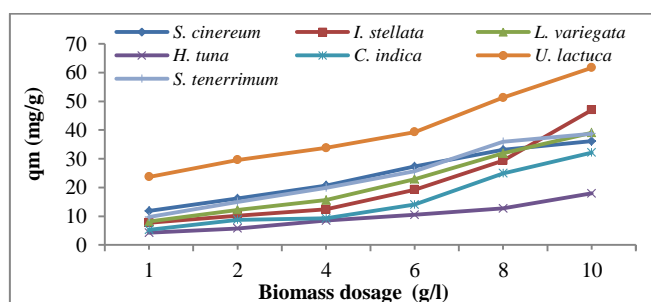


Fig. 2 Effect of biosorbent dosage on removal efficiency by seaweeds (initial metal concentration = 50 mg/l; pH = 5; agitation speed = 120 rpm and contact time = 24 hrs)

3.3 Effect of Contact Time

It is evident from the results of different metal concentration that the process of biosorption reaches the equilibrium state after approximately 120 min of contact (Fig. 3). The rate of reaction is very rapid at initial period of time and 90% of total biosorption of Cu^{2+} occurs in the first 60 min. Binding of the metal ions reaches to constant value as rate of adsorption and rate of desorption balance each other at equilibrium. Thereafter, it proceeds at a lower rate and very negligible adsorption is obtained after 6 hrs.

The maximum adsorption of Cu^{2+} occurs very rapidly within 3 hrs and then system reaches equilibrium at 6 hrs. Thus rapid biosorption occurs at the initial time of biosorption process and then very negligible biosorption is observed. It can be said that system attains equilibrium after 3 hrs where maximum biosorption was completed. After attaining equilibrium the process of adsorption is very slow or minimum adsorption occurs. Biosorption has a great influence on the contact time. As the biosorption proceeds there is a rapid adsorption of the metal ions on the algal biomass. Eventually at particular time a system reaches equilibrium where rate of adsorption and rate of desorption are equal. At this stage no further adsorption occurs or rate of adsorption are decreased [26]. The biosorption of metal ions by algal biomass acts as a function of contact time.

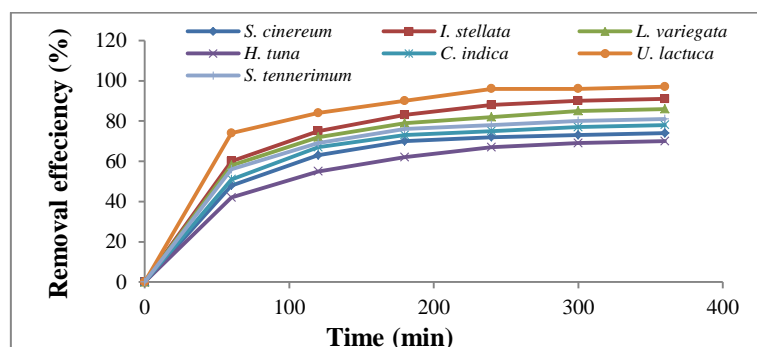


Fig. 3 Effect of contact time on removal efficiency by seaweeds (initial metal concentration = 50 mg/l; biosorbent dosage = 10 g/l; pH = 5 and agitation speed = 120 rpm).

3.4 Effect of initial metal concentration

The biosorption study as a function of initial concentration on Cu^{+2} is studied on different metal concentrations at 10, 20, 30, 40 and 50 mg/l (Fig. 4). A plodding increase in the electrostatic interactions between the copper ions and adsorbent sites was observed. As the concentration of the metal ions increases more and more adsorbent sites are being covered by the metal ions [32]. This is due to a large driving force provided between the biosorbent and biosorbate due to increase in the metal ion concentration minimizing all the other mass transfer resistances. Similar results were obtained for copper and lead on chaff by several researchers [33-34].

