

A Thesis

On

BIOSORPTION OF CHROMIUM (VI) USING ORANGE PEEL

For partial fulfilment of the requirement for the degree of

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In

Chemical Engineering

Submitted by:

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National Institute of Technology Rourkela

CERTIFICATE

This is to certify that the thesis entitled “**Biosorption of chromium (VI) using orange peel**” submitted by **Giriraj Angoria Roll No.-111ch0409** in partial fulfilment of the requirement for the award of degree of Bachelor of Technology in Chemical Engineering at National Institute of Technology Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of knowledge, the matter included in this thesis has not been submitted to any other university or institute for the award of any degree.

Date: 10th May 2015

Place: Rourkela

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ABSTRACT

In this work sorption potential has been explored by using orange peel from the local market as a bio sorbent by the removal of the heavy metals mainly chromium (VI). Bio-sorbent was prepared following the standard physical and chemical operations. It was planned to find the effect of the contact time, temperature, solution pH, initial metal concentration on the kinetic isotherm. For the stock solution of Cr (VI) ion $K_2Cr_2O_7$ is used. From the UV-Vis spectrophotometer the absorbance is measured and calibration curve is plotted and using that curve final concentration is determined. The experiment is performed at room temperature. The analysis part shows that the UV-Vis absorbance reading after the sorption is more than the calibration reading.

Keywords: orange peel, chromium, biosorption, UV-Vis spectrophotometer

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Because of increased urbanization as well as industrialization a large amount of toxic contaminants especially heavy metals are generating day by day. In the recent years the removal of heavy metals from industrial effluents has pulled in the increasing attention from the scientific group. The presence of heavy metals in wastewater are hazardous and unsafe to the nature and hence their removal before the discharge of waste water has become necessary [1]. These heavy metals are stable and persistent ecological contaminants because they are not degradable [2]. Among heavy metals Chromium is one of the toxic metals frequently found in waste water discharged from industries like textiles, leather tanning, and electroplating, metal finishing. A large amount of heavy metal containing effluents have been producing by the tanning process industries in all over the world. Chromium tanning process is more economical .more efficient and faster than the other conventional process which is making ultimately more use of the chromium and eventually higher amount of discharge of this metal to the environment. Out of all the oxidation number that can exist by chromium metal only chromium (III) and chromium (VI) are stable and only ions that occur in nature [3]. The hexavalent chromium ion in compare to trivalent chromium ion is more soluble, more dangerous and has higher mobility. Chromium mainly present in food, air, water and soil in trivalent form. Soil contains some amount of Cr (VI) which can be removed to the surface water because it is soluble as compared to other chromium ion that exists in nature in stable form.

Inhalation and retention of Cr (VI) containing material can be harmful to internal organs [4]. There is chance of skin disease due contact of skin with the chromium (VI) [5].

Numerous conventional methods like precipitation, resin chelation, electrochemical deposition, ion exchange, coagulation and solid-phase extraction have been used for the removal of the these heavy metals[6]. However these techniques have many disadvantages like removal of metal ion is not so efficient, a high amount of suitable reagent and energy is required and large amount of sludge production which is also toxic in nature [7]. Hence, more economical alternative methods compare to conventional methods got more attraction for the removal of these toxic metals from effluent and waste water coming from the many industries. So the process that has developed to overcome all the drawbacks of the conventional process got a name biosorption which was assumed to be more economical and efficient [8].Bio-sorption is basically a adsorption process which compromise of two phase one is liquid phase that is sorbate and the other one is sorbent. In this process non-living things serves as a bio sorbent which has high affinity towards the metal ion. The Biosorption

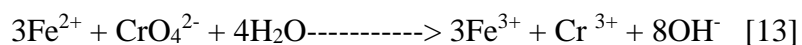
process function in two steps one is metal up taking which is fast because of physical sorption and the other one is assumed to be slower than the former one due to chemical sorption [9]. Metals that are not easily removed by the conventional methods can be efficiently remove by the biosorption method. Low cost, high efficiency, minimization sludge and regeneration of biosorbent and Metal recovery are some of the main advantage over the conventional water treatment method [10].

