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Study of Biosorption and Desorption Process of Cu(II), Cr(VI), Pb(II) and Zn(II) ions by using peels of *Citrus aurantifolia*

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Abstract

Heavy metal pollution in the aquatic water bodies via the discharge of various toxic heavy metals from industrial effluents has been a major concern in the present era. Various physical and chemical processes are available to solve this problem of heavy metal pollution. Biosorption is considered as a potential alternative for the removal of heavy metals from waste waters as compared to other conventional processes. In the present work, biosorption of Cu(II), Cr(VI), Pb(II) and Zn(II) ions from aqueous solutions was carried out by using peels of Citrus aurantifolia. The peels were found to be efficient in the biosorption of all four metal ions under study. The biosorption process was found to be influenced by factors like contact time, temperature, pH, turbidity as well as biosorbent dose. Further, the change in characteristics of Citrus aurantifolia after biosorption process was studied by using E-SEM, EDAX and FT-IR analysis. The adsorption isotherm studies revealed that Freundlich isotherm model showed better fir to experimental data as compared to Langmuir isotherm model. The results were found to be significant statistically. The regeneration of biosorbent was carried out by desorption study by using certain eluents.

Keywords: Biosorption, Citrus aurantifolia, characteristics, adsorption isotherm

1. Introduction

The discharge of industrial, domestic and agricultural wastes in water bodies' cause deposit of pollutants especially heavy metals in sediments which endanger health of living organisms. These heavy metals, in abundance, can be toxic through direct action of the metal itself or through their inorganic salts or via organic compounds from which the metal can become easily detached or introduced into the cell. Some heavy metals which are hazardous to humans include lead, mercury, cadmium, arsenic, copper, zinc, and chromium [1]. Since most of heavy metals are not converted into nontoxic end products and/or remain persistent in the environment, their concentrations must be reduced to acceptable levels before discharging them into environment.

Over the decades, several methods have been devised for the treatment and removal of heavy metals from industrial effluents. These include reverse osmosis, electrolysis, ultrafiltration, ion exchange and chemical precipitation. The disadvantages of the conventional treatment methods have made it imperative for a

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cost-effective treatment process like using biological method that can remove heavy metals from aqueous effluents [2-4].

During 1970's, increasing environmental awareness and concern led to search for new methods capable of inexpensive treatment of heavy metal polluted waters. Adsorption of pollutants on solid adsorbents is an effective method used for heavy metal removal from aqueous solutions [5].

Earlier studies in environmental biotechnology have shown that many organic materials occurring in the environment have the capacity to remove heavy metals from solutions by biosorption process [6]. Biosorption may be defined as the removal of substances from solution by using biological material. Such substances can be organic or inorganic and soluble or insoluble forms [7]. Biosorption has advantages like cost effectiveness, metal selectivity, regenerative, no sludge generation and possibility of metal recovery as compared to other conventional methods [8].

The natural materials that are available in large quantities or certain waste products from industrial or agricultural operations may have potential as inexpensive biosorbents [9]. Various efforts have been made to use various agricultural waste such as rice husk [10], coconut shell [11], peanut shell [12], orange peel [13], pineapple crown [14], etc. as biosorbent to remove heavy metals from aqueous solution.In order to estimate practical or dynamic adsorption capacity, it is essential to have enough information on adsorption equilibrium which is described by adsorption isotherms. Adsorption isotherms are mathematical models which explain the behavior of adsorption species between liquid and solid phases. Langmuir isotherm model and Freundlich isotherm model are two important and commonly used isotherm models [15]. The desorption process which concentrates the metal ions that are previously adsorbed by biosorbent is also important for possible reuse of biosorbent and recovery of metal ions. Different eluents like acids, alkalis, chelating agents, etc. can be used to desorb metal ions from metal loaded biosorbents [16-18].

In the present work, an attempt has been made to explore the efficiency of peels of *Citrus aurantifolia* for the biosorption of Cu(II), Cr(VI), Pb(II) and Zn(II) ions from aqueous solutions. The effect of various factors on metal ions removal from aqueous solution was studied. Further, adsorption isotherm studies were carried out by using Freundlich and Langmuir isotherm models. The desorption process of metal ions from biosorbent was carried out by using various eluents.

2. Materials and Methods

2.1. Plant material collection, authentication and preparation

The plant material was collected from local fruit juice center. The sample was authenticated at Agarkar Research Institute, Pune (MS), India to confirm its species. The peels were washed thoroughly multiple times with tap water followed by distilled water. It was oven dried completely at 60^{o}C to remove moisture from them. Further, the peels were powdered (hereafter referred as biosorbent) and preserved in air tight container for further use. The characteristics of the biosorbent under study included colour, pH, bulk density, iodine index, moisture content and ash content.

