Cadmium Removal from Synthetic Wastewater using Seed Biomass Biosorbent: A Bench-top Reactor Investigation

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Abstract

The cadmium ion concentration in drinking water is frequently found higher in different part of the world as per international recommendation. It is crucial to reduce concentration in water by sustainable and environmentally friendly means. We tested the biomass of Jamun (JP) and Amaltash (AT) seeds to remove cadmium from synthetic wastewater cost effectively. The biomasses were characterized by functional groups (FTIR), crystalline structures (XRD), and elemental analysis (ICP) techniques. Experimentation the optimization study has been carried out by using Design-software 6.0.8. Response surface methodology has been applied to design the experiments where we have used three factors and three levels Box-Behnken design (BBD). Cadmium removal ability of bio-sorbents were evaluated in bench-top reactor and optimized at various solution pH, adsorbent dose, and cadmium concentration in synthetic wastewater. At initial cadmium concentration 2 mg/litre, pH 6, adsorbent dose 60 mg and stirring speed 300 rpm the cadmium removal was \textasciitilde95\% and \textasciitilde93\% from synthetic wastewater by JP and AT seed biomass, respectively. The adsorption behaviour of cadmium ions well explained following Temkin model (AT $r^2=0.988$; JP $r^2=0.984$) and maximum adsorption capacity $3.88$ mg g$^{-1}$ (JP) and $4.54$ mg g$^{-1}$ (AT) after 70 minutes under optimal set of condition and proved to be an efficient and eco-friendly bio-sorbent for cadmium removal.

Keywords: Cadmium removal, Biomass, bio-sorbent, Amaltash, Java Plum, Seeds.

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1. Introduction

Cadmium is an extremely toxic heavy metal pollutant of environment. The major environmental sources of Cd are fossil fuel burning, refineries, metal production, alloy industries, pigments and screens. As per WHO, the maximum concentration of Cd in the drinking water should not exceed 0.003mg L$^{-1}$, which is actually not the case in many parts of
This biologically non-essential and non-biodegradable metal have tendency to be accumulated in living organism through food chain from plants to human and affect health. The acute effects of Cd could result in abdominal pain, nausea, muscle cramp (Lee et al 2012). The metal is a classified carcinogen and teratogen. Chronic exposure to high dose of Cd results in bone degeneration, renal failure and damage of liver, blood and reproductive system in human and other animals (Chen, 2012). The higher concentration above standard is supposed to cause the diseases with increasing the exposure time in the inhabitant consuming the Cd polluted water. There are regulation regarding maximum permissible level of Cd in waste water considering its ill effect on the environment and human beings. In the china maximum permissible limit of Cd in industrial waste water is 1 mg/ L whereas maximum allowable emission level of 0.1 mg/L.

The physicochemical methods for treating Cd polluted water include filtration, precipitation, oxidation reduction, osmosis, membrane technology, ion exchange, evaporation etc. In addition to these methods, biosorption employs materials of the biological origin as sorbent, so reducing the threats of chemical compounds used in the different treatments. The other advantages’ of the green route are easy availability, handling and processing of biomass. The bio-sorption process is especially more suited for treating waste water having low concentration of Cd. The organisms varying in their cell wall components are differentially useful as biosorbent for different metals from water. Plant biomaterials ae rich in lignin, cellulose hemicellulose and other organic compounds rich in different functional groups like carboxyl, amide, amine, hydroxyl Phenols that makes them good adsorbent materials (Feng et al 2011). In recent past large number of research publications are available utilizing inexpensive Biosorbent from for algae, fungi, bacteria and part of different flowering plants. Adansonia digitate root powder was used to remove different divalent ions from waste water including Cd$^{+2}$ (Ekere et al 2016). The dry biomass of marine algae Ulva fasciata biomass was used to remove Cd from aqueous solution with initial Cd concentration of 200 mg/L in static condition (Naggar et al 2012). The berries of Euterpe oleracea, a tropical perennial palm tree fruit endocarp was as used as biosorbent for efficiently removing Cd$^{+2}$.