In recent years, many work has been done and also many test has been done on the agriculture waste products to remove these metal ion from the waste water at pilot and large scale also. Because of the leaching of organic compounds such as, cellulose lignin, pectin into solution during the biosorption has limited the utilization of these waste products but many work has done to overcome this problem like one is chemical modification. Chemical modification on solid biomasses has become more appropriate method to improve their biosorption capacity of up taking than heavy metals from the solution or waste water [11]. Like other waste material orange peel also contain some components such as cellulose, pectin, hemicellulose and lignin which serves as a ligant to bind metal ion present in the solution. Higher the no of the responsible functional group leads to the high metal removing ability. The easy availability and cheapness of orange peel pull the attraction of process developers and the researchers which presents the biosorption process more precisely [12]. The objective of this work is to perform biosorption process using orange peel to remove the form the solution and also study the effect of the chemical modification of the orange peel on metal removal efficiency and also to observe the effect of different pH on performance of the biosorptio process.

1.2 CONVENTIONAL WASTE WATER TREATMENT PROCESS

1.2.1 Chemical reduction

For the last many years, many industries have been following reduction method for the removal of Cr (VI) which can be achieved by the application of the electrical and chemical units together. In this unit ferrous ion is produced by using electric current and iron electrodes and then it reacts with the Cr (VI) ion present in the solution to give Cr (III) ion which is less toxic in nature. The reduction process actually somewhat reducing the more toxic ion by producing less toxic ion [13].



1.2.2 Chemical precipitation

Precipitation is also one of the leading industry process which has been using for the removal of metals form the effluents for the last many decades. To carry out this process a special agent required called coagulants such as alums and limes. But the application of this method has limitation of production of toxic sludge because huge production of sludge leads to environmental pollution. Mainly lime or sodium hydroxide is used to precipitate out the metal ion in the form of hydroxide. As the pH of lime can be easily controlled which raise the use of hydroxide to carry out precipitation process efficiently. Like all other process in this process also there are many factors which affect the performance such as degree of agitation, pH and how easy the hydrolysis of the metal ions is. Sometimes settling of precipitate becomes a big problem in process like this because a huge amount of settling of the sludge reduces the efficiency of the process.

There is other type of precipitation called carbonate precipitation [14]. In this method carbonate is used as coagulant but there is a limitation in the application of sodium and calcium carbonate. As it has been found out by the researcher that heavy metal form a stable sulphide and hence the application of the sulphide as a coagulants increased because it gives an excellent precipitation of the metals. This property of the sulphides make them more useful over other precipitation process.

1.2.3 Solvent extraction

Liquid-liquid extraction also known as solvent extraction [15] which involves the removal of metal form the solution using a carrier solvent. This involves two phases and here both phases are liquid. A solvent is used as a carrier solution which serves to carry out the metal ion from the solution. Sometimes it is very difficult to remove heavy metal from the solution even if the carries is effective. To overcome such problem sometimes complexing agents are used to remove metal effectively. Previously it has been using for the hydrometallurgy purpose only but for the last many decades it has been doing well in processing the waste water and effluents. Solvent extraction involves an organic and an aqueous phase. The solution having metal ion in it is mixed with the other organic solvent which function as a carrier. From the solution metal transfer to the interface and then to the organic solvent. The outlet stream having metal dissolving in it can be recovered by the other stripping column and also the solvent is stripped form the streams coming out of the extractor.

1.2.4 Ion exchange

Ion exchange method work on selectivity of the ion resins for the metal ion and this involves two exchange resins one cation and other one is anion. There is exchange of Na^+ or H^+ for the cations. Most of the cation resins are synthetic polymer having SO_3H as active group. In This method natural material zeolite [16] is used as media to carry out the exchange reaction between the cations. But there is some limitation of this method for the inorganic effluents processing because of the requirements of pre-processing system and high cost. Ion exchange is capable of providing metal ion concentrations to parts per million levels. The efficiency and the extent of the exchange depends on the presence of the ion because a large amount of the sodium(Na^+) or calcium(Ca^{2+}) can affect the performance to such level that it may even become ineffective for the metal removal.

1.2.5 Adsorption

Adsorption process is carried out with suitable adsorbent like alumina silica, silica gel, activated carbon and zeolite but out these all adsorbent activated carbon have a large affinity for the metals most likely heavy metals. But the main attraction is towards removal of heavy metals from the waste water of industry effluents. Many research has been done on the removal of Cr (III) and Cr (VI) from the waste water and effluent from the metal plating. Many researcher has observed that removal of Cr (VI) takes place in various steps [17].

- (i) In the first step Cr (VI) is directly adsorbed on the activated carbon surface.
- (ii) In the second step Cr (VI) is reduced to Cr (III) by action of carbon.
- (iii) In the third step the produced Cr (III) is adsorbed which is less toxic than the adsorption of the Cr (VI).

