Results and discussion of Objective 3:

Objective 3: **Assessment of the adsorption kinetics and equilibrium studies for the potential removal of toxic metals using polyaniline (PAni) biocomposite.**

The adsorption performance of the bio-composites were evaluated through batch adsorption experiments. Results indicated that the PAni-based bio-composites exhibited significantly improved adsorption capacities for both cadmium and lead ions compared to pristine PAni. The enhanced adsorption properties can be attributed to the synergistic effects between PAni and the biomass-derived components, providing a high surface area and functional groups conducive to metal ion binding. Furthermore, the bio-composites demonstrated good reusability and stability over multiple adsorption-desorption cycles. Overall, the developed PAni−sugar cane bagasse and saw dust bio-composites present a promising approach for efficient removal of heavy metal ions from aqueous solutions, contributing to the advancement of sustainable and eco-friendly adsorbent materials for environmental remediation.

6. To conduct adsorption studies and effect of operational parameters: contact time, dosage, pH and initial ion concentration on uptake capacity.

6.1.Contact time

Contact time plays a vital role in determining the efficacy of biosorption in removal of heavy metal from aqueous solution [4].

6.1.1. Effect of contact time on biosorption of Cd onto SC dope, SC UD, SD dope and SD UD.

A series of batch experiments were performed to determine the effect of contact time on Cd for 6-24 hrs the rate of elimination by PAni modified doped sugarcane bagasse, undoped sugarcane bagasse, doped sawdust and undoped sawdust with five different concentrations i.e. 10, 20, 30, 40, 50 ppm by keeping all other parameters constant [Adsorbent dose = 0.3 g, pH = 6.5, agitation speed = 110 rpm, in room temperature] as shown in **Fig 6.1**.

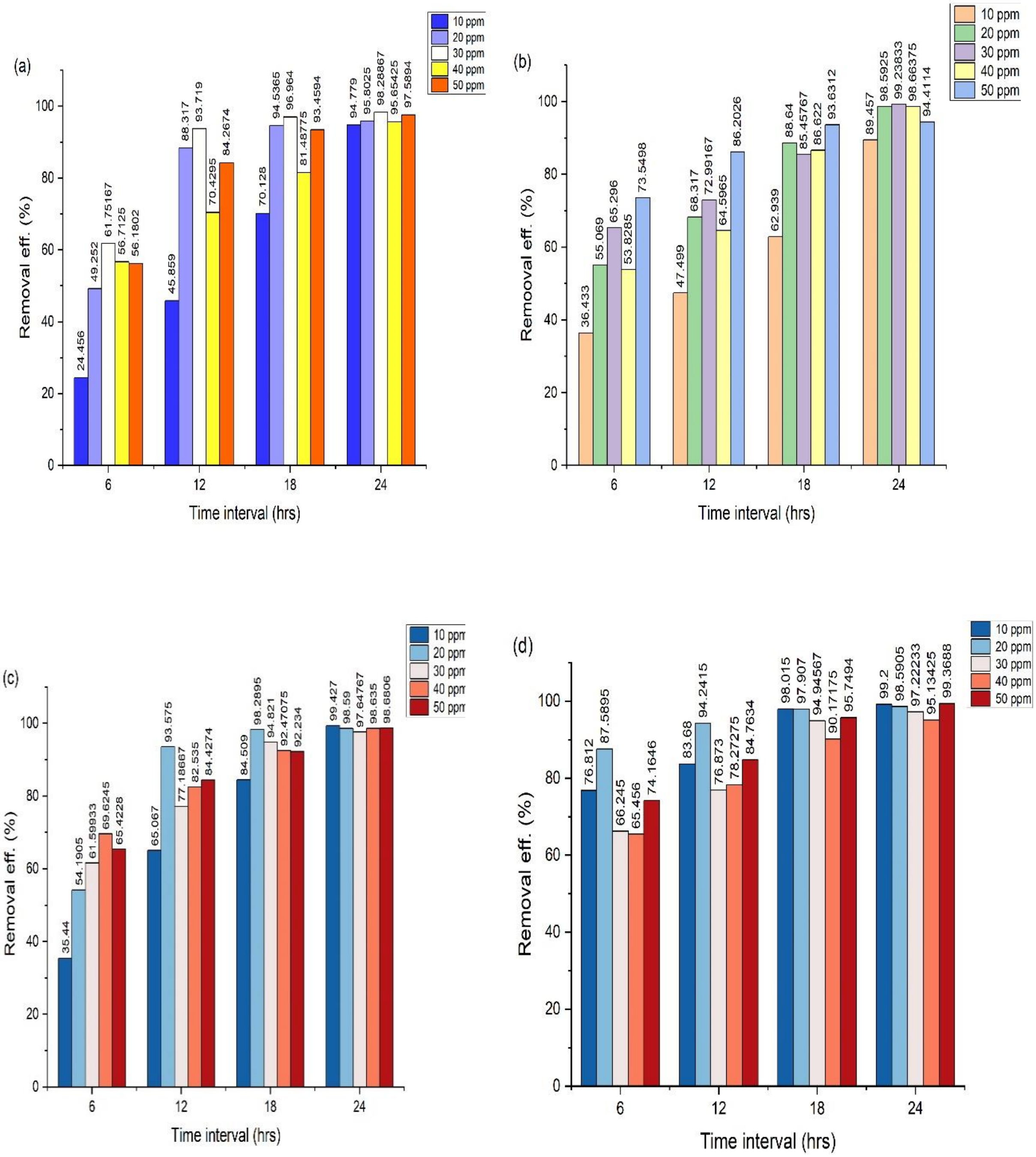
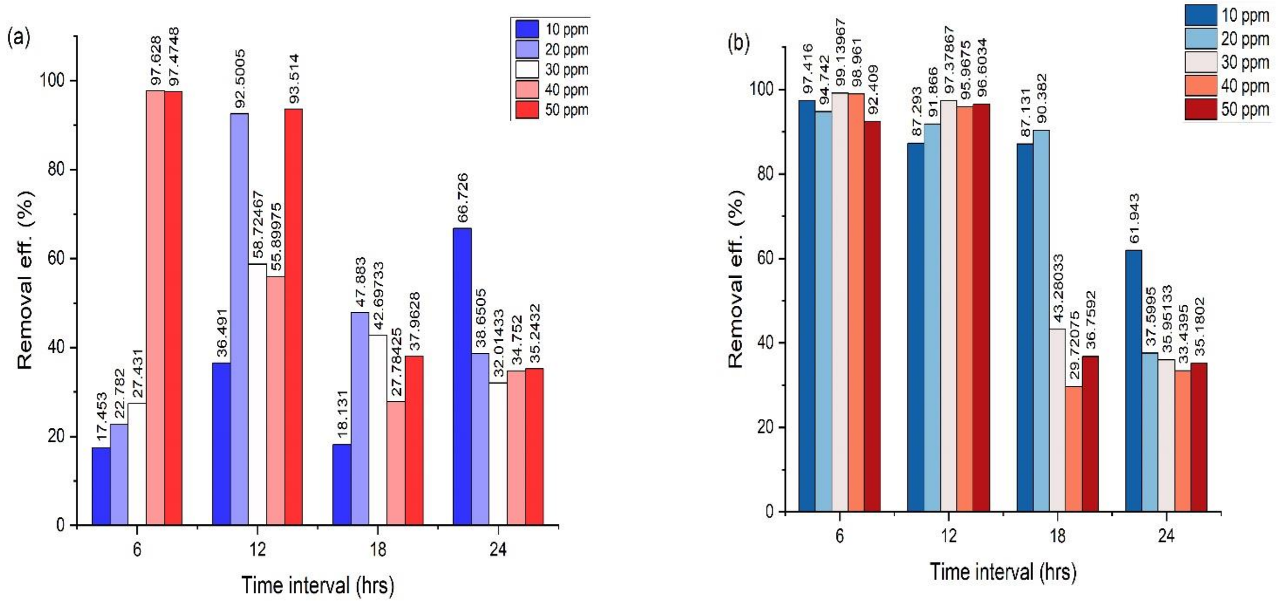