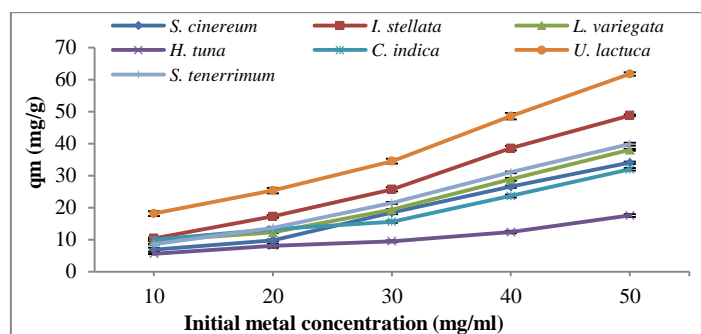


Fig. 4 Effect of initial metal concentration on removal efficiency by seaweeds (biosorbent dosage = 10 g/l; pH = 5; agitation speed = 120 rpm and contact time = 24 hrs).

3.5 Equilibrium Isotherms

Biosorption equilibrium of heavy metal on seaweeds provides information about the maximum uptake capacities of the sorbent (Table. 1). The optimization of the biosorption process becomes possible using parameters obtained from equilibrium studies. There are various mathematical models that have developed to describe sorption equilibrium, but Langmuir and Freundlich isotherms models are the most widely and accepted models used. Single ion and multi ions solution studies are possible using these models [35-39]. The simple expression of Langmuir adsorption model examines relationship between adsorbed (Q_e) and metal

concentration (C_e) at equilibrium. Langmuir sorption isotherm model for the mentioned seaweeds are shown in Fig. 5A-G and Freundlich isotherm model is shown in Fig. 6.

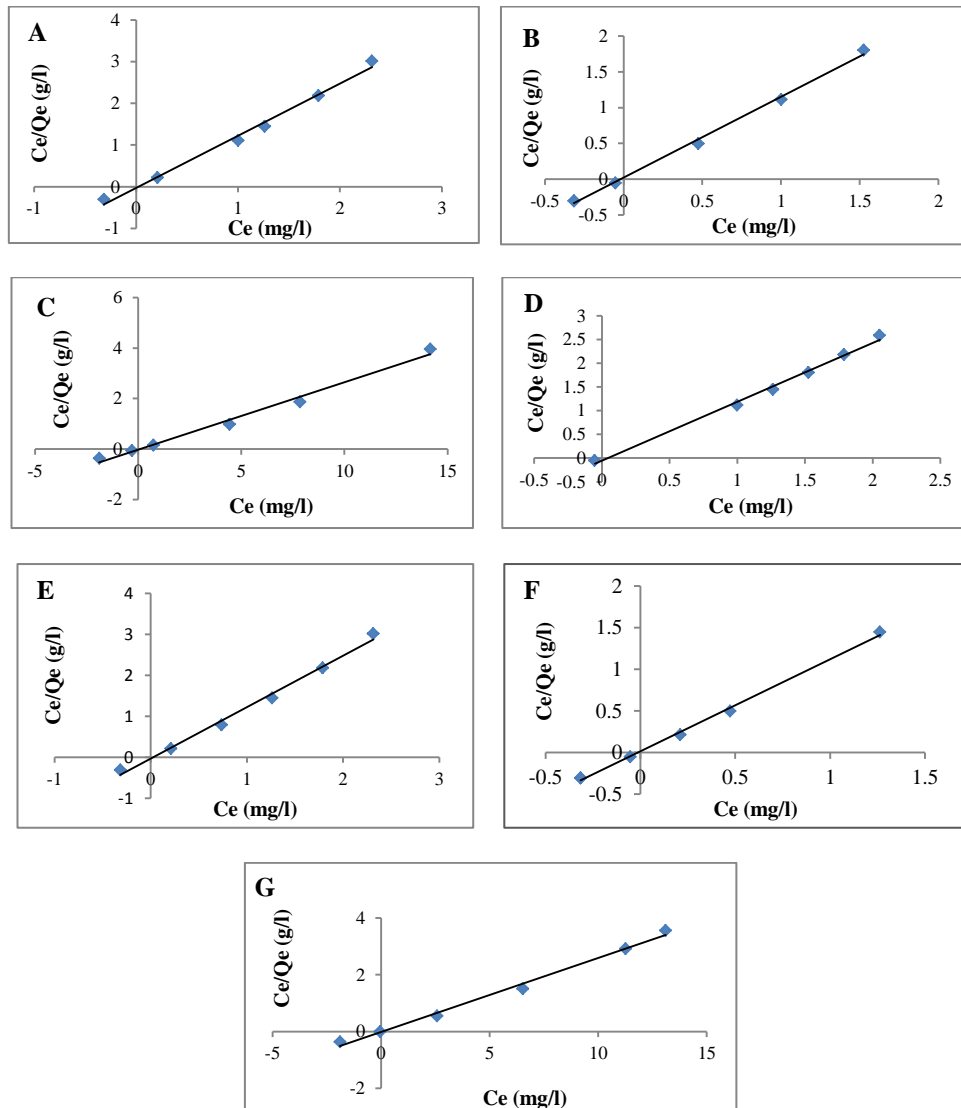
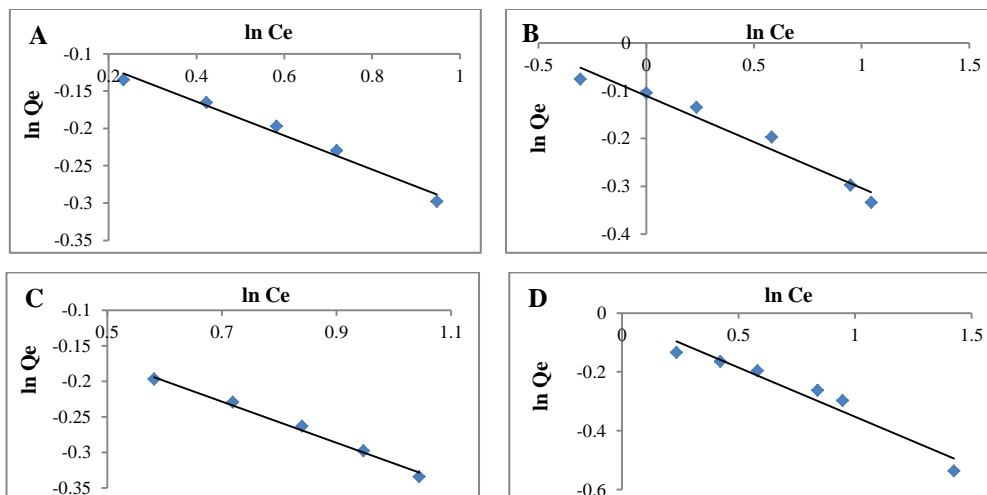


