Research Article
Volume 10:04, 2023

Journal of Environmental Analytical Chemistry

ISSN:2380-2391

Open Access

Equilibrium and Kinetic Study on the Abolition of Hexavalent Chromium from Aqueous Solutions Utilizing Xanthated Tea Waste

Padam Joshi[1]*, Priyanka Chand[1], and Dinesh Bista[2]

[1]Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal

[2]Department Chemistry, Tribhuvan University, Kathmandu, Nepal

Abstract

Heavy metal removal is critically necessary to prevent water pollution. At various initial hexavalent chromium concentrations, adsorbent dosages, pHs, and contact periods, the removal of hexavalent chromium from aqueous solutions onto xanthated tea waste was investigated. FTIR and XRD techniques were used to characterize the adsorbent. Hexavalent chromium was initially removed from aqueous solutions with an increase in adsorbent dosage and contact time, but it was shown that the adsorption of Cr (VI) was best at a contact period of 120 min and an adsorbent dose of 100 mg/L. In a similar manner, the amount of hexavalent chromium eliminated from the aqueous solutions increased as the hexavalent chromium concentration grew and decreased as the solution's pH increased, with pH 2.0 being the ideal. Using a pseudo second-order model, the kinetics of hexavalent chromium adsorption onto modified tea trash was studied. The adsorption equilibrium data were modeled using Langmuir isotherm models. The equilibrium results for the elimination of hexavalent chromium by modified tea trash were well represented by the Langmuir isotherm model. According to the isotherm analysis, the adsorption equilibrium fit the Langmuir isotherm well. At pH 2.0, the obtained maximum adsorption capacity was around 82%. According to the findings, chromium-containing aqueous solutions can be treated using Xanthated Tea Waste as a low-cost adsorbent.

Keywords: Adsorbent • Xanthated tea waste chromium (VI) • Isotherms • Natural material • Thermodynamic • Chromium • pH

Introduction

In recent years, there has been a great deal of research on the removal of harmful heavy metal ions from wastewater. One of the heavy metals that are currently of concern is chromium. Chromium species are present in industrial effluents from the tanning, electroplating, painting, and textile industries at levels over the maximum permitted contamination level. Several pollutants, both organic and inorganic, impair the ecosystem. The greatest danger to the modern world comes from heavy metal ions, which are naturally exceedingly harmful and cancerous. Human activity has resulted in heavy metal contamination, which has implications for the food chain of the ecosystem.

A surface-level occurrence is absorption. Physical and chemical adsorptions are the two categories into which adsorption may be separated. Chemical adsorption is one approach that could be used to remove hexavalent chromium from wastewater effluents. This method is flexible in terms of design and operation, and it frequently results in high-quality treated effluent. Because adsorption can occasionally be reversed, adsorbents can also be replenished by utilizing the proper desorption technique. When a gas or liquid solute accumulates on a liquid or solid surface and forms an adsorbate layer as a result of physical and chemical interactions, this phenomenon is known as adsorption. The search for inexpensive adsorbents to remove contaminants from wastewater is become more intense. Several researchers have confirmed that bio adsorbents made from diverse agricultural byproducts or wastes are the best candidates as precursors to extract heavy metal ions from effluents.

Bayou et al., had studied chromium (VI) is removed from a groundnut shell by adsorptive means. Even without physical or chemical treatment, the groundnut shells used in this investigation showed a great capacity for removing chromium ions from aqueous solutions. In chromium ion adsorbents, the contact time, pH, adsorbent dosage, initial metal ion concentration, and temperature all played a part. The most effective conditions for chromium adsorption were found to be 120 minutes of contact time, 2.0 g/L of adsorbent, 25 mg/L of metal ions, and 41.5°C of temperature. The temkin model had highest correlation coefficient and thus the best match of all the isotherm models examined. Osasona et al. studied employing cow hooves for the adsorptive removal of Cr (VI) from an aqueous solution. They found that cow hoof powder can be employed as an inexpensive adsorbent for the removal of Cr (VI) from wastewater when used under ideal conditions of pH 2 and a contact time of 30 minutes. Compared to the D-R model, the Freundlich and Langmuir isotherms better describe the equilibrium data. The D-R model showed that the adsorption process is driven by physisorption, despite the fact that the Freundlich and Langmuir isotherm parameters showed that the cow hoof powder had a favorable affinity for Cr (VI) ions. The pseudo-second order kinetic model provided a good description of the adsorption data, and thermodynamic parameters predicted spontaneous and endothermic Cr (VI) ion sorption on cow hoof [1].

Mia et al., studied adsorption of Cr (VI) from tannery wastewater

**Address for Correspondence: Padam Joshi, Department of Environmental Science, Tribhuvan University, Kathmandu, Nepal, Tel: 9861362929; E-mail: padamjoshi16@gmail.com*

Received: 08 March, 2023, Manuscript No.JREAC-23-91098; **Editor assigned**: 13 March, 2023, PreQC No. JREAC-23-91098 (PQ); **Reviewed:** 27 March, 2023, QC No. JREAC-23-91098; **Revised:** 22 May, 2023, Manuscript No. JREAC-23-91098 (R); **Published:** 20 June, 2023, DOI: 10.37421/2380-2391.2023.10.430

using low-cost spent tea leaves absorbent. Spent tea leaves, a cheap and readily available resource that is discharged as waste in the environment without treatment from tea shops to hotels can be converted into valuable goods such as adsorbent for Cr (VI) removal from tannery wastewater. This study showed the highest removal of Cr (VI) was found to be pH 10 and adsorbent dosage of 14 g/L. The percentage of elimination of Cr (VI) ions increased with time until equilibrium was attained for sample of same concentration. Langmuir and Freundlich adsorption isotherms of 0.915 and 0.935 respectively justified the experimental results. The maximum adsorption capacity of Cr (VI) on tea waste was found to be 10.64 mg/g. This study concluded that tea waste collection can be considered as low cost, locally available and freely abundantly available, eco-friendly, and efficient bio-adsorbent for the removal of Cr (VI) from tannery effluents.