2.2. Preparation of metal salt solution

All the chemicals used in the study were of analytical grade. Stock solutions (1000 mg/L) of metal ions *viz.* Cu(II), Cr(VI), Pb(II) and Zn(II) were prepared by dissolving required amount of respective metal salts in deionized water. The working standard solutions were prepared by diluting the stock solutions to appropriate volumes.

2.3. Biosorption process

100 mL of metal ions solution (50 mg/L) *viz.* Cu (II), Cr(VI), Pb(II) and Zn(II) ions were treated with 1 % of biosorbent in 250 mL conical flask at 30 °C and the solution was shaken at 150 rpm in an orbital shaker. After an hour, the solution was filtered using Whatmann filter paper No. 1. The aqueous solution of biosorbent under study was used as blank. The concentrations of the metal ions in the filtrate were determined by using ICP- AES (ARCOS, Simultaneous ICP Spectrometer, IIT-SAIF Bombay).

2.4. Calculation of biosorption capacity and percentage biosorption

The biosorption capacity (q_e) determines the amount of metal ions adsorbed per gram of biosorbent (Kariuki *et al.*, 2017) and it was calculated as follows:

$$q_e\ (mg/g) = (Co - Ce) * \frac{V}{m} \qquad (1)$$

Percentage of biosorption of metal ions was calculated as follows:

$$Biosorption\ (\%) = \frac{(Co - Ce)}{Co} * 100 \qquad (2)$$

Where Co is the initial metal ion concentration (mg/L)

Ce is the final metal ion concentration after biosorption process (mg/L) V is the Volume of solution (L)

m is the mass of biosorbent (g)

2.5. Factors affecting biosorption process

The effect of various factors *viz.* pH, temperature, biosorbent dosage, contact time and turbidity of aqueous solutions on biosorption process by using peels of *Citrus aurantifolia* was studied by using batch experiments.

To study the effect of pH on biosorption process, 1 g of biosorbent was added to 100 mL of aqueous solutions containing 50 mg/L of each ions *viz.* Cr(VI), Cu(II), Pb(II) and Zn(II) in 250 mL conical flasks and the biosorption process was studied at different pH *viz.* 2, 4, 6, 8 and 10 for 60 mins at 30 °C. The pH of the solution was adjusted using 1N NaOH and 1N HCl.

The biosorption process of Cr(VI), Cu(II), Pb(II) and Zn(II) ions by *Citrus aurantifolia* was studied at different temperatures by adding 1 g of biosorbent into aqueous solutions containing 50 mg/L of four metal ions under study and incubating the solutions at different temperatures *viz.* 10, 30 and 50 °C for 60 mins at pH 8.

The effect of biosorbent dose was studied by adding different doses *viz.* 0.5, 1, 2 and 3 % of biosorbent to 250 mL conical flasks containing 100 mL solutions of 50 mg/L of each metal ions *viz.* Cr(VI), Cu(II), Pb(II) and Zn(II) at pH 8 and the biosorption process was carried out for 60 mins at 30 °C.

The effect of contact time on biosorption process was studied by adding 1 g of biosorbent to 100 mL of aqueous solutions containing 50 mg/L of Cr(VI), Cu(II), Pb(II) and Zn(II) ions at pH 8 and the biosorption process was carried out for different time period *viz.* 60, 120 and 180 minutes at 30 °C.

1 g of biosorbent was added into 100 mL of aqueous solutions having different turbidity and containing 50 mg/L of Cr(VI), Cu(II), Pb(II) and Zn(II) at pH 8 and biosorption process was carried out for 60 minutes at 30 °C. The turbidity of the

solution was adjusted to 10, 50 and 100 NTU using hexamine and hexamethylene sulphate mixture.

The aqueous solutions containing the biosorbents (blank) were kept under same conditions in all the above experiments for reference. All the solutions were subjected to shaker conditions at 150 rpm in an orbital shaker. After the biosorption process all the solutions were filtered by using Whatmann filter paper No. 1 and the filtrates were analyzed for residual metal ions by using ICP-AES (ARCOS, Simultaneous ICP Spectrometer, IIT- SAIF Bombay). All the experiments were performed in triplicates and percent biosorption of the average values were reported.

2.6. Characterization of biosorbent:

The physical and chemical properties as well as surface characteristics of untreated biosorbent were studied. The change in the surface characteristics of biosorbent after treatment with metal salt solutions were analyzed as follows:

For Environmental Scanning Electron Microscope (E-SEM) analysis, the biosorbent was placed on the sample stub and dried under IR light for 2-3 minutes followed by platinum coating for 600 seconds using JEOL JFC-1600 Auto fine Coater. The biosorbents were then scanned using E-SEM (FEI QUANTA 200 E-SEM, IIT- SAIF Bombay) operated at 15 kV under different magnifications.