Fig 5 Langmuir isotherm of Cu^{+2} on (A) *S. cinereum*, (B) *I. stellata*, (C) *L. variegata*, (D) *H. tuna*, (E) *C. indica*, (F) *U. lactuca*, (G) *S. tenerrimum*.



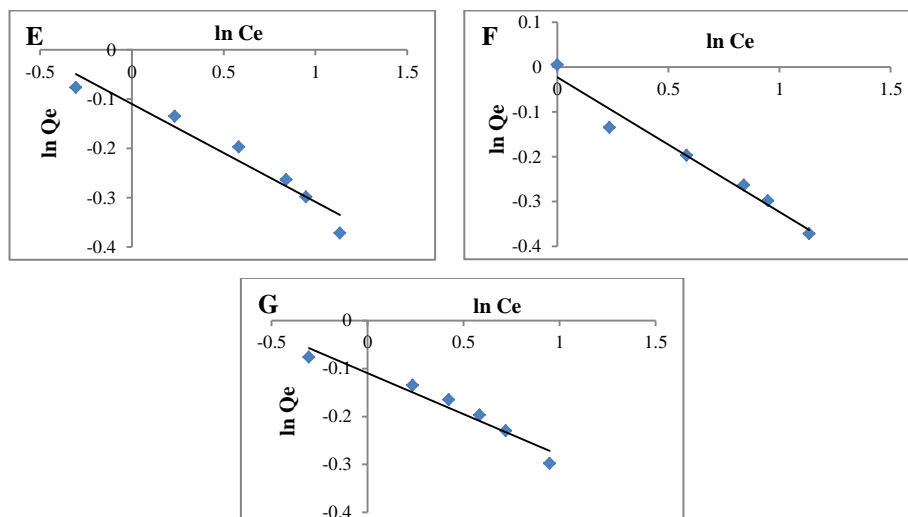


Fig 6 Freundlich isotherm of Cu²⁺ on (A) *S. cinereum*, (B) *I. stellata*, (C) *L. variegata*, (D) *H. tuna*, (E) *C. indica*, (F) *U. lactuca*, (G) *S. tenerrimum*.