In the present investigation we selected commonly available tropical tree called Jamun (Syzygium commune, Java plum Fam. Myrataceae) and Amaltash (Cassia fistula, family- Caesalpinaceae) due to easy availability of plant and ample seed for the process application. The seed bio-sorbent of Java Plum (JP) and Amaltash(AT) were prepared, characterized and applied for bio-sorption batch experiments showed excellent Cd$^{+2}$ ion removal potential from the synthetic wastewater.
2. Materials and Method

2.1. Experimental of Bio-adsorbents

A self-assembled investigational setup used for performing batch adsorption experiments. (Hakimeh et al 2018, Pal et al. 2017). The experiments were conducted in 50 ml beaker containing bio-adsorbent and definite concentration of cadmium (0.8 to 2.5 mg.L\(^{-1}\)) stirring by magnetic stirrer at 300 rpm. The experiments were performed by changing the bio-adsorbent dose (20 to 80 mg) for 120 minutes at the interval of 10 minutes to optimise bio-adsorbent dosing at different pH. Kinetics analysis and removal percentage was calculated by estimating remaining concentration of cadmium in filtrate using ICP-OES. The equilibrium behavior of cadmium bio-adsorbent system was analyzed by equilibrium tests under mentioned set of conditions. The equilibrium concentration (Ce) was calculated by performing the experiments for a period of 24 hours.

2.2. Synthesis of Bio-adsorbents

Java Plum and Amaltash seeds were locally collected from campus of Birla Institute of Technology, Mesra, Ranchi and Jharkhand, India. The seeds surface was washed under running tap water for 15 minutes for removing dust impurities. Seeds were sun dried in open air before oven drying (48 hrs, 60\(^{\circ}\)C). The oven dried seeds crushed and milled to fine powder form. The coarse grains of powder were separated by meshing and milled again to homogeneous particles distribution before (400\(^{\circ}\)C, 3hrs) and other characterisation.

2.3 Adsorption isotherm

Three classical adsorption isotherm models namely Langmuir, Freundlich and Temkin employed in present investigation is given below:

\[
\frac{C_e}{q_e} = \frac{1}{q_m b_0} + \frac{t C_e}{q_m} \quad (1)
\]

Plotting the data Ce/qe versus Ce, using this equation, the values of q\(_m\) and b\(_0\) is calculated from the slope and intercept of the linear plot.

The experimental data were also fitted to Freundlich isotherm which assumes that adsorbent surface is heterogeneous and each adsorption site varies in respect to their bond energy. As per Freundlich model of adsorption, sorption energy exponentially decreases with occupying the sorption sites of the adsorbent [Freundlich et al. 1906].

\[
\ln q_e = \ln K_f + \frac{1}{n} \ln C_e \quad (2)
\]

This isotherm is widely implemented for adsorbents containing heterogeneous organic compound and molecular sieves. The gradient of line represented by 1/n, and its value in
between 0 to 1, and represents the measure of adsorption intensity. If, this value is more than 1, indicates a co-operative adsorption (Foo et al. 2010).

The generalized linear form of Temkin adsorption model can be expressed by equation given below (Temkin et al. 1940). A plot between qe and ln (Ce) gives a straight line and we can find the value of KT and bT from the slope and intercept, respectively.

\[ q_e = \frac{RT}{b_T} \ln K_T + \frac{RT}{b_T} \ln C_e \]  

(3)

The KT is Temkin isotherm coefficient (L.g⁻¹), and is temperature T(K), bT is a coefficient associated to the heat of sorption (J/mol).

2.4 Adsorption kinetics models analysis

For a design of sorption systems, it is necessary to predict the adsorption kinetics, response time and controlling measure in the substance response. The sorption process is affected by physical and chemical properties of the bio-adsorbent as well as environmental conditions such as temperature of reaction [Nadeem et al. 2006]. The quantity of metals adsorbed at bio-sorbent surface at time t (qt) was calculated using equation (7) given below:

\[ q_t = \frac{(C_0 - C_e) V}{W} \]  

(4)

Where qt is the sorption capacity at time t (mg.g⁻¹), Volume of solution in liter is represented by V, whereas weight of the bio-adsorbent W is represented in grams (Coskun et al. 2006, Liu et al. 2010).