Energy Dispersive X-ray Analysis (EDAX) in conjunction with Scanning Electron Microscope was used to perform elemental analysis of the biosorbent. The energy of the beam was used in the range of 10-20 keV. This causes X-rays to be emitted from the irradiated material. The X-rays were generated in a region about 2 microns in depth. By moving the electron beam across the biosorbent, a 2-D (two dimensional) image of each element present in the biosorbent was acquired. The EDAX analysis of biosorbent was carried out at IIT- SAIF Bombay.

Fourier Transform InfraRed (FT-IR) Spectroscopy was used as a qualitative technique to assess the presence of functional groups on the surface of the biosorbent. The study was carried out by using potassium bromide (KBr) disc method. The spectrum of the biosorbent was measured within range of 400 to 4000 cm^{-1} wavenumbers. The biosorbent was mixed with KBr in the ratio of 1:10 and was converted into pellet. The FT-IR spectrum was recorded on a FT-IR spectrophotometer (FT/IR 4100 type A C208161016, Nanotechnology Research Centre, B. K. Birla College, Kalyan.) using a standard light source and TGS detector.

2.7. Study of adsorption isotherm

The equilibrium relationship between the metal ions concentration in the aqueous solution and on the biosorbent at 30 ^{o}C was studied by using Langmuir and Freundlich adsorption isotherm models. The amount of adsorbate (metal ions) per unit weight of adsorbent (biosorbent) against the equilibrium concentration of the adsorbate remaining in solution was plotted for each metal ions concentration. The linearized graph of log q_e versus log C_e was plotted for Freundlich isotherm while C_e/q_e versus C_e was plotted in the case of Langmuir isotherm. The parameters for both the isotherms were calculated by using Microsoft excel 2010.

The linear form of the Langmuir equation can be expressed as follows:

$$C_e/ q_e = (1/ q_m) * Ce + 1/ (b\ q_m) \qquad (3)$$

Based on the further analysis of Langmuir equation, the dimensionless parameter of the equilibrium known as separation factor (R_L) is expressed by:

$$R_L = 1 / (1 + b\, C_o) \qquad (4)$$

where C_o is the initial concentration of metal ion (mg/L)
C_e is the equilibrium concentration of metal ion (mg/L)
q_e is the amount of the metal ions adsorbed (mg/g) per unit mass of the biosorbent q_m and b are Langmuir constants evaluated from slope and the intercept respectively
The R_L parameter is considered as a reliable indicator of the adsorption process. R_L value between 0 to 1 indicates favorable adsorption condition [17,19].
The linearized Freundlich equation can be expressed as follows:

$$\log q_e = \log K_f + \frac{1}{n} \log C_e \qquad (5)$$

Where K_f is an indicator of adsorption capacity n is the adsorption intensity

The constant 'n' gives an idea of the grade of heterogenicity in the distribution of energetic centers and is related to magnitude of adsorption driving force. The 'n' values between 2 to 10 indicate good adsorption condition [20-23].

2.8. Statistical analysis

Chi-square test was applied to the data collected from the experiments conducted for the metal ions removal from the metal salt solutions having initial metal ions concentration of 10 to 50 mg/L by using 1 % biosorbent dose at pH 8. The two main parameters used in this test were experimental value obtained for biosorption capacity (q_{exp}) and biosorption capacity calculated from model (q_{calc}).

The Chi-square (χ^2) test can be calculated as follows:

$$\chi^2 = \frac{(qe\ exp - qe\ cal)^2}{qe\ cal} \qquad (6)$$

Where $q_{e\ exp}$ (mg/g) is the equilibrium capacity obtained experimentally
$q_{e\ cal}$ (mg/g) is the equilibrium capacity obtained by calculation from the model.

If the data from the model are similar to the experimental data, the value of χ^2 will be small and if they differ, χ^2 value will be larger [24,25].

2.9. Desorption process

For the study of desorption process, 2 g of air dried biosorbent loaded with metals ions *viz.* Cu(II), Cr(VI), Pb(II) and Zn(II) (hereafter referred as metal ions loaded biosorbent) was transferred to flasks containing 100 mL of desorbing agent (eluant) *viz.* 0.1 M HNO_3,
0.1 M EDTA, 0.1 M NaOH and deionized water. The solutions were agitated at 100 rpm
in a rotary shaking incubator (Remi Orbital Shaking Incubator, CIS 24 BL) at 30 °C for 2 hrs followed by filtration by using Whatmann filter paper no. 1. The concentrations of metals ions released in the desorbing agent were determined by using ICP-AES (ARCOS, Simultaneous ICP Spectrometer, IIT Bombay (M. S.).