Fig 6.1: Effect of contact time on Cd biosorption onto (a) PAni dope SC, (b) PAni UD SC,(c) PAni dope SD and (d) PAni UD SD (agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3 g/30 mL metal solution, pH=6.5, temperature= 298.15 K)

The study investigates the efficiency of PAni-doped and undoped sugarcane bagasse and sawdust in removing cadmium (Cd) ions from aqueous solutions. As demonstrated in Figure 6.1, for PAni-doped sugarcane bagasse, an increase in initial Cd concentration from 10 ppm to 50 ppm resulted in a significant rise in removal efficiency from 24.56% to 56.18% within the first 6 hours of contact. After 24 hours, the removal rates reached 94.77% and 97.58% for initial concentrations of 10 ppm and 50 ppm, respectively, establishing equilibrium as no further adsorption occurred beyond this time. Similarly, undoped sugarcane bagasse showed an increase in removal efficiency from 36.43% to 73.45% within the first 6 hours, eventually reaching 89.45% and 94.41% after 24 hours for the respective initial concentrations. PAni-doped sawdust also demonstrated an increase in Cd removal from 35.44% to 65.42% in the initial 6 hours, achieving near-complete removal rates of 99.42% and 99.68% after 24 hours. Undoped sawdust exhibited a removal efficiency of 76.12% and 74.16% within the first 6 hours, progressing to 99.2% and 99.36% after 24 hours. The rapid adsorption within the first 12 hours across all four composites is attributed to the availability of high-energy binding sites, which become saturated over time, leading to a reduced adsorption rate as the contact time increases[4].

6.1.2. Effect of contact time on biosorption of Pb onto SC dope, SC UD, SD dope and SD UD.

A series of batch experiments were performed to determine the effect of contact time on Pb for 6-24 hrs the rate of elimination by PAni modified doped sugarcane bagasse, undoped sugarcane bagasse, doped sawdust and undoped sawdust with five different concentrations i.e. 10, 20, 30, 40, 50 ppm by keeping all other parameters constant [Adsorbent dose = 0.3 g, pH = 6.5, agitation speed = 110 rpm, temperature= 298.15 K] as shown in **Fig 6.2**.



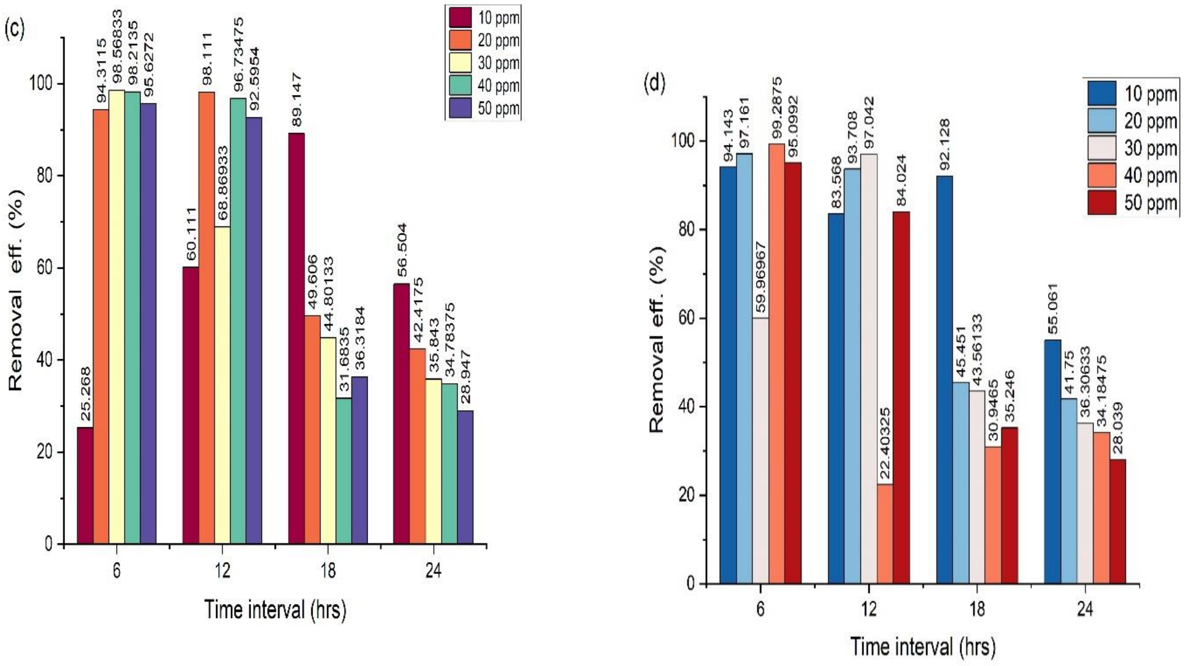


Fig 6.2: Effect of contact time on Pb biosorption onto ((a) PAni dope SC, (b) PAni UD SC, (c) PAni dope SD and (d) PAni UD SD (agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3 g/30 mL metal solution, pH=6.5, temperature = 298.15 K)