Biosorption equilibrium isotherm of Cu²⁺ metal ion with different seaweed biomass at optimum conditions (pH 5, metal concentration 50 mg/l and biomass dosage 10 g/L) is shown in Fig. 5. While performing experiments it was observed that 6 hrs was found to be adequate to attain equilibrium. The maximum uptake capacity and a significant upward slope for Cu²⁺ were obtained at relatively higher concentration. Equilibrium isotherms results were fitted to linearized Langmuir isotherms equation (Eq. 3) to obtain parameters q_{max} and K_L. Despite its highly idealistic simplicity, the Langmuir isotherm remains a useful and convenient tool for comparing results from different sources on the quantitative basis. Among all the seaweeds studied the highest metal uptake q_{max} 60.97 mg/g of Cu²⁺ and K_L value 0.014 was observed in *U. lactuca*. The q_{max} and K_L value of *I. stellata*, *L. variegata*, *S. cinereum* and *C. indica* were observed to be 46.29 mg/g and 0.019, 38.02 mg/g and 0.024, 39.84 and 0.018, 30.86 and 0.025 respectively. The correlation coefficient (R²) for *U. lactuca*, *I. stellata*, *L. variegata*, *S. cinereum* and *C. indica* was found to be 0.9975, 0.9972, 0.9990, 0.9933 and 0.9926 respectively. Extremely high R² value validates the Langmuir isotherm and hence the sorption of the Cu²⁺ ions at the active binding sites on the biomass surface is considered to be monolayer biosorption [40, 18, 26]. Langmuir sorption model served to estimate the maximum metal uptake values where they could not be reached in the experiments. For good biosorbents, high q_{max} and high K_L are desirable [41]. Biosorbent with a low q_{max} and a high b could outperform a biosorbent with high q_{max} and a low b [42]. Maximum metal uptakes for Cu²⁺ for various biosorbents used are shown in Table 2.

Table 1 Isotherm constants of Langmuir and Freundlich model for Cu²⁺ biosorption on *S. cinereum*, *I. stellata*, *L. variegata*, *H. tuna*, *C. indica*, *U. lactuca* and *S. tenerrimum*.

Two parameter models	Seaweeds						
	<i>Sargassum cinereum</i>	<i>Iyengaria stellata</i>	<i>Lobophora variegata</i>	<i>Halimeda tuna</i>	<i>Cystoseira indica</i>	<i>Ulva lactuca</i>	<i>Sargassum tenerrimum</i>
Langmuir							
q _m (mg/g)	34.01	46.29	38.02	17.92	30.86	60.97	39.84
K _L	0.023	0.019	0.024	0.044	0.025	0.014	0.018
R ²	0.9920	0.9972	0.9990	0.9943	0.9926	0.9975	0.9933
SE	0.0524	0.0639	0.0561	0.0649	0.0839	0.0721	0.0808
Freundlich							
K _f	0.090	0.097	0.042	0.172	0.094	0.064	0.23
1/n	0.14	0.12	0.08	0.09	0.14	0.11	0.09
R ²	0.9810	0.9596	0.9932	0.9417	0.9404	0.9680	0.9424
SE	0.0545	0.0822	0.0566	0.1024	0.0869	0.0693	0.0762

Table 2 Maximum metal uptake values of various biosorbents for Cu²⁺ removal

Sr.No	Adsorbent material	Adsorption capacity (mg/g)	pH	References
1.	Thyme leaves	0.0464	-	[8]
2.	<i>Ceratophyllum demersum</i>	6.17	-	[8]
3.	Activated sawdust	13.495	4	[43]
4.	Sawdust (<i>basialatifolia</i>)	1.74	7.3	[5]
5.	<i>Palmaria palmata</i>	12.7	5-6	[44]
6.	Beer draff	9.01	5-6	[44]