3. Results and Discussion

The plant material was authenticated and was found to be the peels of Citrus aurantifolia. Figures 1a and 1b shows dried and powder form of peels of Citrus aurantifolia respectively.

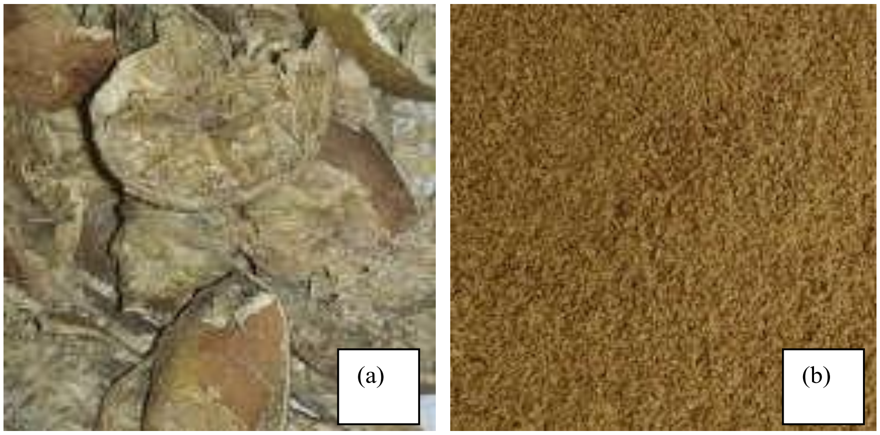

Figure 1. Peels of *Citrus aurantifolia* in (a) dried (b) powder form

It has been reported that the pH of biosorbents in the range of 6-8 can be used for many applications [26-27]. The bulk density less than 1.2 g/mL represents that biosorbents are fine in nature [28]. Iodine Index for commercial adsorbent ranges from 300 to 1200 mg/g [29]. By comparing the above data with the values of characteristics shown in table 1, it can be observed that peels of *Citrus aurantifolia* may have good adsorption properties.

Table 1: Characteristics of powder peels of *Citrus aurantifolia*

Characteristics	Values
Colour	Yellow
Moisture content (%)	6.36
pH	6.21 ± 0.25
Ash content (%)	6.6667
Bulk density (g/mL)	0.3233 ± 0.13
Iodine Index (mg/g)	442.69

The percent biosorption and biosorption capacity (mg/g) by the biosorbent are shown in table 2. The peels were found to be more efficient in the biosorption of Pb(II) and Cr(VI) ions as compared to Zn(II) and Cu(II) ions from the aqueous solution.

Table 2: Percent biosorption and biosorption capacity of peels of *Citrus aurantifolia*

Metal ions	% biosorption	Biosorption capacity (mg/g)
Cu(II)	55.79	2.30
Cr(VI)	80.2	5.31
Pb(II)	89.83	6.12
Zn(II)	61.26	2.55

The biosorption process was found to be affected by various factors.

3.1. Effect of pH:

As the pH of the solution increases, the concentration of H^+ ions in the solution reduces. Hence pH towards alkaline range indicates that the number of H^+ ions is less which decreases the competition between proton and metal ion. Thus, increased pH is an indication that the ligand is available for metal ion binding and so biosorption is enhanced [30]. In the present work it was observed that as the pH of the aqueous solution increased from 2 to 8, the biosorption process by peels was found to increase but further increase in pH to 10 led to reduction in the biosorption process of all four metal ions under study (Figure 2).

3.2. Effect of temperature:

According to adsorption theory, adsorption decreases at higher temperature and molecules adsorbed earlier tend to desorb from the surface at elevated temperature [31]. This may be due to the fact that when the temperature of the solution increases, the attractive forces between biomass surface and metal ions are weakened and adsorption process declines.

[32] Showed that the biosorption process of Cd (II) and Ni (II) ions by using *Glycine max* pod decreased with increase in temperature from 35 to 50 ^oC. In the present work, the biosorption process was found to increase with the rise in temperature from 10 to 30 ^oC but further increase in temperature to 50 ^oC showed marginal changes in biosorption process by the biosorbent under study (Figure 3).

3.3. Effect of biosorbent dose:

The dose of biosorbent (0.5 to 3 %) was found to be a factor influencing biosorption process. It was observed that as the dose of the biosorbent increased from 0.5 to 1 %, the biosorption process was increased. This may be due to the fact that increasing dose of biosorbent increases the number of active sites on biosorbent to bind to metal ions but further increase of biosorbent might lead to crowding of biosorbents and making them unavailable to bind to metal ions (shell effect). The decrease in biosorption with increase in biosorbent dosage to 3 % might have been due to shell effect (Figure 4).