From the **Fig 6.2.** we can conclude that the removal percentage of Pb ion in PAni doped sugarcane bagasse with increase in initial metal concentration from 10 ppm to 50 ppm, the removal percentage is 17.45 % to 97.47 % for the first 6hrs of contact time. The percentage of removal of Pb ion reaches its peak till the next 6 hrs of contact time. There is rapid increase as the removal percentage for 10 ppm and 50 ppm is 36.49 % and 93.51 % respectively and it starts to slowly decrease. A state of equilibrium is achieved at 24 hrs and after this no change in removal percentage with further increase in contact time[6].

As for the PAni undoped sugarcane bagasse the removal percentage of Pb ion with increase in initial concentration from 10 ppm to 50 ppm is 97.41 % to 92.40 % at the first 6 hrs of contact time. At the 12 hrs of contact time, we can see that for the 10ppm concentration the percentage of removal gradually starts to decline to 87.29 % while for the 50ppm concentration it rapidly increased to 96.60 %. Whereas at 24 hrs it reaches equilibrium state and there is no change in removal percentage of Pb with further increase in contact time[6].

Furthermore, for PAni doped sawdust, in the first 6 hrs of contact time the rate of removal percentage from 10 ppm to 50 ppm of initial concentration is 25.26 % to 95.62 %. At further increase in contact time till 12 hrs, the percentage of removal for the 10ppm concentration it increased rapidly to 60.11 % and for the 50ppm concentration the rate of removal is 92.59 %. We can observe a trend that for the 10ppm concentration it started to rise whereas for the 50ppm concentration it stared to gradually decline till it reaches in equilibrium. A state of equilibrium is achieved and there is no further increase in removal percentage with increase in contact time[6].

Additionally, for PAni undoped sawdust the rate of removal percentage for the initial concentration from 10 ppm to 50 ppm is 94.13 % to 95.09 % in the first 6 hrs of contact time. As the trend for the 10ppm concentration the removal percentage first decrease gradually to 82.56% then again increased to 92.12% and then started rapidly decreasing with further increase in contact time and it reaches its equilibrium state at 24 hrs. But for the 50ppm concentration the trend is different it rapidly decreases to 84.02 % in 12 hrs and 35.24 % in 18 hrs of contact time. With further increases in contact time there is no increase in removal percentage and reaches its equilibrium.

The rate of lead (Pb) ion sorption decreases over time, eventually reaching equilibrium where the amount of metal sorption remains constant. Initially, the sorbent surface has numerous available binding sites, allowing metal ions to be sorbed efficiently without competition. However, as these sites become occupied, the number of available sites for further sorption decreases. Additionally, repulsive interactions between the sorbed metal ions on the sorbent surface and the metal ions still present in the solution further complicate the sorption process. Consequently, the rate of metal ion sorption declines over time, ultimately leading to a state of equilibrium where no significant additional sorption occurs [6]

6.2.Bio adsorbent dose

The dose of biosorbent is a significant quantity that influences biosorption from the aqueous solution.

6.2.1. Effect of biosorbent dosage on biosorption of Cd onto SC dope, SC UD, SD dope and SD UD.

A series of batch experiments were performed to determine the effect of dosage by three different quantities viz. 0.1 g, 0.25 g and 0.5 g of biosorbent on removal of Cd ion onto PAni modified dope/UD sugarcane bagasse and PAni modified dope/UD sawdust. At initial concentration of 10 ppm Cd ion metal solution and keeping all other parameters constant [contact time= 24hrs, agitation speed= 110 rpms, temperature = 298.15 K]. The effect of biosorbent is shown in the **Fig 6.3.**

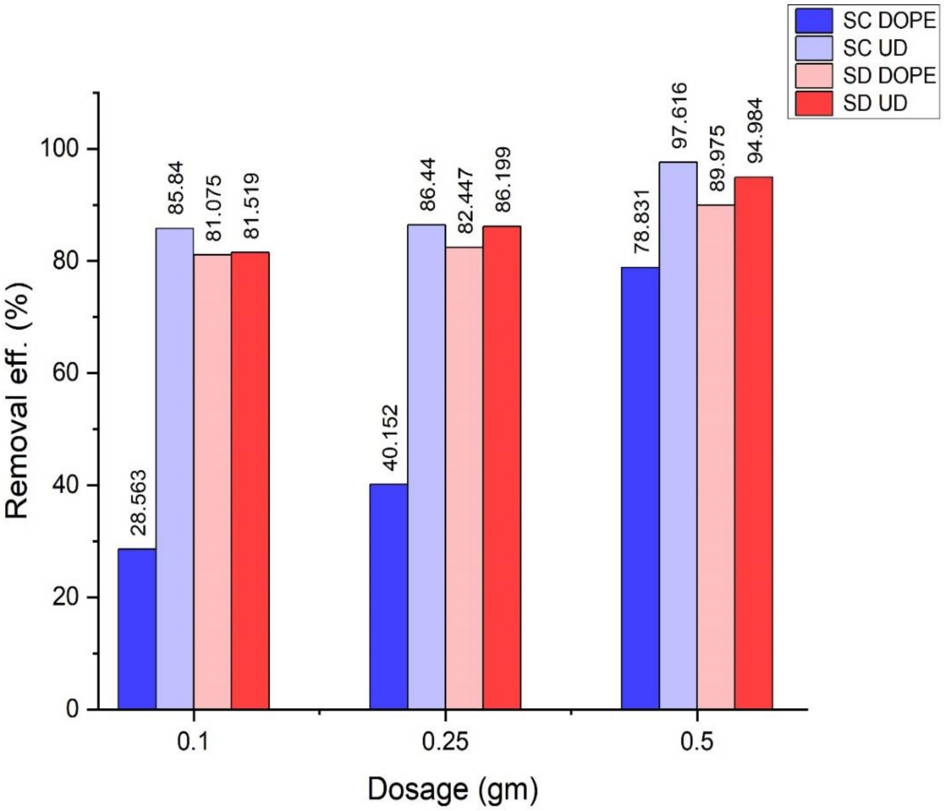


Fig 6.3: Effect of biosorbent dosage on Cd biosorption onto PAni modified SC dope, SC UD, SD dope and SD UD respectively (agitation speed= 110 rpm, contact time= 24 hrs,biosorbent dose= 0.1, 0.25, 0.5 g/30 mL metal solution, pH=6.5, temperature = 29.15 K)