Chun et al., studied adsorptive removal of Cr (VI) by Fe-modified steam exploded wheat straw. Hexavalent chromium adsorption on Fe-steam exploded wheat straw is a surface phenomenon and the Langmuir isotherm curves shows linearity. The optimum condition for adsorption was pH 1.0-3.0 and initial Cr (VI) concentration 70-80 mg/L. The similar high removal capacity of chromium was found either in synthetic wastewater or actual electroplating wastewater. The adsorbed Cr (VI) could be recovered by desorption and the desorption rate reached 87%-90%. Thus Fe-steam exploded wheat straw serves as an excellent alternate adsorbent for removal of hexavalent chromium from aqueous medium.

Kumar et al., studied using binary bio polymeric beads generated from bagasse, chromium (VI) was removed from aqueous solutions through adsorptive means. In this study, sodium alginate and bio-polymeric gel beads generated from synthetic and lab-made bagasse demonstrate remarkable potential as an adsorbent for the removal of chromium ions. The degree of ionization of the adsorbent solubility of metal ions and the change present on the adsorption sites are both influenced by pH, according to research. Because the metal binding sites are deprotonated as pH rises, the adsorption capacity increases. Although synthetic gel beads and bagasse gel beads remove a high percentage of chromium (94.5%) and (98.45%), respectively, activated carbon manufactured from bagasse only removes a significantly lower amount (64%). The concentration of gel beads has an impact on the elimination of Cr (VI). Because laboratory-made bagasse has a higher degree of substitution, which improves surface area and porosity and consequently provides more active sites for adsorption, it is used in bagasse bio-polymeric gel beads and activated carbon. The electrostatic attraction between the carboxylate anions (COO-), which causes the pores in the gel beads to enlarge, is what causes this porosity. This research aids in the discovery of a practical, affordable adsorbent for the elimination of Cr (VI) ions from aqueous solutions [2].

Chakraborty et al., studied adsorption of heavy metal ions by various low cost adsobents. This study revealed that in the last several decades, rapid industrialization has led in an increase in the use of heavy metal ions creating a severe global environmental hazard. Due to its hazardous and bioaccumulation nature, there have been various attempts to develop a suitable corrective solution ion exchange chemical precipitation, coagulation, membrane separation, reverse osmosis and adsorption procedures have all been utilized in the past to remove heavy metal ions, however these technologies have proven ineffective due to a variety of challenges and limitation. Adsorption is one of them and it is quite beneficial and effective for removing heavy metal ions, even at low concentration. For example, activated carbon is particularly effective at absorbing heavy metal ions, but its application is limited due to cost considerations. The development of low cost, readily available adsorbents for the adsorption of heavy metal irons from wastewater has thus become critical. High adsorption capacity, easy separation, abundance, low cost and renewability are some of the benefits of using low cost adsorbents. This study presented a range of low cost adsorbents used to remove heavy metal ions from aqueous solutions, including agriculture waste materials, animal waste materials and industrial by-products. Functional groups are found in all adsorbents and play important role in metal ion adsorption. In this investigation, researcher concluded that chemically modified adsorbents, on average have a larger surface area and have a better adsorption capacity than unmodified adsorbents.

Malkoc and Nuhoglu studied fixed bed studies for the sorption of Cr (VI) ions onto tea factory waste, this study shows that the adsorption of chromium ions from manufacturing waste in a fixed bed column is a cost effective way to remove metal irons from wastewater. Tea industry waste is an excellent and economical adsorbent for chromium removal from aqueous solution. Adsorption break through curves were obtained at various flow rates, feed chromium concentration, particle size, feed pH and bed depth. The results show that increasing the flow rate reduces the volume treated until saturation time and hence reduces the bed's capacity most likely because contact periods were insufficient to build an adsorption equilibrium between the waste inclined to the characteristic ‘S' shaped shape. The time was increased in the bed depth from 5 to 30 cm.

Dula et al., studied adsorption of hexavalent Cr from aqueous solution using chemically activated carbon prepared from locally available waste of bamboo. Experimental findings of this work suggested that adsorption of hexavalent chromium on bamboo waste activated carbon is a physical adsorption process attaining equilibrium within 20 minutes. Both Freundlich and Langmuir models were used to fit the data to estimate model parameters but the overall data is better fitted by Freundlich isotherm. The kinetic studies conducted using the Weber’s and Morris equation showed that the adsorption mechanism involves intra particle diffusion but it was not the fully operative mechanism in the adsorption of hexavalent chromium by bamboo waste activated carbon. The pseudo-second order Kinetic model was found to be a better fit for the adsorption of Cr (VI) by BWAC. Thermodynamic studies predict that the adsorption is feasible, spontaneous, and exothermic in nature at temperature of 298.2 K, 308.2 K and 318 K with negative values of standard change in Gibb's free energy ($\Delta G°$), enthalpy ($\Delta H°$) and positive value of standard.