1.3 BIOSORPTION

A new technique has developed termed as biosorption which is inexpensively and more efficiently remove the heavy metals from the waste water. Biosorbents are getting more attraction since they are occurred naturally and easily available in the market and in the agriculture. Biosorption is a rapid phenomenon of passive metal sequestration by the non-growing biomass. The biosorption process mainly involves two phase one is a solid phase known as sorbent and the other one is liquid phase termed as sorbate. It is the sorbent whose affinity towards the metal removal ability gives the efficiency of the whole process [18]. More the affinity of the sorbent towards the liquid phase having metal more is the removal of the metal from the solution. Due to affection of sorbent for the sorbate, the metal ion bounded

to the sorbent surface and the process will be continuous till the equilibrium concentration is not achieved. The distribution of the sorbate in liquid and solid phases is depends on the degree of the sorbent affinity for the sorbate. Biosorption has some advantages [19] over the conventional methods.

- Cheap: most of the bio sorbents are cheap because they are available as waste material.
- Metal selective: different bio sorbents have different metal sorbing performances.
- Regenerative: biosorbents can be regenerated after the completion of the reaction.
- No sludge generation: in biosorption there is no problem like sludge formation.
- Metal recovery possible: metal can be recovered after the reaction completion.
- Efficiency of biosorption is more than the other.

1.3.1 Biosorption using living organism as biosorbent

It has been reported by the previous researchers that a large number of microorganisms belongs to groups like fungi, algae, yeast and bacteria have great tendency to remove heavy metals from the effluents. The work on biosorption using various biomass again and again reviewed and studied to check the efficiency of the different biomass over removal of heavy metals. Before the introduction of the inorganic or waste material as biosorbent many studies have been reviewed by the researcher on biosorption using living microorganism [20, 21, and 22].

However due to having some disadvantages which are inherited with these biomass or microorganism has limited the use of living microorganism in all situations. For instance, all the effluent from the many industries containing heavy metals has a widely varying pH which is not so favourable for the active population of the living microorganism.

Fungal group living microorganisms have high percentage of cell wall material which makes them very advantageous over other microorganisms.

There are some drawbacks of using microorganisms for the biosorption of heavy metals like the protein rich living microorganism of group such as fungal and algae have some problem of putrefying under the moisture. Further, biomass required nutrient and these biomass have main disadvantage that these very sensitive at even low temperature. Hence at high temperature biomass can be degraded.

1.3.2 Biosorption using non-living material

The drawbacks of biosorption of using living microorganisms can be overcome by using cost effective adsorbents. In general, a sorbent can be assumed to be low cost than the biomass

since it is present in large in nature, or waste material from agriculture or a by-product of the food industries [26]. Some of the low-cost sorbents reported so far include: tea waste, neem sawdust, neem leaves, banana peel, wood sawdust, sugar cane dust. The waste material or these several inorganic materials also possess several other advantages that make them excellent materials for environmental purposes, such as high capacity and rate of adsorption high selectivity for different concentrations, and also rapid kinetics. By-products from many industries have been used for the removal of heavy metals.

1.4 MECHANISM INVOLVED

1.4.1 Complexation

Complex formation of metal ions with organic species has totally depend on the ligands which are the no of atoms having lone pair electrons tom donate. Ligands like sulphur atom, neutral divalent and neutral trivalent nitrogen mainly present in the biopolymers. Complexation may be electrostatic or covalent. Complexation by the monodentate legants is the simplest one compare to the complex formation with the multidentate legants. There are more than one ligant atoms are available for species in the multidentate legant.

1.4.2 Chelation

When a central ion is bounded by more than one atom at a time to form a ring a structure termed as chelation. As the chelating forming agent can be attached to the central ion at more than one place it makes this chelate more stable than the complex formed by unidentate ligant. As the chelating sites increases the stability of the ring increases.

In general, since chelation recommended where the removal of ion is difficult with the ordinary compound. There are so many chelating agents are available EDTA is one of the agent which has been using in the removal of the copper ion from the solution.

1.4.3 Ion exchange

In metal ion-exchange there are some cation binding ionizable groups that are primarily present in biopolymers, are mainly carboxyl, organic phosphate, organic sulfite and carboxyl. The metal ion exchange method involved two method one is cation exchange and the other is anion exchange method.

Anion exchange mainly take place on different types of organic-nitrogen-based groups. Many of the researcher have come to one conclusion and have proven that the ion exchange method is incorporated in biosorption of metal ion from the solution. However, it has been told by the

evidence that the ion exchange method is one and only or sole method to employ in removal of metal ion.