Figure 6.3 clearly demonstrates that increasing the biosorbent dosage significantly enhances the removal percentage of Cd ions. For instance, using 0.1 g of PAni-doped sugarcane bagasse results in a 28.56% removal rate, whereas increasing the biosorbent dose to 0.5 g raises the removal rate to 50.27%. This trend is consistent across all four biosorbents studied, with the highest removal percentages observed at the 0.5 g dosage. The improved removal efficiency can be attributed to the increased number of active sites available for Cd ion adsorption due to the higher concentration of biosorbent in the solution. Conversely, at lower biosorbent dosages, the residual filtrate becomes almost saturated, indicating a decrease in removal efficiency. This saturation likely occurs because the active sites on the biosorbent become fully occupied by Cd ions, preventing further adsorption [5].

6.2.2. Effect of biosorbent dosage on biosorption of Pb onto SC dope, SC UD, SD dope and SD UD.

The removal of Pb from aqueous solution by SC dope, SC UD, SD dope and SD UD was examined by three different dosages of the sorbent species i.e. 0.1g, 0.25g and 0.5g for 10 ppm of Pb ion of initial metal concentration solution keeping all the parameter constant [contact time= 24hrs, pH = 6.5, agitation speed = 110 rpm and temperature= room temperature]. The influence of the absorbent dosage is shown in **Fig 6.4**.

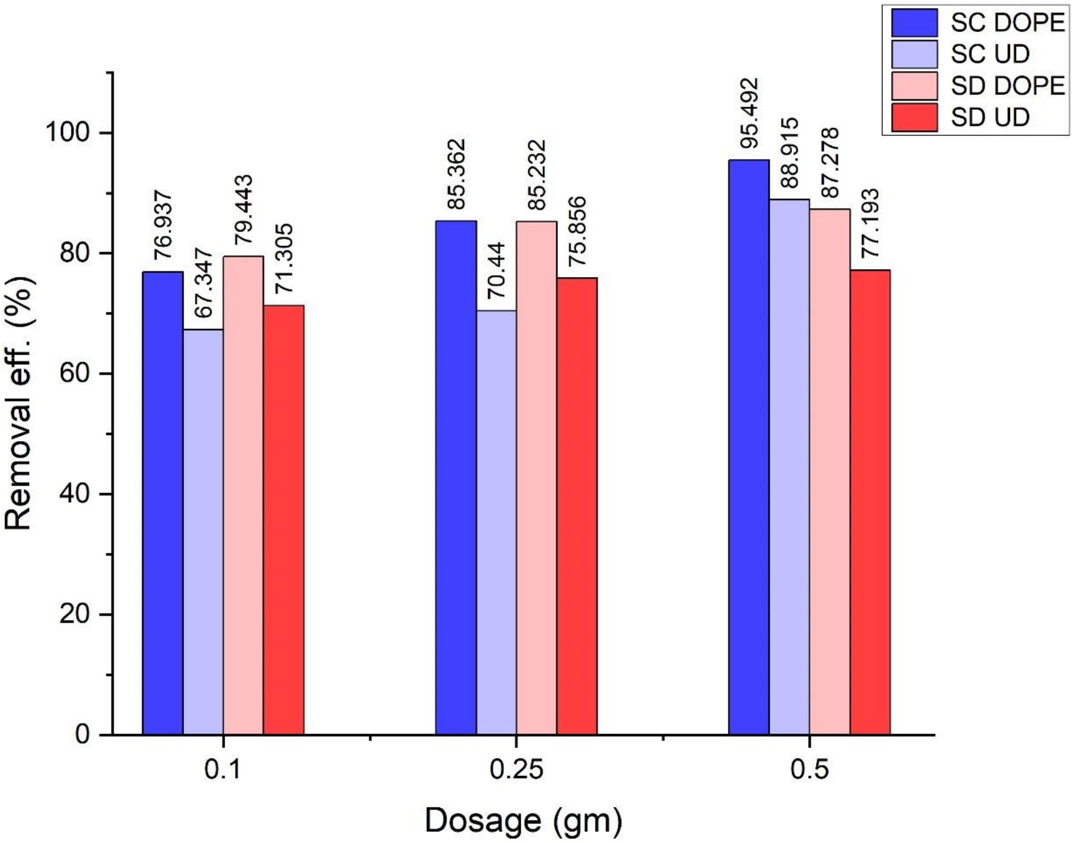


Fig 6.4: Effect of biosorbent dosage on Pb biosorption onto SC dope, SC UD, SD dope and SD UD (agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.1, 0.25, 0.5 g/30 mL metal solution, pH=6.5, temperature= 298.15K)

The experiment results revealed that the removal percentage of Pb ion onto PAni dope/UD sugarcane bagasse and sawdust gradually increases with increase in adsorbent dosage. For example, in case of 0.1 g of adsorbent dose the removal is 76.93 % where as in 0.5 g of adsorbent dosage it increases by 18.56 % for PAni doped sugarcane bagasse. At a dose of 0.5 g biosorbent the removal was higher than in 0.1 g and 0.25 g for all the four biosorbent. This may be due to the reason that high number of active sites are present for sorption due to high number of adsorbent present in the feed solution. It can also be concluded from the **Fig 6.4**, that at lowered feed content, residual filtrate becomes practically become saturated as adsorbent dosage decreases. This could be related to the saturation of active sites with Pb ions [5].

6.3.pH of the metal solution

The pH of a solution plays a crucial role in the adsorption process, as it impacts the ionization state of the adsorbate molecules and the characteristics of the adsorbent surface [2]. Variations in pH can significantly influence biosorption mechanisms by altering the surface charges on biosorbents, which in turn affects ion exchange processes. At different pH levels, the adsorbent surface may gain or lose protons, changing its charge and thus its affinity for the adsorbate ions. For instance, at low pH, an adsorbent surface might be more positively charged, enhancing the attraction of negatively charged adsorbates.