3.4. Effect of contact time:

The biosorption capacity of the biosorbent for metal ions *viz.* Cu(II), Cr(VI), Pb(II) and Zn(II) were found to increase with rise in contact time from 60 to 180 minutes (figure 5). This may be because of the increase in time duration for the metal ions to bind to the active sites on the biosorbent. Similar result was observed by [33] in which they showed that biosorption process enhanced with increase in contact time.

3.5. Effect of turbidity:

The efficiency of biosorption process was found to decrease with increase in turbidity from 10 to 100 NTU of the aqueous solution. The decrease in the biosorption process may be due to the adsorption of positively charged metal ions to the negatively charged ions present in the turbid solution, thereby rendering them unavailable for the biosorption process (Figure 6). Geoffrey *et al*., [34] observed that as turbidity of aqueous solution increased from 20 to 50 NTU, the biosorption process of Ni(II) and Pb(II) ions by using *Moringa oleifera* seed was reduced.

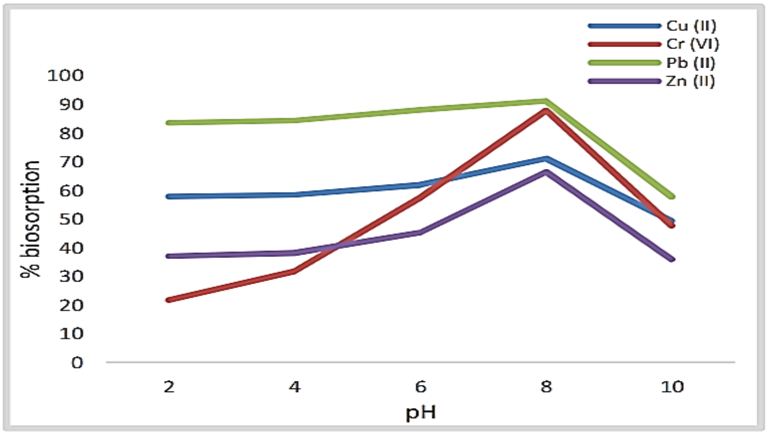

Figure 2. Effect of pH on Bio sorption process

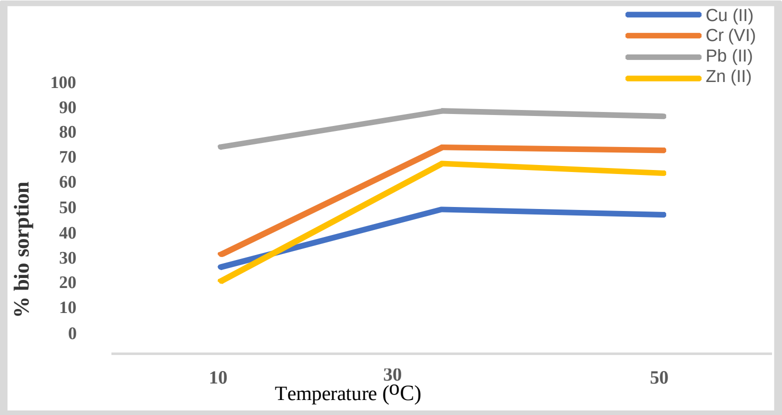

Figure 3. Effect of temperature on bio-sorption process