7.	<i>Saccharomyces cerevisiae</i>	120.7	4	[45]
8.	Dehydrated Wheat Bran	51.1	5	[46]
9.	<i>Spirogyra</i> sp.	133.3	5	[7]
10.	Lentil shell	7.391	-	[6]
11.	Wheat shell	10.84 - 16.077	-	[6,47]
12.	Rice shell	17.422	-	[6]
13.	Activated carbon from <i>Adhatoda vasaca</i> stem	17.53	-	[48]
14.	Sphagnum moss peat	16.4	5	[49]
15.	<i>Sargassum tenerrimum</i>	39.84	5	Present Study
16.	<i>Sargassum cinnereum</i>	34.01	5	Present Study
17.	<i>Iyengaria stellata</i>	46.29	5	Present Study
18.	<i>Lobophora variegata</i>	38.02	5	Present Study
19.	<i>Halimeda tuna</i>	17.92	5	Present Study
20.	<i>Ulva lactuca</i>	60.97	5	Present Study
21.	<i>Cystoseira indica</i>	30.86	5	Present Study

3.6 SEM (Surface Electron Microscope Study)

SEM micrograph of the untreated *I. stellata* and metal treated *I. stellata* is shown in Fig. 7 and Fig. 8 respectively. Similarly untreated *U. lactuca* and treated *U. lactuca* is shown in the Fig. 9 and Fig. 10. The surface of untreated biomass of *I. stellata* can be observed as smooth and less grooves while in Cu^{2+} treated *I. stellata*, surface becomes more irregular and rough. Also white aggregates could be observed on the biomass. It can be observed from the SEM micrograph image of the treated *U. lactuca* that white aggregates were visible on the surface and it indicates that the Cu^{2+} were deposited on the surface of the biomass. SEM study revealed that Cu^{2+} ions were not uniformly distributed on to the surface of the biomass.