During the investigation we tested pseudo-1st order, pseudo 2nd order, intra-particle and Elovich models for best curve fit for adsorption data.

The pseudo-1st order model of Lagrange is expressed as given below (Farhan et al. 2012):

\[ \log(q_e - q_t) = \log q_e + \frac{k_1}{2.303} t \]  

(5)

A graph plot between log (qe-qt) versus t gives a straight line. The value of k1 and qe can be estimated from the slope and intercept of regression line.

The pseudo 2nd-order model is depending on sorption ability of the solid phases, which have been utilised for calculating chemisorptions kinetics.

\[ \frac{t}{q_t} = \frac{1}{q_e k_2} + \frac{t}{q_e} \]  

(6)

The intra-particle diffusion equation (Furusawa et al. 1974) can be written as

\[ q_t = t^{0.5} k_{ipd} + C \]  

(7)
Where $q_t$ is the amount of dye adsorbed onto the adsorbent at time $t$ (mg/g), $C$ is the intercept, and $K_{ipd}$ is the intra-particle diffusion rate constant (mg g$^{-1}$ min$^{-1}$).

Elovich model (Zhang et al., 2019):

$$q_t = \frac{1}{\beta} \log(\alpha \beta) + \frac{1}{\beta} \log t$$  \hspace{1cm} (8)

Where $\alpha$ (mg g$^{-1}$ min$^{-1}$) and $\beta$ (mg g$^{-1}$) are the rate coefficients associated with the adsorption and desorption techniques, correspondingly, and the values be able to observed from the curve of $q_t$ versus $\ln t$.

### 2.5 Experimental Design

The biomass of Amaltas and Java Plume seeds are used as a catalyst to remove the cadmium from waste water. In the current research experimental investigation has been made with synthetic waste water with a wider range of process parameters (Concentration ($C$), catalyst dose ($CD$) and pH). The range of the cadmium concentration has been varied from 0.5 to 2.5 ppm and the range of catalyst dose has been varied from 20 to 100 ppm whereas the pH variation made from 3 to 11. After the completion of experimentation the optimization study has been carried out by using Design-software 6.0.8. Response surface methodology has been applied to design the experiments where we have used three factors and three levels Box-Behnken design (BBD). The range and levels in Box-Behnken design (BBD) is used as shown in table 1. Using each biomass catalyst seventeen experiments has been performed and the effects of all individual parameters on response have been recorded. A second-order polynomial model has been derived using non-linear regression analysis.

### 2.6 Characterizations

Adsorbents were morphologically characterized using field emission scanning electron microscope equipped with EDX (FESEM-EDX) and micrographs were developed (Sigma-300 with EDX, Ametek). Fourier transforms infrared analysis of the biomass (Shimadzu Corporation, Japan; IR-Prestige 21). At room temperature, X-ray diffraction (XRD) measurements were performed using 40 kV, 40 mA 9kW diffracto-meter having Cu-K$_\alpha$ radiation (Rigaku, Smart Lab, Japan). The elemental analysis of samples was done by Inductively Coupled Plasma Optical Emissions spectrometer (ICP-OES) in spectral range of 160-900nm, resolution 0.009 nm at 200nm with capacity to analyseupto25 elements within 5 minutes (Perkin Elmer, Optical 2100, DV ICP-OES (USA).

### 3. Results and Discussion

#### 3.1. Inductively Coupled Plasma Optical Emissions spectrometer (ICP-OES)
ICP-OES analysis of the biomasses before the calcinations of sample, the elements detected is magnesium, iron, calcium, copper, zinc, manganese, nickel and cobalt etc. In the earlier investigation by Theivasanthi et al. (2011) also reported presence of magnesium, aluminium, phosphorus, potassium, titanium, iron, nickel and molybdenum in addition to carbon and oxygen.