Ashour Tony studied hexavalent chromium removal from aqueous solutions utilizing natural clay material. According to the experimental findings, the equilibrium isotherm time is attained after 90 minutes, and the adsorption capacity increases as the adsorbent dosage and agitation speed increase to a certain point. The highest amount of chromium can be removed by adding 0.5 grams of clay per liter of solution and keeping the pH of the solution at 5.0.

The adsorption capacities of the native and modified clay minerals, which were compared in this study, were 10.0 and 7.0 correspondingly. Moreover, the Freundlich isotherm model provided a good fit for the equilibrium sorption data. Moreover, kinetic studies were looked at, and they showed that the removal of Cr from the adsorbent is consistent with the pseudo-second order kinetic model. In this study, inexpensive, widely accessible adsorbents are introduced for removing chromium ions from aqueous solutions.

Wanees et al., using activated carbon and bentonite, research were done on the removal of Cr (VI) from contaminated wastewater. This study shows that both activated carbon and bentonite can be successfully used for removing of chromium’s from wastewater. The maximum adsorption percentage of chromium ions using both adsorbents were achieved within 120 minutes. The adsorption percentage of chromium ions increased sharply by increasing adsorbent dose as the initial concentration of ions increased, the percentage removal using activated carbon and bentonite decreased. The best temperature for the maximum adsorption is found to be 30 to 40^{0}C for activated carbon while the adsorption using bentonites less affected by increasing temperature. The maximum removal of chromium ions by both adsorbents were carried out at pH 2.0. The pseudo-second kinetic order model is suitable for describing the adsorption system. The obtained experimental data has been well described by Langmuir and Freundlich endothermic in nature. The positive value of the entropy change suggested the increased randomness [3].

Objectives

General objective: Xanthated tea waste preparation from raw tea waste and investigation of its adsorption capability for removing Cr (VI).

Specific objectives:

- Xanthation of charred tea powder using sodium hydroxide and carbon disulphide.
- Study of physicochemical characterization of xanthated tea powder.
- Study of kinetic parameter of xanthated tea powder.
- Study of various isotherm models for the best fit of isotherm.

Materials and Methods

All the experiments in this study were carried out with chemically xanthated tea waste collected from a local market in Lainchaur, Kathmandu, Nepal. And the chemicals used for this research work were used of LA/AR grades without further purification.

Instruments used

- UV-visible single beam spectrophotometer (SPECTRO UV-2510 TS).
- UV-visible double beam spectrophotometer (LABTRONICS, Modellt-2802).
- Electric balance (Machine number: 038943).
- Hot air oven (ELITE OVEN).
- Auto deluxe pH meter (Model:LT-10).
- Rotary flask shaker.
- Magnetic stirrer (LABINCO-L34).
- Sieve (NEW DELHI-110055).
- Mortar and pestle.
- FTIR-spectrometer (PerkinElmer).

Preparation of reagents

Preparation of 1000 ppm chromium (VI) solution: Stock solution of Cr (VI) was prepared by dissolving 1.414 gram of $K_2Cr_2O_7$ in 500 ml volumetric flask adding distilled water to give 1000 ppm solution. Other working solutions of Cr (VI) were prepared by diluting the stock solution in distilled water.

Preparation of 1 M sodioum hydroxide (NaOH) solution: 40 grams of NaOH pallets was added in 250 ml volumetric flask and distilled water was added up to the mark level to make 1 M NaOH solution and it was further diluted as per the requirements.

Preparation of 1 M hydrochloric acid (HCl) solution: 16.02 mL of conc. HCl was taken in 250 mL volumetric flask and then distilled water was added up to the mark level and was shake vigorously and thus prepared solution was further diluted as per the requirement.

Preparation of buffer solution:

- Buffer solution pH 4.0.
- The buffer tablet of pH 4 was dissolved in 100 mL of distilled water in the volumetric flask.
- Buffer solution pH 7.0.
- The buffer tablet of pH 7 was dissolved in 100 mL of distilled water in the volumetric flask.

Preparation of adsorbent from raw tea waste: Raw tea waste was collected from the local tea shop situated at Lainchaur, Kathmandu, Nepal. It was then sun dried for 3-4 days to remove moisture from the tea waste. After completely dried it was taken for the further process in laboratory and thus adsorbent was prepared [4].

Preparation of Charred Tea Waste adsorbent (CTW): 500 gram of dry raw tea waste was taken in 4 liter bucket and conc. H_2SO_4 was added and stirred it with wooden spatula until it turns to complete black color. Then it was left for 24 hours with occasional stirring with wooden spatula and thus complete reaction took place. The process is hence called the charring process. In this charring process ring opening of cellulose takes place. The charcoal formed was soaked in rain water for more 24 hours. Again, the charcoal was washed several times with rain water. Further, sample was washed with distilled water and the sample was completely neutralized up to pH 7 and was left for shade dry. After 3-4 days of shade dry it was dried in an oven for 6 hours. The dried charcoal was grinded and sieved with 150 micrometers. Finally, the charred sample of tea waste got ready and was kept in air tight bottle [5].

Preparation of Xanthated Tea Waste (XTW): 100 gram of the CTW was added into the 300 mL of 15% NaOH solution and shaken for two hours. Further 20 mL of CS2 was added and stirred for 3 hours then left for overnight. It was filtered and washed repeatedly with rain water until the pH of the suspension become neutral. Then it was kept for shade dry. After 1-2 days of shade dry, it was kept in hot air oven 80 degree Celsius to make it completely dry and finally, it was kept in air tight bottle. This material is ready for the experiments and called as Xanthated Tea Waste (XTW).