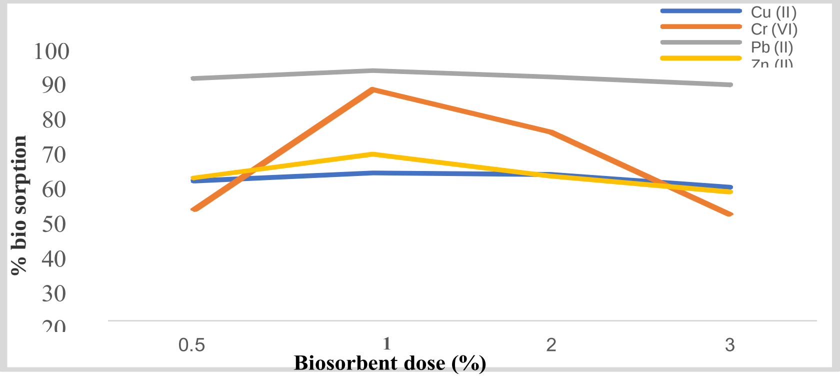

Figure 4. Effect of biosorbent dose on biosorbent process

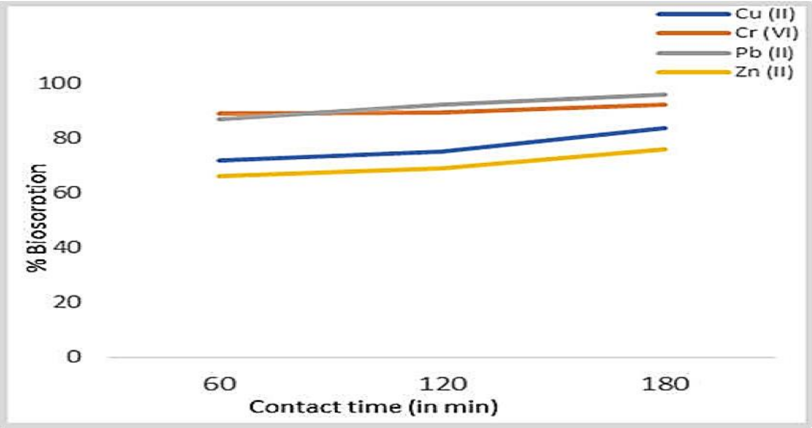

Figure 5. Effect of contact time on biosorption process

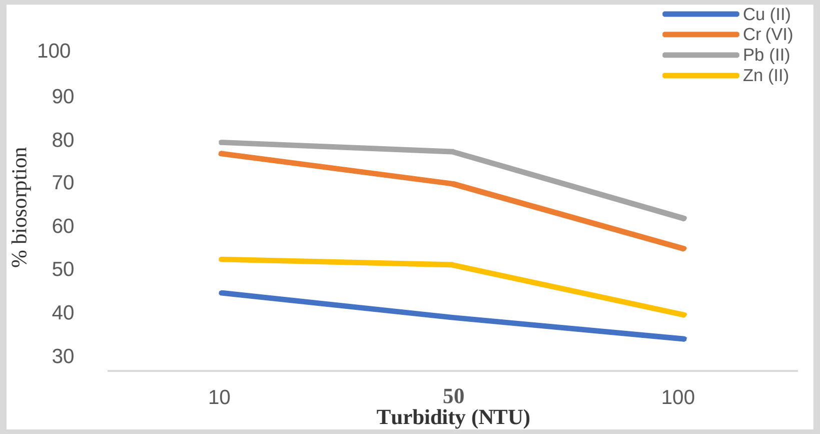

Figure 6. Effect of turbidity on biosorption process

The surface morphology of biosorbent showed more roughness after biosorption process (Figure 7b) as compared to its surface before biosorption (Figure 7a). The roughness may be due to the interaction and deposition of metal ions on the surface of bio-sorbent. Hence, the surface morphology of bio-sorbent are modified after treatment with metal salt solutions.

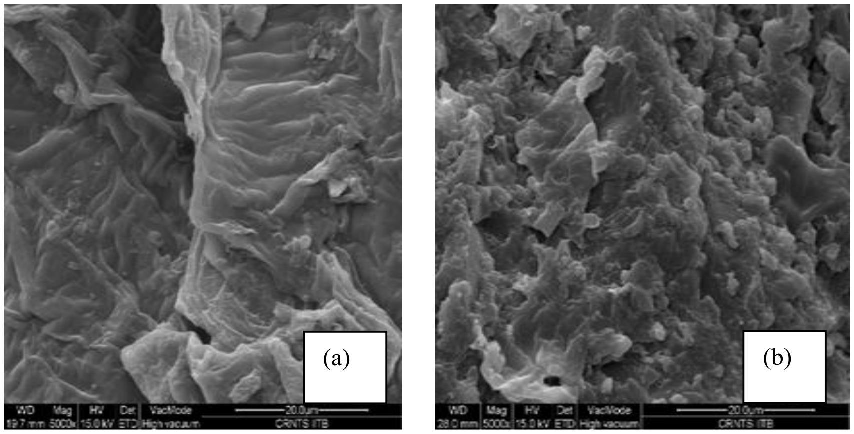

Figure 7. E-SEM images of bio-sorbent (a) before (b)after treatment

The SEM-EDAX analysis confirmed the deposition of metal ions on the surface of the biosorbent as the weight (%) of the heavy metals *viz.* Cu, Cr, Pb and Zn was detected after biosorption process (Figure 8b). Cu (0.32 %) which was detected on the biosorbent before biosorption process (Figure 8a) was found to increase after biosorption process. This indicates that biosorption has taken place. Further the weight (%) of lead was found to be maximum as compared to other three heavy metals under study.