3.2. Fourier Transform Infrared Analysis (FTIR)

The functional groups present on the surface of the biomass were identified by FTIR spectra. The functional groups identified are presented in figure 1. The absorption peak observed for O-H stretching vibration (3279 cm\(^{-1}\)), C-H aliphatic stretching shaking (2927 cm\(^{-1}\) and 2364 cm\(^{-1}\)). The peak indicative of P=O stretching (1150 cm\(^{-1}\)) present and a weak band at 1314 and 1088 cm\(^{-1}\)represents the existence of C–O functional group on the adsorbent surface. It has been observed by the Kim et al., 2015 the carboxyl group present in biomass significantly remove cation from solution. The intense band reflected the stretching and bending vibration of C-C, C-O or C-OH (1088 cm\(^{-1}\)) in the spectrum of hydrocarbon whereas the peak (929 cm\(^{-1}\)) was due to the C-C linkage. The polar groups present on the biomass surface provide substantial cation exchange capacity to the adsorbent (Abdel Ghani et al., 2009). The peaks in range of 1000-1200 cm\(^{-1}\)are mainly due to C-C and C-O stretching and peak at 574cm\(^{-1}\)was due to presence of iron oxide (magnetite) in the adsorbent.

3.3 X-Ray Diffraction (XRD)

Figure 2 shows the XRD patterns of biomass pyrolized at 400 °C for 3hrs were mostly amorphous and the crystalline part was very small. The diffraction peaks at 2\(\theta\) of 10.45, 13.5, and 20.85 are related to magnetite and hematite (Qian and Chen, 2013) whereas peak at 16, 22, 34 are represent cellulose in biomass (Kian et al 2018). A peak at 29.5° in biomaterial was parallel to the uppermost peak of CaCO\(_3\) (Qian and Chen, 2013). New peaks appeared when the pyrolysis temperature increased resulted in new diffraction peaks for magnesia calcite (MgCO\(_3\)), calcite (CaCO\(_3\)), dolomite CaMg(CO\(_3\))\(_2\) in the same biomass (Qian and Chen, 2013) whereas crystallinity decreased or eliminated.

3.4 Kinetics study and equilibrium isotherm of Java plum seed and amaltash seed

The rate of the cadmium adsorption onto JP and AT seed bio-adsorbent shown in Fig. 4a indicated that the initial adsorption of cadmium occurs rapidly. In the same experimental set up, approximately 95% of the cadmium gets removed by JP and about 93% cadmium was removed by AT bio-adsorbent within an hour under both in flask as well as in bench-top reactor. Initially, adsorption was fast and later it slows down and the above adsorption % achieved in two hours. So, all the experiments were conducted for a period of 24 hours to...
achieve the equilibrium adsorption. Han et al. (2019) during his investigation of cadmium removal from synthetic wastewater using copper based sulfide achieved around 75% adsorption of the initial heavy metals within 6 hours. The seed bio-sorbents used in present study have maximum adsorption capacity 3.88 mg g⁻¹ for JP and 4.54 mg g⁻¹ for AT in 70 min. Earlier modified biochar of Amaltash (AT) with Fe / Mn impregnation showed adsorption capacity 0.75 mg g⁻¹ at room temperature by Alam et al. (2018). Alkurdi and coworkers (2019) reported that pyrolysed pinewood biochar sorption capacity around 0.50 mg g⁻¹. The explanation of biosorption behavior of adsorbent were mainly explained by fitting Pseudo-first-order, pseudo-second-order, intra-particle and Elovich models in previous investigations (Farhan et al. 2012; Furusawa et al. 1974; Zhang et al., 2019) following equations number (5), (6), (7) and (8), respectively.