1.4.4 Reduction

In the past decades many work has been reported on biosorption of Cr (VI) from the solution by using different biomass like waste product from the industries and on living microorganism also. This reduction process involves the reduction of Cr (VI) high toxic metal ion to Cr (III) less toxic metal ion when there is reaction between the metal and the biosorbent material. This whole process proceeds in steps.

1.5 FACTORS AFFECTING BIOSORPTION

1.5.1 Temperature

Temperature is one of the processing parameter that cannot be ignored during the any chemical and physical process. In biosorption process the sorbent material is non-living material mainly for the agriculture and food industry which are sensitive to even low temperature. Processing these material at high temperature leads to the degradation which is one the drawbacks of this method. Here the entire sorption process has been carried out at room temperature because the sorbent is orange peel and the high temperature may lead to the stop of the reaction in between of the experiment due to the degradation of the sorbent. Hence to avoid all these problem the process is carried out at room temperature.

1.5.2 pH of the solution

Before the introduction of the non-living material as biosorbent in biosorption process the biomass living microorganism had been using which were also facing the main challenge of performing the process under high pH . In biosorption of chromium (VI) ion the main problem is to maintain the pH of the solution. The change in the pH of the solution there will be change in the sorbent loading that is mg of the ion adsorbed on 1g of the sorbent. If the pH is more like acidic there will be competition between the Cr (VI) and the H⁺ to adsorb at the orange peel surface. Hence due to repulsion between the H⁺ and Cr (VI), results in the reduction of the amount of ion removing from the solution to the sorbent surface.

CHAPTER 2

SAMPLE PREPARATION

2.1 CHEMICALS

- a) 0.1 M HCl
- b) 0.1M NaOH
- c) $K_2Cr_2O_7$

All chemicals used in the present work are of analytical purity 0.1 mol/L HCl and 0.1 mol/L NaOH is used for pH value. Double distilled water is used to prepare all solutions throughout the experiments. Cr (VI) stock solution is prepared by dissolving $K_2Cr_2O_7$ in double distilled water.

2.2 SAMPLE PREPARATION

Orange peel (OP) is used as the biosorbent material to perform the biosorption process. To do this job first the orange peel collected from a local market and then cut into was cut into small pieces, to remove the dust it is washed many times with distilled water and then kept for drying in the oven at 80°C. After the drying over the dried sample are crushed using the grinder and sieved at mess size between 425µm-600µm and then treated with 0.5M sodium hydroxide (NaOH) and 1.5M calcium chloride ($CaCl_2$) solutions to enhance the metal removal ability of biosorbent to carry out the experiment, 10 g of dried OP was soaked in solution containing 50 ml ethanol, 25ml NaOH (0.5 mol/L) and 25 ml $CaCl_2$ (1.5 mol/L) for 24 h. After repeating decantation and filtration, the modified biomass was washed with distilled water until pH value of the solutions reached 7.0 and then dried to perform the biosorption experimental test.

2.3 SOLUTION PREPARATION

The stock solution of Cr (VI) is prepared by dissolving the analytical grade $K_2Cr_2O_7$ in the 1000ml distilled water to make (1000mg/l) solution. Then by diluting the stock solution different solutions of different concentration (400ppm, 300ppm, 200ppm, 100ppm,50ppm)are prepared .The prepared solutions are kept in 250ml conical flask shield with aluminium foil in dark environment.

CHAPTER 3

EXPERIMENTAL PROCEDURE

3.1 FINAL SOLUTION PREPARATION

The stock solution of Cr (VI) at different concentration are then mixed with chemically modified orange peel. To prepare such solution 25ml of stock solution is taken in 100ml conical flask and then 0.1g chemically modified orange peel is mixed with the solution taken in flask. Like the former solution here also different solution at different concentration are prepared by soaking 0.1 g orange peel in it and kept for some times in dark condition.