Characterization of the adsorbent

To enhance the adsorption capacity of the tea waste, it was chemically modified with different chemicals sulphuric acid, sodium hydroxide, carbon sulphide etc. The main aim of this project work was to develop noble, low-cost adsorbent from the tea waste modified by the Chemical treatments for the effective removal of Cr (VI) from the aqueous solution. The tea waste was characterized by using Fourier Transform Infrared Spectrometer to determine the functional groups on the adsorbent. Characterization of tea waste was done before and after the metal ion adsorption [6].

Ftir analysis

The IR-spectra of the xanthated tea waste before and after Cr (VI) adsorption were obtained to determine the possible involvement of the functional group present in the xanthated tea waste on the adsorption process. The FTIR spectrum of Raw Tea Waste (RTW) and Tea Waste (XTW) before and after the adsorption of Cr (VI) was carried out in laboratory of Amrit Campus, Lainchaur, and Kathmandu, Nepal. In infrared spectroscopy IR radiations were passed through sample. Some of the IR radiation was absorbed by the sample and some of it was transmitted. The resulting spectrum represents the molecular absorption and transmission, creating a molecular fingerprint of the sample. The FTIR approach is an important tool for identifying some characteristic functional groups which can adsorb the heavy metal. The effects of presence of the surface functional group on adsorption of heavy metal were analyzed by observing the shifting of the FTIR peaks before and after the adsorption experiment [7].

Adsorption study

Adsorption study was done with prepared working solution of Cr (VI) and adsorbent prepared from raw tea waste that is xanthated and investigated the effect of initial concentration of metal ion, pH of the solution, contact time, effect of dose and effect of temperature of the adsorption process. Most of the chemical used in this study were LA/ AR grades and were fresh. The working solutions of various concentrations were prepared by diluting the stock solution. For the diluting purpose distilled water was used. The pH of the solution was maintained by using hydrochloric acid and sodium hydroxide of different concentration. 25 mL of chromium solution was taken in a reagent bottle and 0.2 gram of prepared adsorbent was poured in it. It was equilibrate in a mechanical shaker for 6 hours at room temperature. The equilibrate solution was filtered using filter paper and filtrate was used to analyze the remaining concentration of Cr (VI). Firstly, absorbance before and after adsorption were determined by using UV-visible spectrophotometer. After that concentration before and after adsorption were calculated [8].

Effect of pH

The adsorptive removal of metal lions from aqueous solution is dependent on the pH of the solution as it affects the surface charge of the adsorbent, the degree of ionization and the species of adsorbate. Batch adsorption tests for Cr (VI) removal were carried out to examine the adsorption behavior onto Xanthated Tea Waste (XTW). In the test, pH studies were performed by shaking 25 mL of Cr (VI) solution of known concentration that is 50 ppm containing 0.2 gram of each xanthated tea waste in the reagent bottle. To study the effect of pH on the chromium removal efficiency the pH of the solution was varied from 2 to 10. Each bottle was then agitated in a mechanical shaker at room temperature 170 rpm-180 rpm for about 5-6 hours to attain equilibrium. The equilibrium pH of the solution was measured by using digital pH meter and recorded. The filtrate was used for measuring concentration. The pH affects the solubility of metal ion and ionization state of functional group, such as carboxyl, phenols, hydroxides, amino groups and hydrocarbons of the cell wall. The pH value of 2.0 was taken as optimum pH [9].

Effect of adsorbent dose

Adsorbent dose seems to have a great influence on adsorption process. The effect of adsorbent dose on the adsorption process can be carried out by preparing the adsorbent-adsorbate solution with the different amount of adsorbents added to fix initial Cr (VI) concentration and shaken together for 6 hours. Different studies show that the amount of adsorption increased with increasing the amount of adsorbent dosage. The heavy metal removal efficiency of adsorbent is directly related to the number of available adsorption sites. This suggest that after a certain dose of adsorbent, the maximum adsorption sets in and hence the amount of ions bound to the adsorbent and the amount of free ions remains constant even with further addition of the dose of adsorbent. For lower values of adsorbent dose there was an increase in percentage removal of Cr (VI). Amount of adsorbent added to the solution determines the number of binding sites available for adsorption. The decrease in the sorption capacity with the increasing adsorbent dose suggests that at constant concentration on increasing sorbent amount, number or binding sites increases. Thus the effect of adsorbent dosage on percentage adsorption and uptake is important parameter.

Effect of initial Cr (vi) concentration

The study of adsorption isotherm indicates the adsorption capacity of the adsorbent at experimental condition. The adsorption isotherm is a plot which relates the amount of adsorbate adsorbed per unit mass of adsorbent to the amount of unabsorbed adsorbate remaining in a solution at equilibrium time. Though adsorption of metal ions increases initially with increase in equilibrium metal ion concentration, several methods have been developed to describe adsorption system, behavior of heavy metals. Isotherm study was carried out with different initial concentration of chromium ranging from 50 ppm to 700 ppm with an adsorbent dose of 0.2 g at optimum pH 2. The solutions were equilibrated for 5-6 hours and Cr (VI) absorbance of xanthated tea waste before and after was absorbed using UV-visible spectrophotometer. Hence, using absorbance, concentration of before and after adsorption of xanthated tea waste was calculated [10].