In the Table 2 and figure 3, we have comparatively represented different kinetic parameters for the Pseudo-first-order, pseudo-second-order, intra-particle and Elovich models for JP and AT seed biomass. Further, we compared it with the some of the data previously published by different authors. Our experimental data high value of regression coefficients of Elovich (AT, R²= 0.93, JP, R²= 0.989) and for pseudo first order (AT R²= 0.41, JP R²= 0.32 for) indicating chemical adsorption process (Tang et al. 2017). The calculated qₘ values for adsorption of cadmium on the seed adsorbent of JP and AT following pseudo first order was 3.8 mg/g and 4.54 mg/g, whereas following pseudo second order it was 3.075 mg/g and 3.057 mg/g, respectively. These values are very close to the experimental findings and higher than the majority of the biomaterials represented in the literature (Table 2).The kinetic parameters and models when compared for regression a coefficient, the present study gives better values than others bio-adsorbents. Example White sandstone [Rauf et al. 2020], CeO₂-Si- nanocomposite [Rehab et al. 2020], maghemite nanoparticles [Devatha et al. 2020], garbage ash (Mehdi et al. 2018).Thus, it can be safely concluded that JP and AT seed bio-adsorbents used in this study are brilliant adsorbent for cadmium ions.

Investigational data were evaluated to observe the finest adsorption isotherm that describes the adsorption method on these two selected bio adsorbents. To explain adsorption isotherms mechanism using equation (1), (2), and (3) for Langmuir, Freundlich and Tempkin model isotherms, respectively. The best possible isotherm is evaluated based on the principles of the constant of evaluation or R² (Kanet al. 2017). The adsorption coefficients obtained from isotherm are showed in figure 4 (A, B & C) and Table 3. Based on the determination coefficient (R²) values, the Freundlich isotherm model (AT R²= 0.95, JP R²= 0.95) explained better compared to Temkin model (AT, R²= 0.98, JP R²= 0.98) and Langmuir isotherm model (AT R²=
Isotherm coefficient (L/mg) of adsorption of cadmium were $b_0=0.0038$ (JP) and $b_0=0.0048$ (AT) for Langmuir were whereas for Freundlich model $K_f$ was 2.98 (L g$^{-1}$) for JP and 2.63 (L g$^{-1}$) for AT. For the Temkin model constants were $b_T = 3140.30$ (J mol$^{-1}$), $K_T=47.47$ (L g$^{-1}$) for AT and $b_T = 3205.37$ (J mol$^{-1}$), $K_T=4.27$ (L g$^{-1}$) JP, respectively [Yao et al. 2014; Joshi et al. 2019; Idrees et al. 2018]. The calculated $q_m$ values that reflect the adsorption of cadmium on the JP and AT adsorbent for Langmuir isotherm were 3191.50 mg/g and 1886.80 mg/g, respectively, which are very close to the experiment results and much higher than previously reported biomaterials given in Table 3. It might be interpreted that the sorption techniques followed the Freundlich and Temkin models whereby heterogeneous adsorption took place on the adsorbent surface. Table 2 explained the comparative equilibrium studied of present and other researchers such as White sandstone [Rauf et al. 2020], CeO$_2$-Si nanocomposite [Rehab et al. 2020], Farmyard manure bio-char [Idrees et al. 2018], Poultry manure based bio-char [Idrees et al. 2018], Bark [Aregawi et al. 2013] and garbage ash [Mehdi et al. 2018].

Figure 5 A & B showed the adsorption capacity of cadmium by using different biomasses such as JP and AT through the initial concentration, the value of adsorption capacity for JP changed from 0.6183, 0.7825, 1.1758, 1.575 and 1.935 mg/g for initial concentration of 0.8, 1.1.5, 2, and 2.5 ppm of cadmium, respectively. The graph for 0.8 ppm initial concentration has not been shown here. Whereas the value of adsorption capacity in case of AT changed from 0.602, 0.768, 1.153, 1.545 and 1.650 mg/g for initial concentration of 0.8, 1.1.5, 2, and 2.5 ppm of cadmium, respectively. The graph for 0.8 ppm initial concentration has not been shown here.

Figure 6 showed the removal of cadmium by using different biomasses such as JP and AT through the study of initial effect of pH for the initial concentration of 2 ppm, the removal % was 88.3, 91.8, 90.75, and 90.5 for AT at pH 3, 6, 9 and 11 whereas the values were 92.7, 94.7, 93.75 and 92.55 for the JP at this pH respectively.