6.3.1. **Effect of pH on biosorption of Cd onto SC dope, SC UD, SD dope and SD UD.**

Biosorption processes are highly dependent on pH, as variations in pH can alter the surface charges on biosorbents, thereby affecting ion exchange mechanisms, a key aspect of biosorption. This variation in surface charge influences the physicochemical interactions between species in solution and the adsorptive sites on the biosorbent. Different adsorbates may have optimal pH levels that maximize their adsorption due to their unique solution chemistry (Rub & Fahmi, 2006). Figure 6.5 illustrates the effect of pH on the sorption of Cd ions onto PAni-modified and unmodified sugarcane bagasse and sawdust, with all other parameters held constant: an agitation speed of 110 rpm, a contact time of 24 hours, an adsorbent dosage of 0.3 g per 30 mL metal solution, a temperature of 298.15 K, and pH levels of 2, 4, 6.5, 8, and 10. This setup highlights the significant influence of pH on the efficiency of Cd ion removal by these biosorbents. Conducting a pH study in waste water treatment allows us to determine the ideal pH level for achieving maximum removal effectiveness of metal ions using an adsorbent. Cation Exchange Capacity (CEC) is important in relation to pH because CEC is dependent on pH and CEC is a key factor. Based on **Fig 6.5**, it is evident that the removal effectiveness is lower at acidic pH compared to the alkaline medium and near neutral pH. For instance, the removal effectiveness of PAni doped sugarcane bagasse is 41.23 % at pH 2. However, at pH 8 and pH 10, which are somewhat alkaline and alkaline, respectively, the removal efficiency increases to 86.03 % and 77.02 %. Further, it has been observed that all four biosorbents (i.e. SC Dope, SC UD, SD Dope and SD UD) exhibit their highest removal effectiveness for Cd ions at a pH 8, which is slightly alkaline. This may be because of to the fact that as the pH rises, there is less electrostatic repulsion since there is less positive charge density on the sorption sites, which favours the effective removal of Cd. As the pH rises the adsorption of Cd ions was notably high because the enormous positive charge density induced by protons on the surface sites diminished. This was most likely produced by protons and Cd ions contending for a limited number of adsorption sites on the biosorbent [1]. Zeta potential provides additional insights into the stability of colloidal systems, surface interactions, and the impact of pH on material properties. Zeta potential could help explain how the surface charge of the materials might affect their behaviour in adsorption or ion exchange processes.

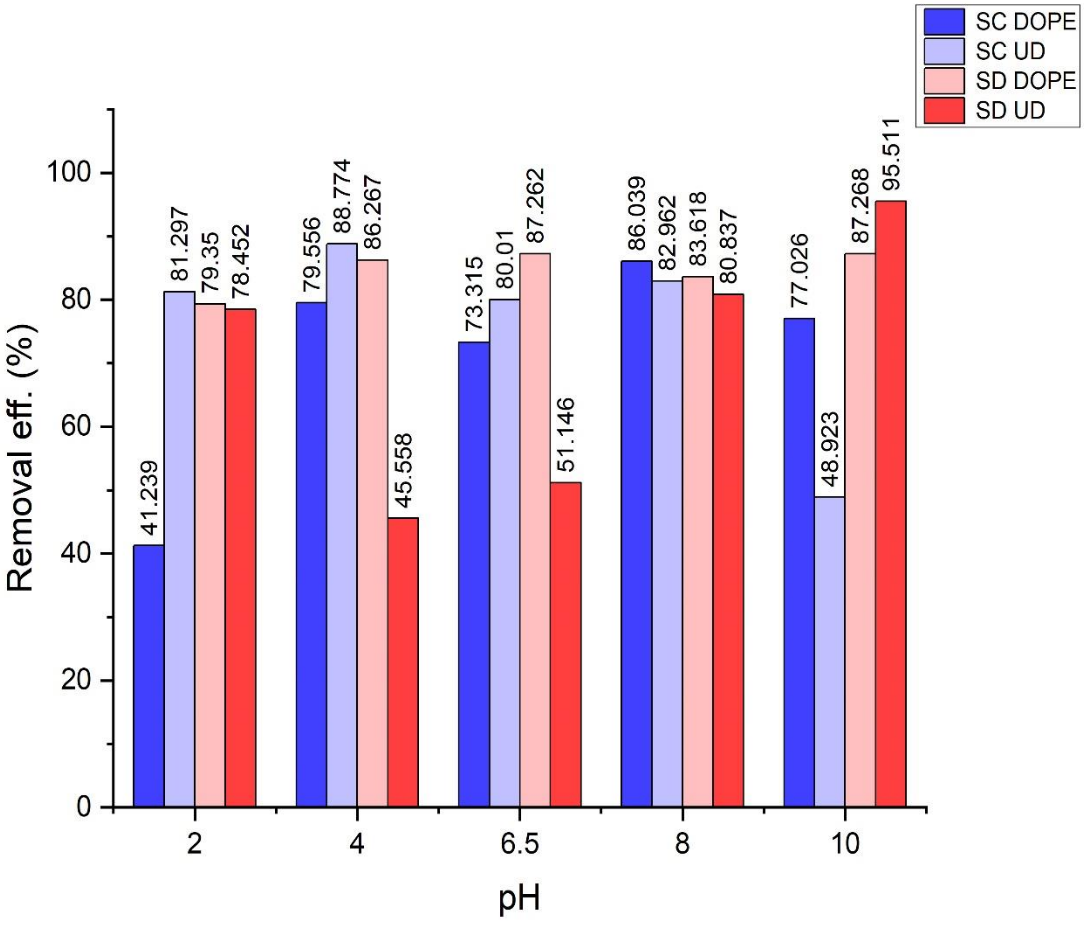


Fig 6.5: Effect of pH on Cd biosorption onto PAni modified SC dope, SC UD, SD dope and SD UD (agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=2, 4, 6.5, 8, 10, temperature= 298.15 K).

6.3.2. Effect of pH on biosorption of Pb onto SC dope, SC UD, SD dope and SD UD.

The effect of pH on Pb ions uptake by biosorbent prepared from PAni modified dope/UD sugarcane bagasse and sawdust by conducting a series batch experiments with pH value 2,4,6.5,8, and 10 ranging from acidic to alkaline to understand its effect on the biosorption rate. The experiment was conducted at room temperature for 24 hrs with an adsorbent dose of 0.3 g with 10 ppm of initial concentration of Pb ions solution. And keeping all other parameters constant [Agitation speed= 110 rpm, Adsorbent dose= 0.3g/30 mL metal solution, Contact time= 24 hrs, Temperature= 298.15 K and pH=2,4,6.5,8 and 10].