Effect of contact time

Contact time is another important factor that affects efficiency of metal uptake in batch adsorption processes. The investigation was done to determine the optimum time for adsorption of Cr (VI) using Xanthated Tea Waste. The influence of the contact time for the removal of Cr (VI) from the aqueous solution using the adsorbent was analyzed under keeping the other parameters constant. The effect of contact time on adsorption of Cr (VI) was carried out by preparing the adsorbent-adsorbate solution with fixed adsorbent dose and initial Cr (VI) concentration for different time intervals (10-180 min) and shaken together. The contact time required to attain equilibrium is dependent of the initial concentration of the pollutants. The percentage of removal increases with time until equilibrium is attended.

Effect of temperature

Temperature is another crucial parameter in adsorption process. According to the adsorption theory, adsorption decreases with increase in temperature and molecules adsorbed earlier on a surface tend to desorbs from the surface at elevated temperature. In this study the effect of temperature was performed at three different temperatures in a thermostatic shaker machine while keeping all other parameter constant (optimum contact time, pH, adsorbent dose, and initial concentration). The adsorbent-adsorbate solutions were agitated with a fixed speed of 170-180 rpm, and the mixture was filtered and filtrate analyzed for the residual metal ion [11].

Kinetics study of adsorption of chromium (vi)

Adsorption kinetic was studied to evaluate the efficiency of adsorption. The adsorption kinetics of the biosorption process was analyzed using the pseudo-first order and pseudo-second order kinetic models. After evaluating the optimum pH adsorbent dose and initial concentration, equilibrium time of adsorbent of Cr (VI) was investigated at optimum pH value at room temperature to determine the equilibrium time. Kinetic studies were carried out by shaking 0.02 gram of adsorbent with 25 mL of solution of known concentration 50 ppm for Xanthated Tea Waste. The absorbance before and after adding adsorbent were taken by using UV-visible spectrophotometer. In a reagent bottle each with 0.2 g adsorbent of Xanthated Tea Waste was shaken in a mechanical shaker for 10 min, 20 min, 30 min, 60 min, 90 min and 180 min respectively. The sample were collected and then filtered and then analyzed. The absorbance of the chromium before and after was determined by using UV-visible spectrophotometer [12].

Results and Discussion

X-Ray Diffraction (XRD) analysis of adsorbents

The XRD patterns for RTW and XTW in the Figure 1 below exhibit weak, poorly resolved peaks, which indicate an amorphous nature. The biosorbent's employment in biosorption was made possible by its amorphous form, which enables the metal ions to quickly enter the surface. According to Reddy et al., the bio sorbent's amorphous form is caused by its high lignin, cellulose, and hemicellulose content. The XRD patterns of tea waste before and after modification to generate adsorbents like RTW and XTW show no discernible difference.

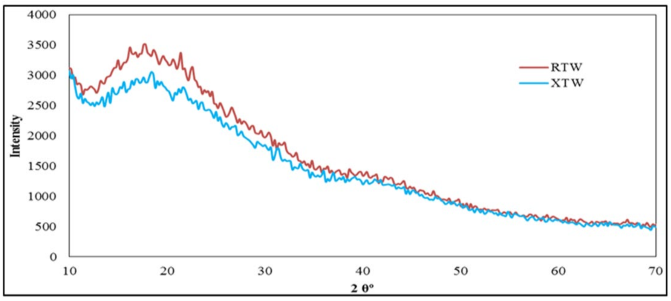

Figure 1. X-ray diffraction patterns of RTW and XTW.

Ftir analysis

The FTIR spectrum of RTW and XTW are shown in the following Figures 2 and 3 separately. The FTIR spectrum of adsorbents was taken between 300-4500 per centimeter (cm^{-1}) using IR tracer. By the close inspection of FTIR spectrum the sample showed clear peak at 2930 cm^{-1} which can be assigned to C-H group. The peak around 1209 cm^{-1} is the characteristic of C-O group. The stretching vibration of C=O and C=C found at 1627 cm^{-1} and 1700 cm^{-1} respectively [13].

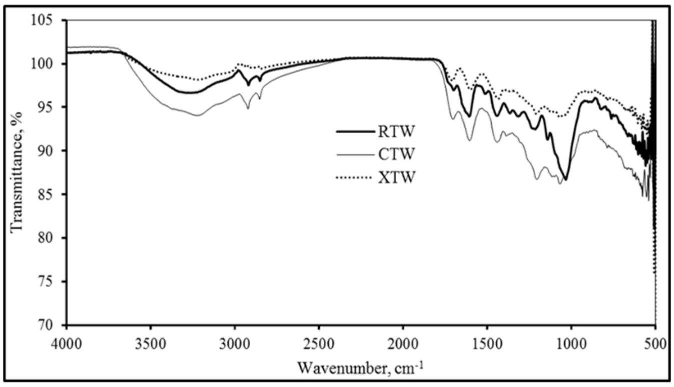

Figure 2. FTIR spectra of RTW, CTW and XTW.