Clearly, we observed higher Cd removal at dose 60 for both the case and further experiments were conducted at this dose for kinetic study. In the Table 3 study of comparative equilibrium parameters of different models and their regression coefficients were better in presently used seed biomass compared to activated carbon (Yao et al. 2014), starch maghemite (Siddiqui et al. 2020), Fe$_3$O$_4$/activated carbon composite (Joshi et al. 2019), Farmyard manure bio-char (Idrees et al. 2018), Poultry manure based...
bio-char (Idrees et al. 2018), plant bark (Aregawi et al. 2013) and other seed (Aregawi et al. 2013). It showed the amount of non-linearity between composition and adsorption of cadmium into the adsorbent plane and exhibits no uniformity regarding binding site sharing.

3.5 Percentage cadmium removal from synthetic wastewater

3.5.1 Statistical analysis

The waste biomass Amaltas seed and Jamun seed has been successfully experimented for the removal of cadmium from waste water. The experimental result in terms of percentage removal of cadmium from synthetic waste water has been fed to the DOE for statistical analysis. The DOE provided the analysis result in terms of model equation and counter plot. From the plot given by DOE we can easily discuss the dependence of individual parameters on percentage removal. The current research focuses the maximization of percentage removal of cadmium by optimizing process parameters. All the experimental result has been fed to the DOE and the analysis gives the model equation 9 and 10 which relates the dependent parameters (pH, bio-adsorbent doses, and Concentration of cadmium) and independent parameters.

\[
%\text{removal} = +58.89 + 0.45pH + 0.92CD + 0.55C - 0.199pH^2 - 0.0086CD^2 \\
- 1.73C^2 + 0.027pH \times CD + 0.3166pH \times C + 0.047 \times CD \times C
\]  

Equation 9 showed the relation between input and output parameters. From the equation it can be says that percentage removal is strongly dependent upon pH, catalytic dose and cadmium concentration present in the solution. The model F value and R² can be found from ANOVA table which is 3.77 and 0.82 respectively.

The similar experiments have been performed by using Jamun seed catalyst for cadmium removal. The result has been analyzed and model equation has been fit and presented in equation number 10. This model equation shows that the dependence of % removal on independent parameters. The model F value and R² is 7.71 and 0.90 respectively, which shows that the model is significant.

\[
%\text{removal} = +74.19 + 1.06pH + 0.46CD - 1.39C - 0.229pH^2 - 0.0054CD^2 \\
- 1.43C^2 + 0.027pH \times CD + 0.1166pH \times C + 0.0917 \times CD \times C
\]

3.5.2 Effects of adsorbent doses, pH, concentration and contact time on Cadmium removal from synthetic wastewater

The pH value of the solution strongly affects the removal of cadmium from waste water. From figure 8 and 9 it can be depicts that the percentage removal of cadmium is initially increasing as on increasing the solution pH and it gets maximum value at pH 6 than decreases.
The results agree with the work performed by Aggrawal et al. 2016 who observed reasonable spreading of cadmium and ionization of useful functional groups on the adsorbent surface depends on the pH of the solution (Aggrawal et al. 2016). Effect of pH on the percentage of adsorption of cadmium by AT and JP bio-adsorbent at various pH values is presented in figure 6, figure 9 (a and b) (for AT bio-adsorbent) and figure 8 (a and b) (for JP bio-adsorbent). A sharp increase in the cadmium removal has been observed by increasing the solution pH from 3 to 6 as shown in figure 6, and afterwards it decreased. The maximum cadmium ions adsorption was achieved at pH 6 and it was the optimum pH for cadmium adsorption on the JP and AT seed bio-adsorbents as shown in the figure 8 and 9 of statistical study. At the optimal pH, the elimination efficiency was around 95% for JP and 93% for AT, respectively. Similarly, at low pH the target molecules were considered stable and percentage removal ranged between 50 and 80% (Tsoi et al. 2012). Niazi et al. (2018) when investigating perilla leaf biochar for cadmium adsorption found that removal was pH dependent varying (55-90%) in pH range 3.2 to 9.1 with maximum cadmium removal percentage (88-90%) between pH 7.2 and 9.1. Thus, solution pH is one of the most significant parameters in controlling the cadmium ions adsorption process (Issa et al. 2010). Such adsorption behavior of cadmium at varying pH might be due to the existence of cadmium in different oxidations states.