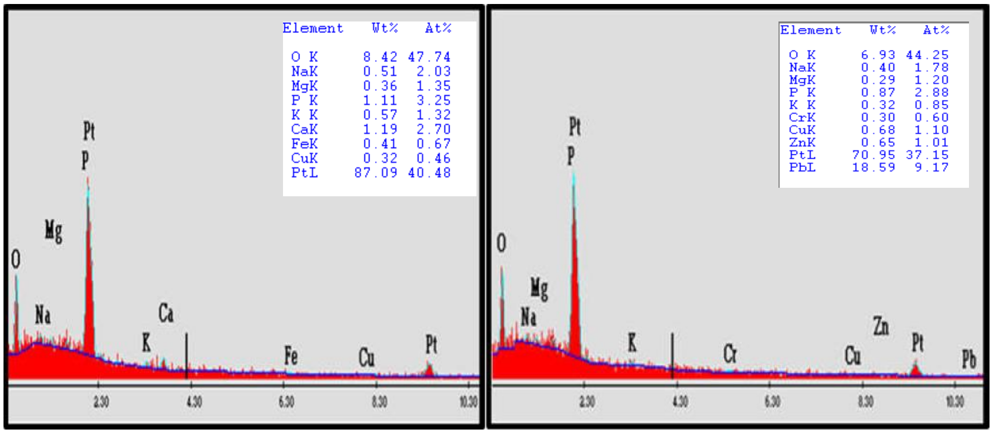

Figure 8. EDAX images of biosorbet (a)before (b)after treatment

FT-IR spectroscopy was used to obtain information about functional groups present on the biosorbent. Figures 9a and 9b represent the FT-IR spectra of untreated and treated biosorbent respectively. Table 3 represents the location wavenumbers and corresponding vibration and functional groups on the biosorbent.

Table 3: FT-IR spectrum analysis of biosorbent

Sr. No.	Location wavenumber (cm^{-1})	Vibration	Functional group
1	3845.36	O-H stretching	hydroxyl groups and alcohol
2	3773.05	O-H stretching	hydroxyl groups and alcohol
3	3435.56	O-H stretching	hydroxyl groups and alcohol
4	2925.48	C-H stretching asymmetrical	alkane
5	2347.91	N-H	ammonium ions
6	2227.38	$-C\equiv C-$ Stretching	alkynes
7	1640.16	C=O stretching COO- stretching	amide I, carboxylates aromatic ring modes, alkenes
8	1563.02	$-NO_2$ groups	nitro-groups
9	1412.6	C-C stretching (in ring)	aromatic
10	1020.16	-C-H plane bending	aromatic
11	928.557	O-H bend	carboxylic acids

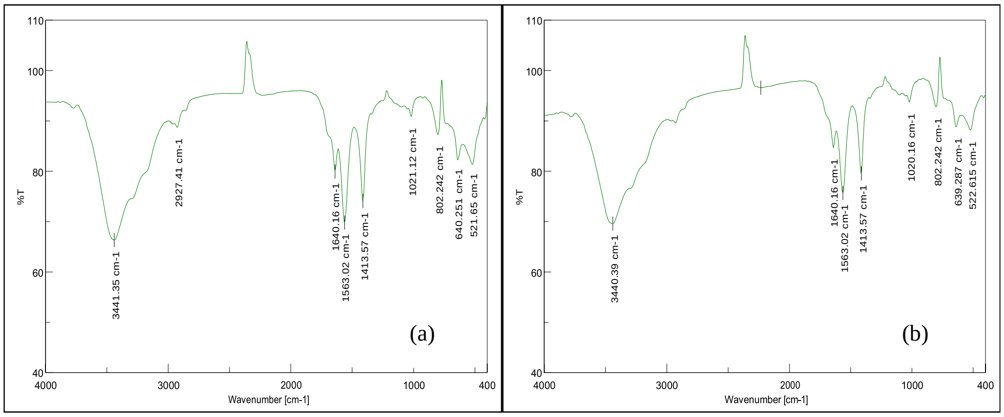

Figure 9. FT-IR spectra of biosorbent (a) untreated (b) after treatment

Considerable changes in the wavenumbers were not observed in most of the cases after the biosorption process. It may be because the electrostatic interactions between metal ions and functional groups were not strong enough to shift the absorption band frequencies or wavenumbers related to the functional groups present on the biosorbent surface. It indicated that there might be weak coordination between the metal ions and functional groups on the surface of biosorbents [35]. The analysis of equilibrium data is very important to develop an equation which precisely represents the results and it can be used for design purposes [36]. In the present work, the experimental equilibrium data (q_e values) was investigated by using mathematical models *viz.*

Freundlich and Langmuir isotherm models. The line regression equations of both isotherm models for Cr(VI), Cu(II), Pb(II) and Zn(II) ions were determined by using Microsoft Excel 2010 and is reported in table 4. The equilibrium parameters for both the models were calculated as shown in table 5.