3.2 EXPERIMENTAL WORK

In this work two experiments are performed one after the other to verify the results .To carry out the experiment a magnetic shaker rotating at certain speed is needed. For both the experiments **experiment 1** and **experiment 2** the solution preparation is somewhat same. The 25ml solution of different concentration (50ppm,100ppm,200ppm,300ppm) are taken and 0.1g of orange is soaked in all the solution and then kept at magnetic shaker for certain time interval for getting the equilibrium concentration. To get the equilibrium concentration samples can be withdrawn at different time interval to check the equilibrium concentration. In **experiment 1** the biosorption process carried out for 6hrs .After 6hrs the solutions are remove from the shaker and filtration is done to get the supernatant and the orange peel after the test to carry out the microscopy analysis. The concentration of the different supernatant of the different solution at different concentration are analysed under UV spectrophotometer in visible range 200-400nm. By getting the peak the absorbance can be find out and then the final concentration. Similarly to carry out experiment 2 again 25 ml solutions 0.1g orange peel soaked in it at different concentration are kept at magnetic shaker for 8-9 hrs and after 8-9hrs. The solutions are taken out form the shaker and filtered to get the supernatant.

3.2.1 Calibration curve

To draw the standard calibration curve the solution needed are reference solution and the solution whose concentration supposed to be analysed under UV-Vis spectrophotometer. The solution at different concentration before the test are analysed by UV-Vis spectrophotometer and different concentration gives different absorbance. A plot between absorbance and known concentration is drawn that is our calibration curve. From the calibration curve the unknown concentration of the supernatant after the test is found out that is our final concentration.

3.2.2 FESEM study

SEM is done after the chemically modification of the orange peel to get the morphology of the orange peel. From the study of the orange peel the presence of active sites can be analysed. After the sorption of ions on the surface of the sorbent from the SEM study it can be easily seen that the pores are no more present as active sites. This study gives the whole idea about the presence of the active sites at adsorbent surface to carry out the reaction.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 CONCENTRATION ANALYSIS

4.1.1 Experimental result

Under the experimental analysis two experiments are carried out, and in both the experiments namely **experiment 1** and **experiment 2**, all the solution at different concentration after the biosorption treatment are filtered. After the filtration process, absorbance of the supernatant is measured by UV-vis spectrophotometer and by using the standard calibration curve the final concentration is measured. Here, after the analysis it is found that the final concentration is higher than the initial concentration.

4.1.2 Chemical modification of sorbent

From the various studies on the binding ability of Cr (VI) to the inactivated biomass and it was found out that the presence of the carboxyl group (COOH) are responsible for the binding of metal ion. Hence it can be worth to say that the binding ability can be increased increasing the presence of carboxylic ligand in the biomass. The biomass like orange peel contain pectin lignin and cellulose which are not that much responsible for removal metal ion. But it can be converted to carboxyl group which are enhance the binding ability. Here in this work sodium hydroxide (NaOH) is used to convert the ester group into the carboxyl group. In here we are adding CaCl₂ also which help to precipitate out the pectin acid which decreases its solubility in the solution. Hence, chemically modified peel are more efficient than the raw orange peel.

4.1.3 Calibration curve

The standard calibration curve is drawn between the absorbance and the known concentration of the solution on which experiment is performed for both the experiments which are carried out in certain time duration. Here calibration is drawn for both the experiments that is **experiment 1** and **experiment 2**. To draw the curve the absorbance of the solution of the known concentration is found out by UV-Vis spectrophotometer by taking reference solution as distilled water. From the plot is found out that the standard curve is a linear plot between the absorbance and the concentration. This plot is further used to read out the reading of the final solution concentration. The absorbance is taken from the local maxima occurring in the wavelength range 200-800nm and the maxima for the known concentration is occurring at 354 nm. To find the final concentration first the absorbance of the supernatants of different solution of different concentration is found out from the UV-Vis spectrophotometer by

observing the corresponding peak at 354nm and then by using this value concentration is read out from the calibration curve.

Table 4.1: Known initial concentration vs absorbance from the UV-Vis spectroscopy study in wavelength range 200-800nm having peak at 354 nm for experiment no 1

Initial concentration(ppm)	Absorbance
400	3.97
300	3.08
200	2.02
100	.985
50	.504