To study effect of adsorbent dose, we conducted experiments at 20, 40, 60 and 80mg seed biomass adsorbent of the JP and AT and results obtained are presented in figure 7, figure8(a) (for AT bio-adsorbent) and figure7, figure 9(a) (for JP bio-adsorbent). Cadmium adsorption percentage increased with increase in adsorbent dose, which can be attributed to the increased adsorptive active sides and greater accessibility of surface binding sites to cadmium ions on the bio-adsorbents. We observed the maximum cadmium removal ~95% for JP and 93% for AT at adsorbent dose 60mg. After the dose of 0.185mg/L for JP and 0.215 mg/L for AT, it attained equilibrium and further addition did not change in the percentage of adsorption. In the experiments of Alam et al. (2018) increased biochar dose of modified Cassia fistula from 1 to 8 gL$^{-1}$, was able to remove about 74.5% cadmium from synthetic wastewater after in batch experiments at dose up to 6 gL$^{-1}$. The dependence of cadmium removal on the amount of adsorbent was investigated at pH of 6 using 50 ml cadmium solution at 28°C for 70 min in the range of 0.05-0.215mg/L adsorbent dosage. The iron modified corn straw biochar dose 0.4 to 5 g/L resulted the adsorption of cadmium from in synthetic wastewater from 2.2 to 95% and further increase in showed no notable effect on the removal percentage of cadmium (Fan et al. 2018). As showed in figure5, the removal percentage of cadmium in both adsorbents increased with the addition of the JP and AT adsorbent dosage due to the improvement of adsorption
active sites happened on the surface of adsorbent particles, which permit extra-contacts with cadmium ions. The experiments were conducted for 120 minutes to study the interaction of cadmium with the seed adsorbents of the JP and AT and results are presented in figure 5. Adsorption percentage was increased linearly from 10 min to 70 minutes until their maximum cadmium removal of ~95% for JP and 93% for AT, followed by almost constant readings indicating the attainment of adsorption equilibrium. Han et al. 2019 investigated cadmium removal from synthetic wastewater by copper based oxysulfide around 75% of the initial As (III) is adsorbed within 6 hours and about 90% of the initial As (V) is removed within 4 hours.

The Table 4 showing the effect of various parameters such as adsorption capacity, pH, adsorption time and percentage removal. The data of present study showed better removal in less adsorption time to others recent study, such as Oak sawdust (Argun et al. 2007), Rice husk (Agrafioti et al. 2014), Pine wood char (Mohan et al. 2007), Mulberry wood (Zama et al. 2017), Orange peel (Annadurai et al. 2003), Cocoa shell (Meunier et al. 2003), Moringastenopetala (Aregawi et al. 2013), almond shell (Pehlivan et al. 2008), ion imprinted polymer (Samah et al. 2020), and Oak pine (Park et al. 2008).

4. Conclusion

Cadmium is a well-known toxic environmental heavy metal pollutant of carcinogenic nature. The bio-sorbent for aqueous cadmium was successfully prepared and adsorption parameters were optimized for cadmium bio-sorption by seeds biomass of java plum (JP) and amaltash (AT) with removal % 95 and 93%, respectively. The cadmium adsorption behaviour of the seeds bio-sorbents well interpreted in terms of Temkin model, with the maximum adsorption capacity 3.88 (JP) and 4.54 mg.g\(^{-1}\) (AT) following pseudo-first order model and Elovich order kinetic model. Thus, prepared biomass could be used as an efficient eco-friendly bio-sorbent for cadmium removal from various polluted water.

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Author’s Contribution:

Dr. Dan Bahadur Pal conducted all experiments, processed experimental data and prepared first draft of the manuscript. Dr. Deen Dayal Giri, Dr. Jay Mant Jha, Dr. Neha Srivastava and others helped in the progress of the work, provided useful suggestions and finalizing the experimental protocol, critically analysing the results.

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