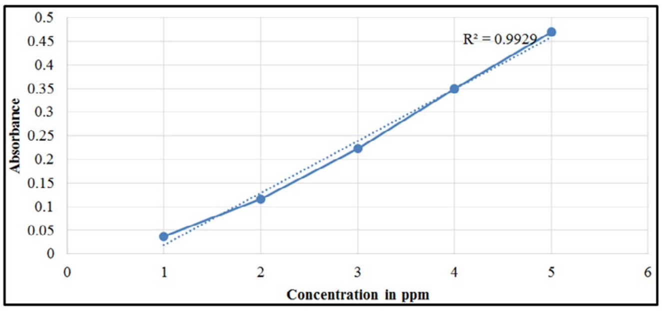

Figure 3. Calibration curve.

Effect of pH

Below Figure 4 shows that, the effect of pH on adsorption of Cr (VI) onto xanthated tea waste at initial concentration of 50 ppm at room temperature. The pH of solution has a significant impact on the uptake of chromium metal, since it determines the surface charge of the adsorbent and the degree of ionization of the adsorbate. In order to establish the effect of pH on the biosorption of chromium metal, the effect of pH at different value from 1.0-7.0 for xanthated tea waste with chromium metal was carried out. The percentage removal of chromium metal by xanthated tea waste increased from 50.39%-82.29% and then again decrease when pH of chromium solution increased from 1.0 to 7.0. From studies, the optimum pH for the XTW was found to be 2.0. The adsorption increases rapidly near optimum pH range. However, Siboni et al research reveals that when the initial pH was raised from 2 to 12; the amount of Cr (VI) removed fell from 99.67 to 29.78%. Both the anionic-type adsorption of Cr (VI) onto holly sawdust and the preferential removal of Cr (VI) at a lower pH were connected [14].

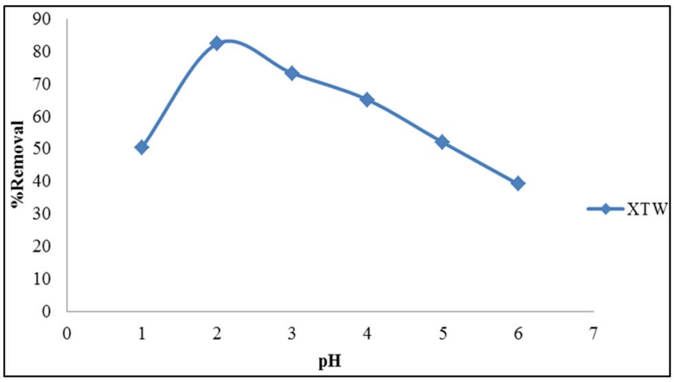

Figure 4. Effect of pH for adsorption of Cr (VI) onto XTW.

Effect of dose

To determine the ideal amount of adsorbent to use while removing Cr (VI) from aqueous solution, adsorption at constant temperature was conducted using various adsorbent dosages. When the dosage of adsorbent is increased from 10 mg to 100 mg while maintaining constant pH, temperature, and adsorbate concentration, as shown in Figure 5, the adsorption efficiency of chromium absorption improves up to a certain point and then remains constant. In the beginning, there are fewer adsorbent active sites available at low doses to absorb the chromium ion, and as the number of adsorbent dosages rises, the proportion of removal likewise rises. Up to 25 mg of adsorbent dose, the removal % increases; after that, it stays constant as adsorbent dose increases. Hence, 25 mg of adsorbent is shown to have the maximum adsorption for hexavalent chromium at 50 ppm adsorbate. No matter how much adsorbent is used, there is little probability of adsorption when the majority of the adsorbate molecules are present in the active sites.

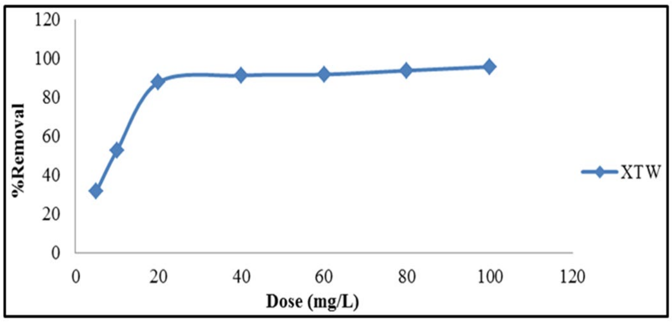

Figure 5. Effect of dose for adsorption of Cr (VI) onto XTW.

Effect of concentration

When the equilibrium concentration of chromium ions rises, so does the adsorption of metal ions. Adsorption eventually reaches an isothermal plateau because the adsorbent's fixed number of active sites equals its limit. This is due to the fact that the active site of the adsorbent is sufficiently available at low chromium ion concentrations, but at high concentrations, the active sites are depleted in comparison to the chromium ions. As a result, the amount of adsorption at high chromium concentrations is independent of the initial concentration of chromium ions. The Langmuir curve for hexavalent chromium adsorption onto XTW is shown in the Figures 6 and 7 below. The best fitting Langmuir model was proven by the high value of the Langmuir correlation coefficient [14].

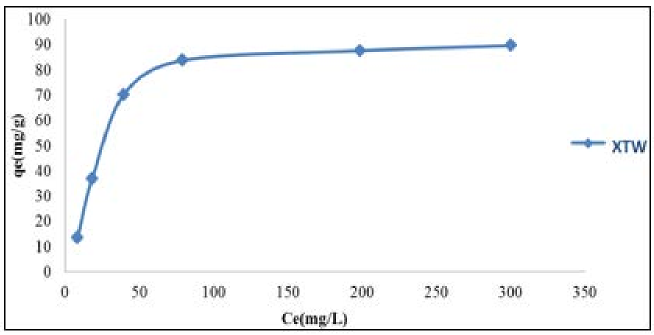

Figure 6. Langmuir isotherm plot for Cr (VI) onto XTW.