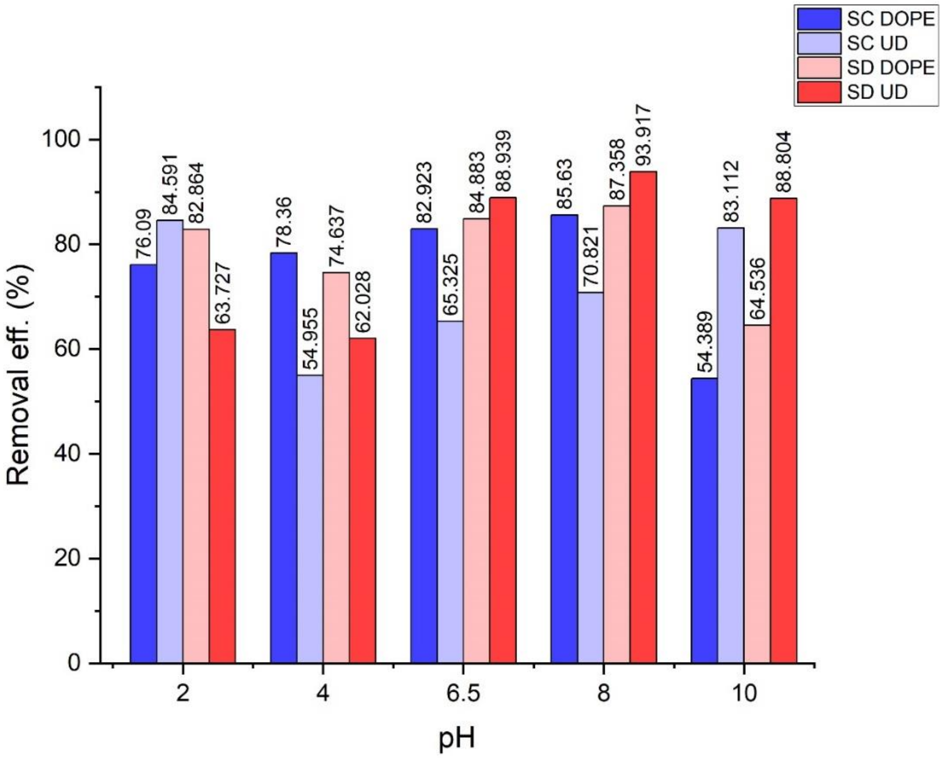


Fig 6.6: Effect of pH on Pb biosorption onto PAni modified SC dope, SC UD, SD dope and SD UD (agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3 g/30 mL metal solution, pH=2, 4, 6.5, 8, 10, temperature= 298.15 K).

The effect of pH on Pb biosorption study in helps in determining the optimum pH level of the wastewater or effluent to attain the highest possible removal efficiency of metal ions by an adsorbent. From the **Fig 6.6,** we can interpret that at acidic and basic pH the removal efficiency is less for example, in case of PAni doped sugarcane bagasse at pH 2 the efficiency is 76.09 % and in pH 10 it is 54.38 % but the maximum Pb ion removal efficiency is obtained at pH 6.5 (near neutral) and at slightly alkaline (pH 8) i.e. 82.92 % and 85.96 % respectively. The same trend is observed for other three biosorbent (i.e. UD SC, dope SD, UD SD) as well. The adsorption of Pb ions was significantly reduced at low pH because of the large positive charge density caused by protons on the surface sites. This was most likely caused by protons and Pb ions competing for a limited number of adsorption sites [1]. As pH rises, there is less electrostatic repulsion because there is less positive charge density on the sorption sites, which promotes efficient removal of Pb.

6.4.Initial ion concentration

The initial metal ion concentration is crucial for overcoming resistance caused by mass transfer between adsorbate and adsorbent interactions. The kinetic and equilibrium aspects of adsorption are greatly impacted by the initial metal ion concentration.

6.4.1. Effect of initial ion concentration on biosorption of Cd onto SC dope, SC UD, SD dope and SD UD.

To know the effect the initial concentration of Cd ions on the removal percentage of PAni doped/UD sugarcane bagasse and sawdust were investigated with a series of batch experiments at five different initial concentration (i.e. 10, 20, 30, 40, 50 ppm) by keeping all other parameter constant [Agitation speed=110 rpm, pH= 6.5, contact time= 24 hrs, adsorbent dose= 0.3 g, temperature= 298.15 K].