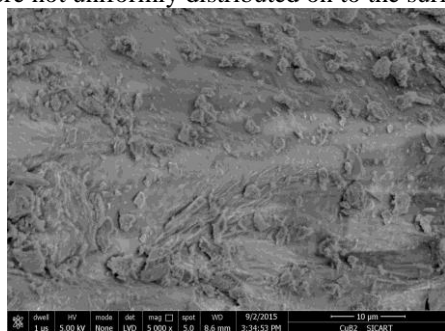


Fig. 7 SEM image of *I. stellata* (5000X) before Cu^{2+} sorption

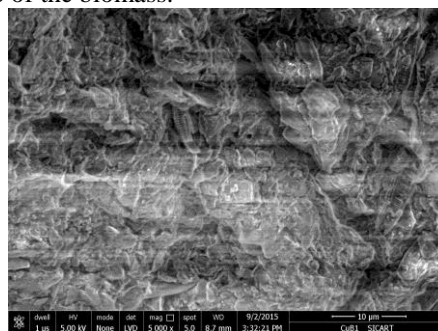


Fig. 8 SEM image of *I. stellata* (5000X) after Cu^{2+} treatment

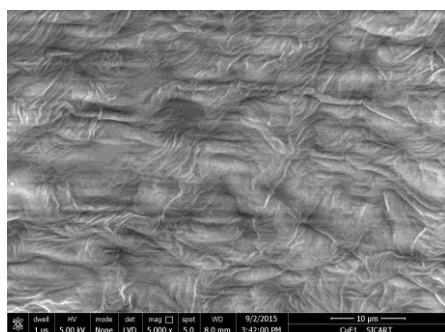


Fig. 9 SEM image of *U. lactuca* (5000X) before Cu^{2+} sorption

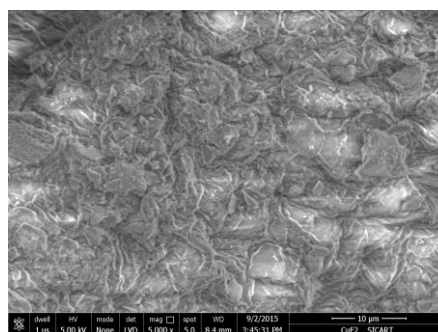


Fig. 10 SEM image of *U. lactuca* (5000X) after Cu^{2+} treatment

3.7 FTIR analysis

The FTIR spectra were used to analyse the functional group present in dried and metal loaded biomass. A shift in the wave number of major peaks is observed when comparing dried biomass with metal loaded biomass. FTIR analysis of untreated biomass (Fig. 11) and Cu treated *I. stellata* were obtained. Absorption at 3444 cm^{-1} in biomass is attributed to H-bonded, O-H stretch (Fig. 12). In the metal treated biomass, this absorption becomes broad and appears at 3434 cm^{-1} resembling strong bond and broad peak. A very weak absorption at 1785 cm^{-1} shows that $\text{C}=\text{O}$ stretch contributing the binding of general carbonyl groups with metal ions. The peak at 1632 cm^{-1} can be attributed to the $\text{C}=\text{O}$ stretching of the carboxylate group or its combined effect with N-H deformation vibration of amide groups. The asymmetric carboxyl band shifted from 1634 cm^{-1} to 1632 cm^{-1} for Cu^{2+} binding. The intensity of peak at 1467 cm^{-1} increases and a change in the band shift from 1471 cm^{-1} to 1467 cm^{-1} indicates the presence of C-H group. This change in the wave numbers indicates that metal chelating complexes are formed during biosorption [50]. The peak at 1082 cm^{-1} and 1034 cm^{-1} are due to

C-O stretching vibration of ketone, aldehydes and lactones or carboxyl groups [51]. The shift in the wave number from 1104 cm^{-1} to 1082 cm^{-1} and 1033 cm^{-1} to 1034 cm^{-1} indicates that CO vibration or involvement of phosphate group (PO_2) present in polysaccharides contribute to the biosorption process. The peak at 862 cm^{-1} and change in the wave number from 860 cm^{-1} to 862 cm^{-1} show the NH wag stretching indicating the presence of primary or secondary amines. Thus it shows that hydroxyl, carbonyl, carboxyl, phosphate groups and to a less extent amine groups are involved in the binding of Cu^{2+} with *I. stellata*.

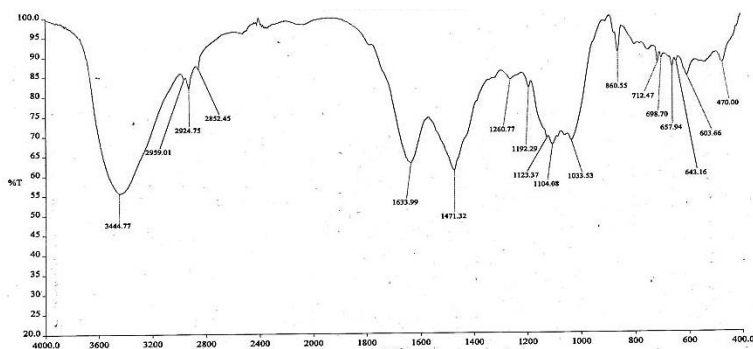


Fig. 11 FTIR analysis of untreated *I. stellata* biomass

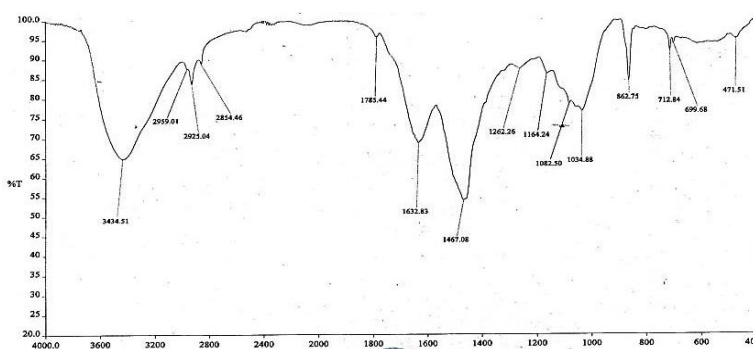


Fig. 12 FTIR analysis of Copper treated *I. stellata* biomass

FTIR spectra of copper untreated and treated on *Ulva* sp. biomass is shown in Fig. 13 and Fig. 14 respectively. The H bonded stretching vibrations in the OH moiety generally appear in the range of 3419 cm^{-1} . The shift in the wave number from 3440 cm^{-1} to 3419 cm^{-1} show interaction between metal and biomass is due to strong and broad OH stretch. A change in the intensity of the peak at 1633 cm^{-1} indicates the presence of carboxylic group due to C=O stretching. The absorption shift from 1643 cm^{-1} to 1633 cm^{-1} reflects the involvement of C=O stretch coupled with the stretching vibration of N-H group. There is a decrease in the intensity of the peak at 1421 cm^{-1} attributes to the presence of amide group formation. Thus the decrease in the wave number from 1427 cm^{-1} to 1421 cm^{-1} indicates that the metal chelates are formed during biosorption. Some shifts in the wave number from 1259 cm^{-1} to 1260 cm^{-1} and 1033 cm^{-1} to 1054 cm^{-1} were observed in the spectra are due to the CO stretching vibration of ketone, aldehyde, esters or carboxyl groups suggesting that the COO vibration and C-O-O or C-O-P groups respectively contributes to the biosorption [50].