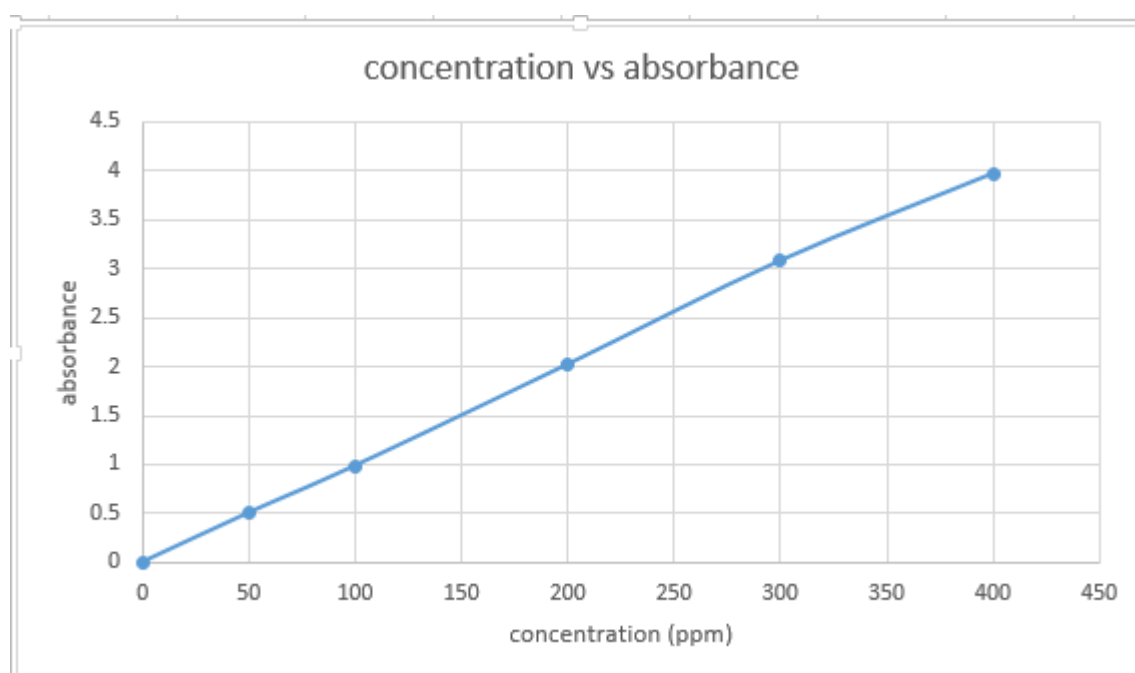


Figure 4.1: Calibration curve 1 for experiment 1 drawn from the UV-Vis spectrophotometer analysis.

Figure 4.1 is a calibration curve which is drawn between the initial known concentration and the value of absorbance measured from the UV-Vis spectrophotometer. This is a linear curve passing through all point. This is the standard curve which is further used to find out the final concentration of Cr (VI) in the solution left after the completion of biosorption process.

Table 4.2: Final concentration vs absorbance from the UV-Vis spectroscopy study in range 200-800nm having peak at 354nm for experiment 1

Final concentration(ppm)	Absorbance
420	4.15
320	3.36
240	2.48
175	1.425
80	1.21

Table 4.2 contain the value of final concentration and the absorbance of the final solution. From the UV-Vis spectrophotometer the absorbance is measured for the final solution left after the completion of biosorption and then from the value of the absorbance the value of the corresponding concentration is calculated from the calibration curve that is figure 4.1.

Table 4.3: Initial concentration vs final concentration

Initial concentration(ppm)	Final concentration(ppm)
400	420
300	320
200	240
100	175
50	80

From the above table 4.3 it is observed that the final concentration is higher than the initial concentration of Cr (VI) for all the solution having different initial concentration.

Table 4.4: Known initial concentration vs the absorbance from the UV-Vis spectroscopy in wavelength range 200-800nm having peak at 354nm for experiment 2