Table 4: Line regression equations for Freundlich and Langmuir adsorption isotherms by using lemon peels as biosorbent

Metal ions	Line regression equation for isotherm models	
	Freundlich isotherm	Langmuir isotherm
Cu(II)	y = 0.307x + 0.4762	y = 0.0922x + 0.6735
Cr(VI)	y = 0.4138x + 0.4187	y = 0.0623x + 0.8318
Pb(II)	y = 0.416x +0.3569	y = 0.0797x + 0.845
Zn(II)	y = 0.2129x + 0.64	y = 0.121x + 0.0607

Table 5: Equilibrium parameters for Freundlich and Langmuir isotherm models

Metal ions	Freundlich isotherm model				Langmuir isotherm model			
	K_F (L/g)	1/n	n	R^2	q_m	b (L/g)	R_L	R^2
Cu(II)	2.9936	0.307	3.2573	0.911	10.8460	0.1369	0.2321	0.905
Cr(VI)	2.6224	0.4138	2.4166	0.7838	16.0514	0.0749	0.3420	0.5929
Pb(II)	2.2746	0.416	2.4038	0.8366	12.5471	0.0943	0.2998	0.7949
Zn(II)	4.365	0.2129	4.9670	0.7145	8.2645	1.9934	0.0222	0.9885

Since the value of ‘n’ lied between 2 to 10 and value of R_L lied between 0 to 1, it indicates good adsorption of all metal ions under study by the peels of *Citrus aurantifolia*. The analysis was supported statistically using Chi-square test. The calculated values of Chi-square test are shown in table 6.

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Table 6 : Chi-square test values for metal ions under study

Metal ions	Isotherm model	
	Freundlich	Langmuir
Cu(II)	0.3014	1.4564
Cr(VI)	1.8271	3.9638
Pb(II)	0.9283	2.2396
Zn(II)	0.7552	0.8822

The Chi-square values of Freundlich isotherm model for Cu(II), Cr(VI) and Pb(II) and Zn(II) were found to be less as compared to Langmuir isotherm model values. This indicates that Freundlich isotherm model showed good fit for experimental data for biosorption of metal ions under study by using peels of *Citrus aurantifolia* as biosorbent. Desorption step is very important in the adsorption process, as it can improve efficiency and economy of removal of metal ions from wastewater. The desorption capacities of agents *viz.* 0.1 M HNO_3, 0.1 M NaOH, 0.1 M EDTA and deionized water (D/W) from biosorbent loaded with metal ions *viz.* Cu(II), Cr(VI), Pb(II) and Zn(II) were observed and calculated. In figure 10, it was observed that the removal of all four metal ions was almost negligible by using deionized water as compared to other desorbing agents under study. Hence, deionized water was considered as noneffective desorbing agent (eluant). The chelating agent (EDTA) showed maximum desorption of metal ions *viz.* Cu(II), Cr(VI), Pb(II) and Zn(II) from biosorbent. The desorption of Pb(II) ions was found to be more as compared to other three metal ions under study. Further the desorption process was found to be better by NaOH as compared to HNO_3. Desorption process studied by [37] showed similar result in which EDTA was found to be effective as a desorbent for the recovery of Pb(II) ions from green algae *Cladophora fascicularis*.

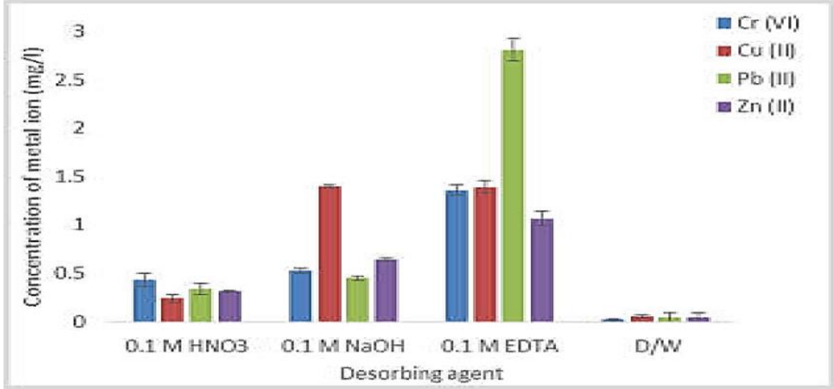

Figure 10. Desorption of metals ions from peels of *Citrus aurantifolia*

4.0. Conclusion

The peels of *Citrus aurantifolia*, an agricultural waste can be considered as a good biosorbent for removing Cu (II), Cr(VI), Zn(II) and Pb(II) ions from aqueous solution. The result was supported by adsorption isotherm studies. The desorption process revealed that the we can regenerate the biosorbent under study for further cycles of adsorption- desorption process along with possibility of recovery of metal ions. The application of present biosorbent for the removal of metal ions from industrial effluents can create an ecofriendly and cost-effective process which is the need of the day.

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