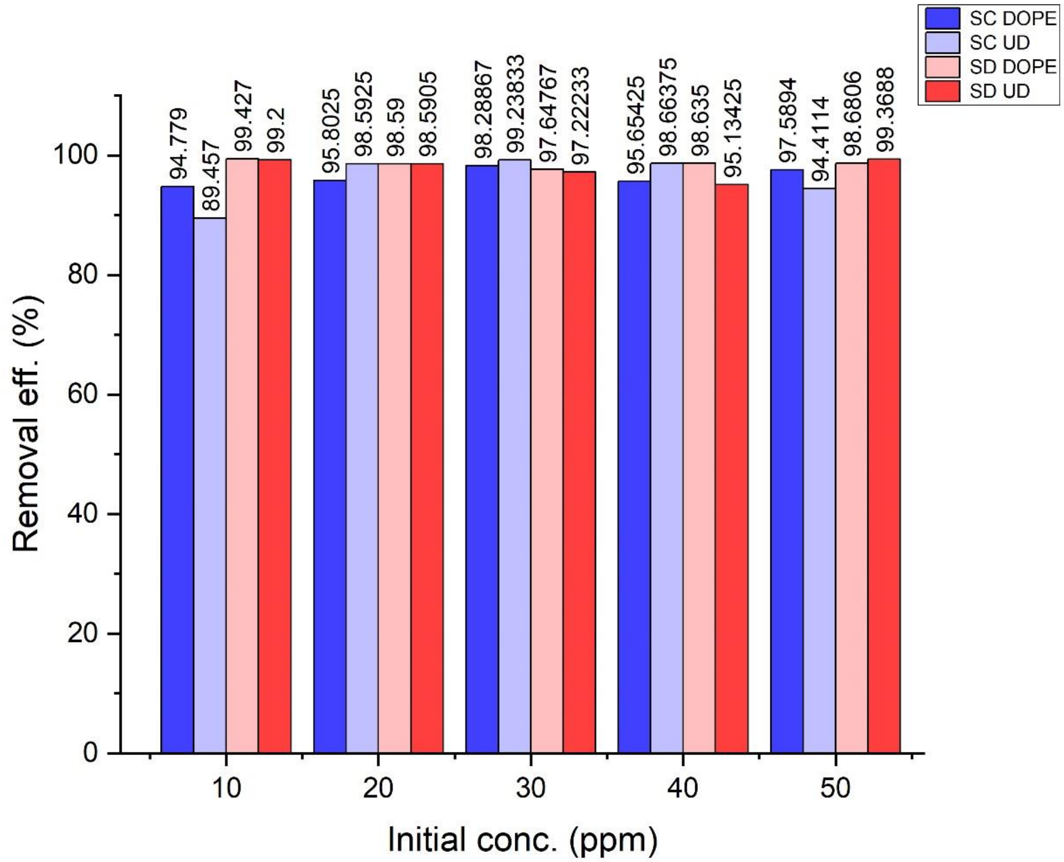


Fig 6.7: Effect of initial ion concentration on Cd biosorption onto PAni modified SC dope, SC UD, SD dope and SD UD [Agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=6.5, temperature= 298.15 K]

As shown in the **Fig 6.7**, it is observed that there are only some minor changes in the removal percentage as the increase in initial ion concentration. For example, in case of PAni dope sugarcane bagasse at initial concentration of 10 ppm the removal percentage is 94.77 % and at 50 ppm concentration it is 97.58 % of removal efficiency. Furthermore, the same trend is observed for the other three biosorbents (i.e. UD SC, dope SD, UD SD) also. This may be because it has reached its maximum adsorption capacity, meaning that regardless of the initial concentration, it can only remove a certain percentage of the Cd ions. This could indicate that the biosorbent is nearing its saturation point. The biosorbents may have reached equilibrium at that particular percentage removal. At equilibrium, the rate of adsorption equals the rate of desorption, leading to a constant percentage of removal regardless of the initial concentration. Also, the biosorbent has a limited surface area available for adsorption, it may only be able to remove a certain percentage of Cd ions regardless of the initial concentration.

6.4.1. Effect of initial ion concentration on biosorption of Pb onto SC dope, SC UD, SD dope and SD UD.

To study the effect of initial metal ion concentration on Pb ion on the removal percentage on PAni modified sugarcane bagasse and sawdust were examined with a series of batch experiments for five different initial concentration (i.e. 10, ,20, 30, 40, 50 ppm) by keeping all other parameter constant [agitation speed= 110 rpms, contact time= 24 hrs, dosage= 0.3 g, pH=6.5, temperature= 298.15 K].

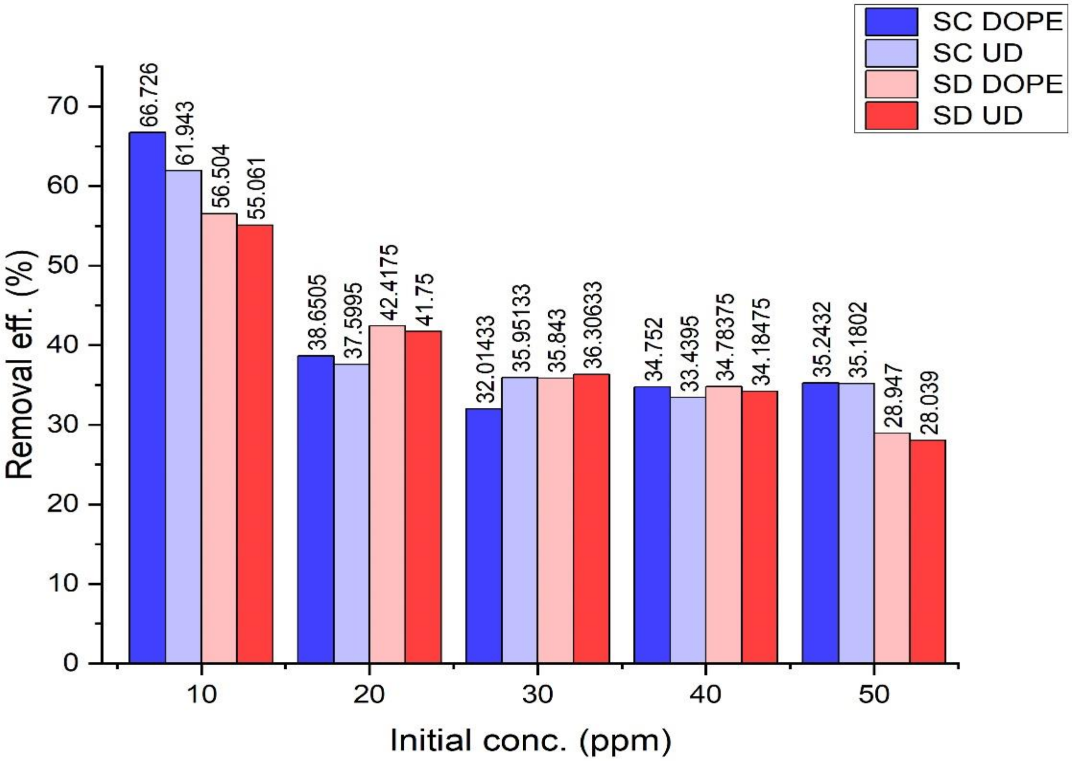


Fig 6.8: Effect of initial ion concentration on Pb biosorption onto PAni SC dope, PAni SC UD, PAni SD dope and PAni SD UD [Agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=6.5, temperature= 298.15 K].

As shown in the **Fig.6.8,** it is evident that with increase in initial metal ion concentration the removal is decreasing drastically. For example, in case of PAni doped sugarcane bagasse the removal efficiency at 10 ppm is 66.72 % whereas as the initial concentration increases to 50 ppm, the removal efficiency drastically reduced to 35.24%. Furthermore, the same trend is observed for all other three biosorbent (i.e. UD SC, dope SD, UD SD) is observed. This is because there may be fewer external binding sites available on the biosorbent's surface due to saturation, which were easily accessible in the biomass at lower concentrations. As a result, we may conclude that at lower concentrations, the removal percentage is high due to the predominance of more binding sites on the surface of the biosorbents, and at higher concentrations, the removal percentage is lower due to the congestion of adsorption sites by Pb ions.