Initial concentration (ppm)	Absorbance
400	3.98
300	3.12
200	2.15
100	1.15

50	.518
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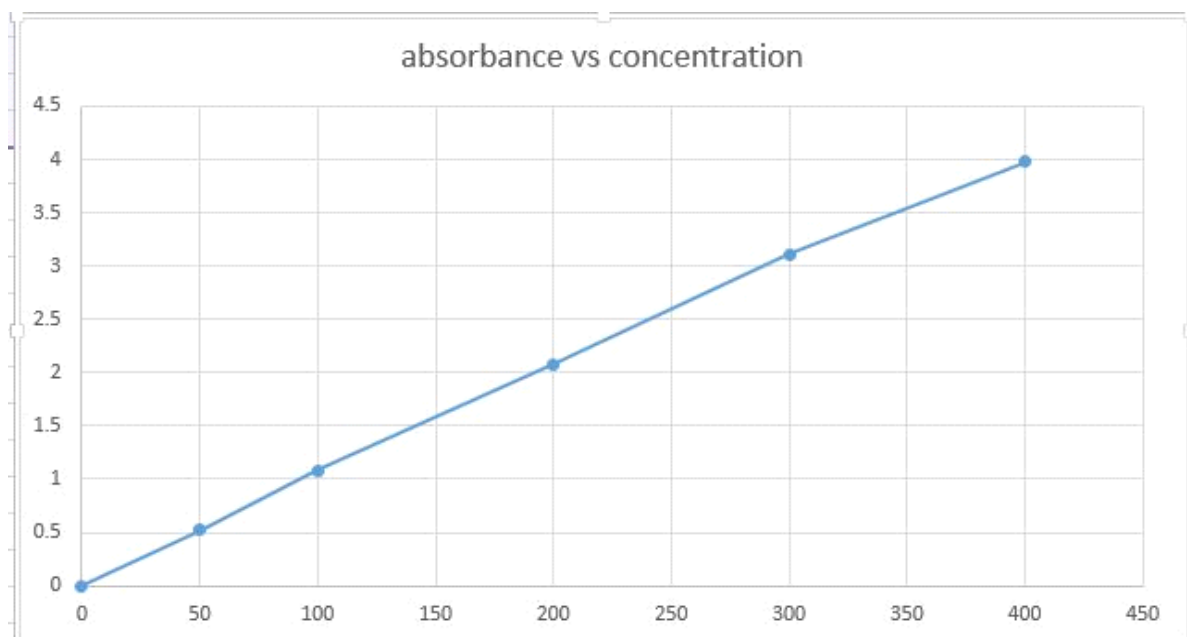


Figure 4.2: Calibration curve 2 for experiment 2 drawn from the UV-Vis spectrophotometer analysis.

Figure 4.2 is a calibration curve for experiment 2 which is drawn between the initial concentration and the corresponding absorbance value measured from the UV-Vis spectrophotometer and the curve is found to be linear passing through all the points. This is the standard curve which is further used to get the final concentration value for corresponding value of absorbance measured from the UV-Vis spectrophotometer.

Table 4.5: Final concentration from the calibration curve vs absorbance from UV-Vis spectrophotometer from the spectroscopy in wavelength range 200-800nm having peak at 354nm for experiment 2

Final concentration(ppm)	Absorbance
420	4.13
380	3.98
240	2.45
135	1.259
95	.595

Table 4.5 contains the value of final concentration and the absorbance of the final solution. From the UV-Vis spectrophotometer the absorbance is measured for the final solution left after the biosorption process is completed and then from the value of the absorbance the value of the corresponding concentration is calculated from the calibration curve that is figure 4.5.

Table 4.6: Initial concentration vs final concentration

Initial concentration(ppm)	Final concentration(ppm)
50	95
100	135
200	240
300	380
400	420

From the above table 4.6 it is observed that the final concentration is higher than the initial concentration of Cr (VI) for all the solution having different initial concentration.

4.2 FESEM STUDY

From the Field Emission Scanning Electron Microscope (FESEM) study of the chemically modified orange peel the presence of many active sites at the surface of the biosorbent are observed. This study shows that there is an increase in the number of the active sites due to chemical modification. The image shows the presence of the pores present at the sorbent surface which is not even possible to imagine without the SEM study. By seeing the figure 3 and figure 4 it is easy to say that the pore size in figure 4 is the more magnified than the other pore size in the figure 4. The presence of these active sites gives the extent of the surface reaction because in the sorption process all the sites available to the sorbent surface are not going to take part in the reaction so active sites are the only sites which are taking part in the process. This makes the SEM imaging very important to analyse the pore size. From the SEM study it is also observed that the pores are in cylindrical shape.