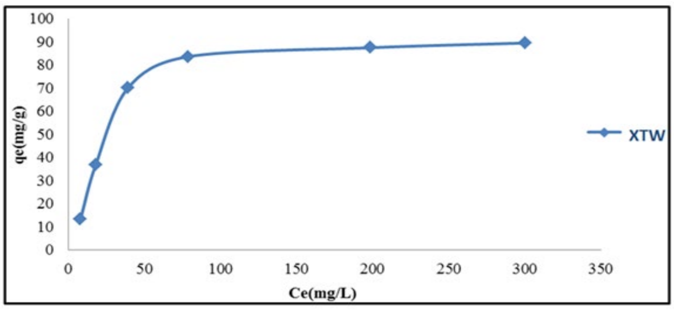

Figure 7. Effect of concentration on adsorption of Cr (VI) onto XTW.

Effect of contact time

The adsorption kinetics of hexavalent chromium onto XTW as a function of time at a starting concentration of 50 mg/L solution is shown in the Figures 8 and 9 below. By using a UV-Visible Spectrophotometer, the concentration of metal ions was measured at an ideal pH of 2.0 at various time intervals. With increasing time, metal ions were initially quickly adsorbed, and then the process slowed down until the steady state was reached. It was discovered that 180 minutes was the ideal amount of time for hexavalent chromium to adsorb utilizing XTW as the bio adsorbent [15].

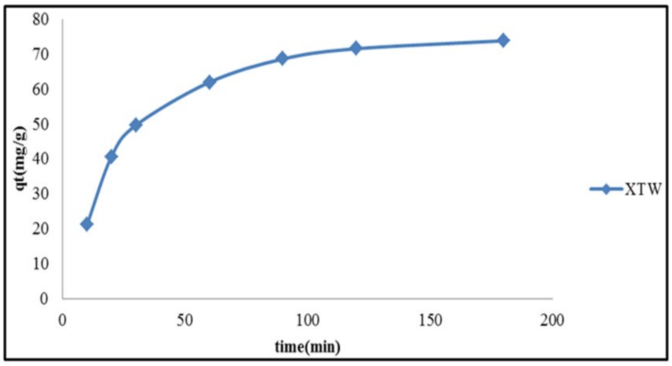

Figure 8. Adsorption kinetics of Cr (VI) onto XTW.

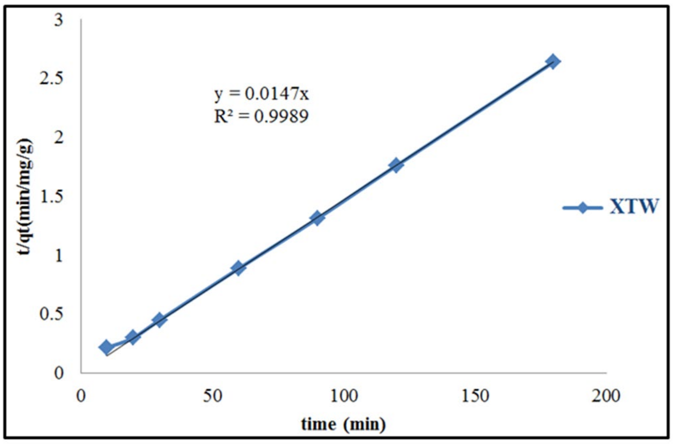

Figure 9. Pseudo second order kinetic model for adsorption of Cr (VI) onto XTW.

Novelty and national prosperity aspect of project work

Heavy metal pollution is increasing day by day in the world. Different industries and power plants are producing high level of different heavy metals along with chromium in environment through effluents produced by them. These heavy metals are very harmful to living beings and environment. Chromium in its hexavalent form is a significant harmful contaminant that got into the water stream through a variety of industrial processes. Source of contamination with chromium includes the chromium-containing waste disposal waste from different industries in water source without any treatment. To control the chromium pollution industries should discharge their waste only after proper treatment. For the treatment of industrial wastewater adsorption is the most effective method and we prepared a bio adsorbent from tea waste. This method has many advantages over.

Other techniques such as low operating cost as this method. It does not require a large initial investment, reusability of biomaterial, selectivity for specific metal, short operation time etc. Furthermore, biological materials are frequently available from agriculture and animal waste. From the results of the project work it can be concluded that tea waste can be used as a very good bio adsorbent. With the simple modification of freely available tea waste, we can treat the wastewater released from industries and can make environment neat and clean around us. This can also help to improve the health of animal and human beings. Therefore, this work is beneficial for our society and Nation.

Conclusion

Waste water discharged with heavy metals has various negative consequences on the environment and human health. Preventing the direct flow of heavy metals into water bodies would be the solution. The adsorption experiments done in our research laboratory indicated that for adsorbent XTW which is among the few of the good adsorbents which were previously researched. Thus it is concluded that XTW is a good adsorbent for the removal of Cr (VI).

The results of the study lead to the following conclusions:

- Xanthated tea waste was successfully prepared.
- The optimum pH was found to be 2.0 for XTW and the percentage adsorption was found to be 82.29%.
- Adsorption was rapidly increased from 20 min and remains constant after 120 min and percentage adsorption at that time were 40.66% and 71.57% respectively.
- Percentage adsorption increased with increase in adsorbent dose and found to be optimum at 100 mg (95.57%).
- The data best fitted for the Langmuir isotherm and pseudo-second order kinetics.
- Finally, it was concluded that Cr (VI) can be removed from cost-effective, locally available and eco-friendly bioadsorbent which saves the environment as well as living beings from harmful effects of Cr (VI).