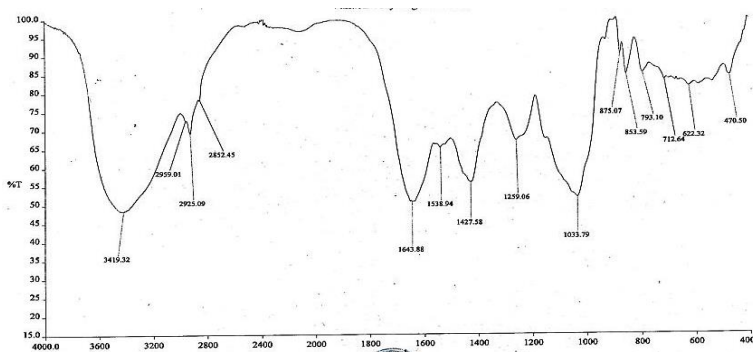


Fig. 13 FTIR analysis of untreated *U. lactuca* biomass

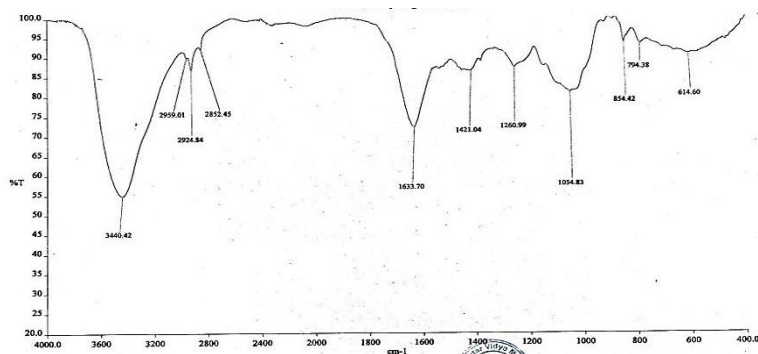


Fig. 14 FTIR analysis of Copper treated *U. lactuca* biomass

Change in the wave number from 853 cm^{-1} to 854 cm^{-1} indicates the participation of other functional groups such as sulfhydryl or sulfonates group participate in the biosorption as shifts in this wave number corresponds to the S=O stretching or S-O stretching. It seems that hydroxyl, carboxylic, amide and phosphate group and to a less extent amines and sulphonate groups are responsible for metal uptake in *U. lactuca*. Similar results were reported for the biosorption of different heavy metals on various algal species [18, 52, 26]. Thus the IR study reveals the participation and change of functional groups due to metal biomass interaction

IV. Conclusions

The biosorption of Cu^{2+} using dry biomass of seven different seaweeds was studied. The initial metal concentration, pH, biomass dosage, contact time influences the uptake of the metal ions from the dried seaweed. Maximum metal uptake was observed in *U. lactuca* and *I. stellata* of 60.97 and 46.29 mg/g respectively at pH 5. The process of the biosorption of the metal ions onto seaweeds was rapid and it was observed that equilibrium was achieved within 3 hours. The isotherm study revealed that Langmuir isotherm best fitted the biosorption. The FTIR study of *U. lactuca* and *I. stellata* showed that mainly hydroxyl, carboxylic, amide and phosphate group and to a less extent amines and sulphonate groups were involved during the process. The study indicated that the seaweed biomass can be treated as an efficient biosorbent material for the removal of heavy metals from the aqueous solution.

Acknowledgement

We thank Charutar Vidya Mandal, Vallabh Vidyanagar for providing facility and financial support to undertake the research work. Authors acknowledge the help of SICART, Vallabh Vidyanagar for analysis of data. The authors thank DR. Nilanjan Roy, Director, Ashok and Rita Patel Institute of Integrated Study and Research in Biotechnology and Allied Sciences, New Vallabh Vidyanagar, for giving the encouragement and valuable suggestions on the manuscript.

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