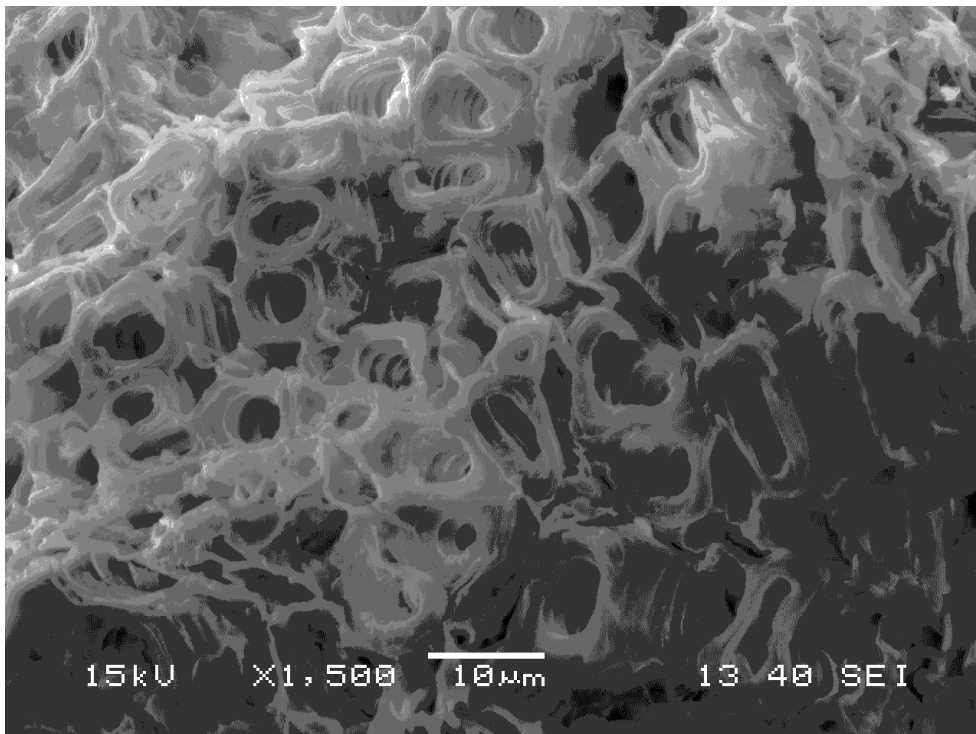


Figure 4.3: showing the pore size of the adsorbent after the chemically modification

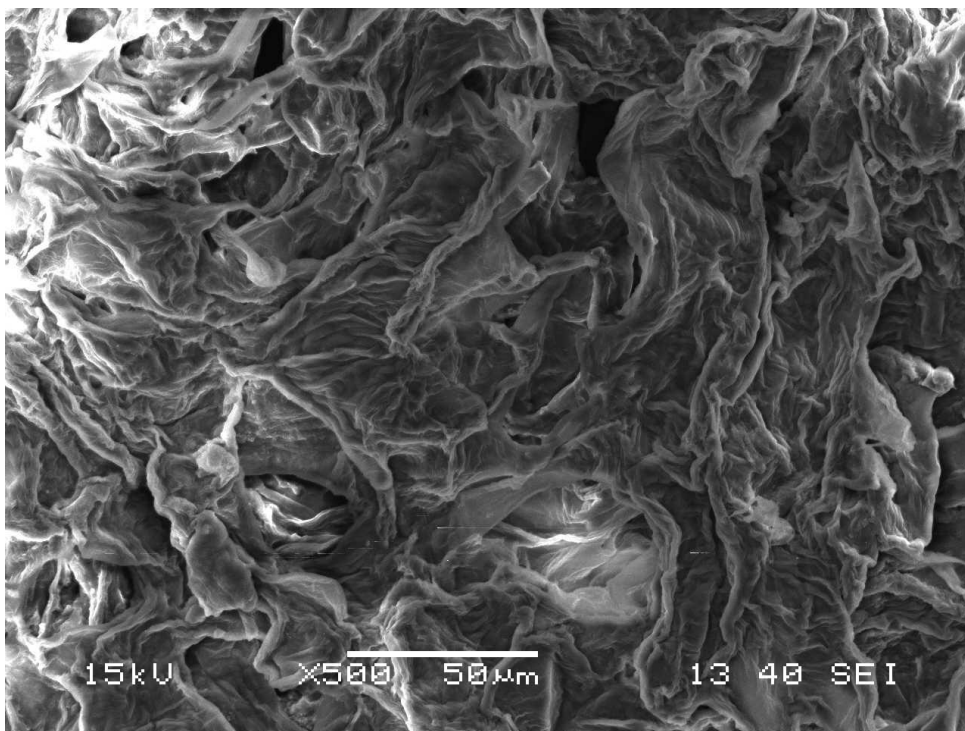


Figure 4. 4: showing the pore size of the adsorbent after the chemically modification

CHAPTER 5

CONCLUSIONS

5.1 CONCLUSIONS

Based on the value of absorbance from 200-800 nm wavelength in an UV-Vis Spectrophotometer the standard calibration curve was drawn and the value of initial concentration and final concentration of chromium (VI) ion for both the experiment 1 and experiment 2 was found and it was observed that the final concentration was coming out more than the initial concentration. Hence there might be some problem or error during experimental analysis. The SEM study was also done to analyse the pore size of the biosorbent used. From the SEM imaging it was observed that the chemical modification has increased the sites to some extent.

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