Limitations of the Project Work

This project work was completed in the Amrit campus laboratory. The raw waste was collected from a nearby place as described in the previous chapter. The project work on this topic was completed successfully, although there are some limitations that are listed below:

- Element analyzer is not available in our lab to detect elements changed in the prepared adsorbent.
- For surface characterization SEM is not available in lab and adsorbent should send to foreign lab for surface characterization.
- All the provided chemicals where of laboratory grade and used without purification.

Adsorption process was studied only in the aqueous solution prepared in laboratory.

Recommendation for Further Work

This project work has been conducted based on the laboratory facilities and the time frame available. However, there are still many works that one can do for further study. Few recommendations for further study are listed below:

- Characterization of adsorbent can also be done by other techniques like SEM, TEM etc.
- Adsorbent can also be synthesized by other agricultural by products and animal waste.
- Synthetic adsorbent can also be used for the removal of chromium from aqueous solution.

References

1. Ashour, Eman A, and Maha AT. "Eco-Friendly Removal of Hexavalent Chromium from Aqueous Solution Using Natural Clay Mineral: Activation and

Modification Effects." *SN Appl Sci* 2 (2020): 1-13.

2. Bayuo, Jonas, Kenneth BP, and Moses AA. "Adsorptive Removal of Chromium (VI) from Aqueous Solution unto Groundnut Shell." *Appl Water Sci* 9 (2019): 107.
3. Chakraborty, Rupa, Anupama A, Ajaya KS, and Bhawana J, et al. "Adsorption of heavy metal ions by various low-cost adsorbents: A review." *Int J Environ Analytical Chem* 102 (2022): 342-379.
4. Chun, Li, Chen H, and Li Z. "Adsorptive Removal of Cr (VI) by Fe-modified Steam Exploded Wheat Straw." *Process Biochem* 39 (2004): 541-545.
5. Dhami, Dilli and Puspa LH. "Adsorptive Removal of Malachite Green Dye from Aqueous Solution Using Chemically Modified Charred and Xanthated Wheat Bran." *J Nepal Chem Soc* 41 (2020): 103-109.
6. Dula, Tamirat, Khalid S, and Shimeles Ae. "Adsorption of Hexavalent Chromium from Aqueous Solution Using Chemically Activated Carbon Prepared from Locally Available Waste of Bamboo (*Oxytenanthera Abyssinica*)." *ISRN Environ Chem* (2014): 1-9.
7. Kumar, Harish, Kanhaiya LM, Avneesh K, and Deepshikha S, et al. "Adsorptive Removal Of Chromium (VI) from Aqueous Solution Using Binary Bio-Polymeric Beads Made from Bagasse." *Appl Water Sci* 10 (2020): 1-10.
8. Labied, Radia, Oumessaad Bi, Adh'Ya EH, and Andre Donnot. "Adsorption of Hexavalent Chromium by Activated Carbon Obtained From a Waste Lignocellulosic Material (*Ziziphus Jujuba* Cores): Kinetic, Equilibrium, and Thermodynamic Study." *Adsorp Sci Technol* 36 (2018): 1066-1099.
9. Malkoc, Emine, and Yasar Nuhoglu. "Fixed Bed Studies for the Sorption of Chromium (VI) Onto Tea Factory Waste." *Chem Eng Sci* 61 (2006): 4363-4372.
10. Meena, Ajay Kumar, Kadirvelu K, Mishra GK, and Chitra R, et al. "Adsorptive Removal of Heavy Metals from Aqueous Solution by Treated Sawdust (*Acacia Arabica*)." *J Hazardous Mat* 150 (2008): 604-611.
11. Nur-E-Alam, Md, Md ASM, Farid Ahmad, and Md MR. "Adsorption of Chromium (Cr) from Tannery Wastewater Using Low-Cost Spent Tea Leaves Adsorbent." *Appl Water Sci* 8 (2018): 1-7.
12. Osasona, Ilesanmi, Albert OA, and Olubode OA. "Adsorptive Removal of Chromium (VI) from Aqueous Solution Using Cow Hooves." 2 (2013): 1-16.
13. Sharma, YC. "Cr (VI) Removal from Industrial Effluents by Adsorption on an Indigenous Low-Cost Material." Colloids Surface : *Physicochem Eng Aspect* 215 (2003): 155-162.
14. Shirzad, Siboni M, Samarghandi MR, Azizian S, and Kim WG, et al. "The Removal of Hexavalent Chromium from Aqueous Solutions Using Modified Holly Sawdust: Equilibrium And Kinetics Studies." *Environ Eng Res* 16 (2011): 55-60.
15. Wanees, Abdel S, Abdel MM, Mohamed S, and Mamdouh AM. "Adsorption Studies on the Removal of Hexavalent Chromium-Contaminated Wastewater Using Activated Carbon And Bentonite." *Chem J* 2 (2012): 95-105.

How to cite this article: Joshi, Padam, Priyanka Chand, and Dinesh Bista. "Equilibrium and Kinetic Study on the Abolition of Hexavalent Chromium from Aqueous Solutions Utilizing Xanthated Tea Waste." *J Environ Anal Chem* 10 (2023): 430.