6.5. Statistical Analysis

The results from the analysis of variance test at significant level (α) of 0.05 and DMRT for different biosorbents shown in tables below.

6.5.1. Contact time and initial ion concentration

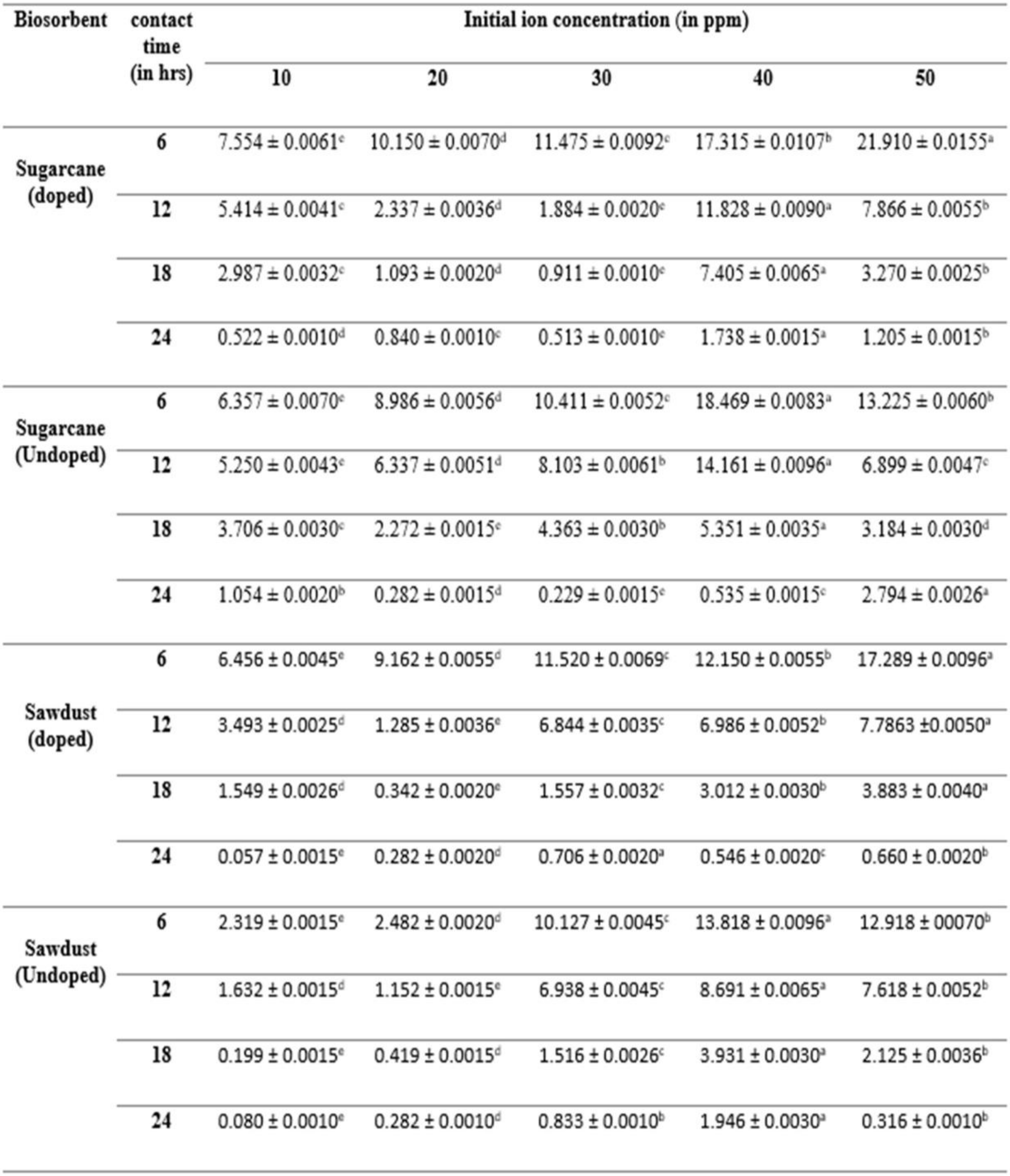
Two-way anova is performed together for the contact time and initial ion concentration separately for all the biosorbents and then DMRT is also conducted at different contact time and ion concentration to check the statistical difference within the biosorbents.

Table.6.1: ANOVA on contact time and initial concentration on biosorption of Cd onto PAni doped and undoped sugarcane bagasse.

ANOVA

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	0.281130013	1	0.28113	0.00473	0.945509	4.084746
Columns	5367.729959	4	1341.932	22.57996	8.19E-10	2.605975
Interaction	25.79385638	4	6.448464	0.108505	0.978867	2.605975
Within	2377.209547	40	59.43024			
Total	7771.014492	49				

Table 6.3: DMRT on different contact time on biosorption of Cd onto PAni doped/undoped sugarcane bagasse and sawdust.



Biosorbent	contact time (in hrs)	Initial ion concentration (in ppm)				
		10	20	30	40	50
Sugarcane (doped)	6	7.554 ± 0.0061^{e}	10.150 ± 0.0070^{d}	11.475 ± 0.0092^{c}	17.315 ± 0.0107^{b}	21.910 ± 0.0155^{a}
	12	5.414 ± 0.0041^{c}	2.337 ± 0.0036^{d}	1.884 ± 0.0020^{e}	11.828 ± 0.0090^{a}	7.866 ± 0.0055^{b}
	18	2.987 ± 0.0032^{c}	1.093 ± 0.0020^{d}	0.911 ± 0.0010^{e}	7.405 ± 0.0065^{a}	3.270 ± 0.0025^{b}
	24	0.522 ± 0.0010^{d}	0.840 ± 0.0010^{c}	0.513 ± 0.0010^{e}	1.738 ± 0.0015^{a}	1.205 ± 0.0015^{b}
Sugarcane (Undoped)	6	6.357 ± 0.0070^{e}	8.986 ± 0.0056^{d}	10.411 ± 0.0052^{c}	18.469 ± 0.0083^{a}	13.225 ± 0.0060^{b}
	12	5.250 ± 0.0043^{e}	6.337 ± 0.0051^{d}	8.103 ± 0.0061^{b}	14.161 ± 0.0096^{a}	6.899 ± 0.0047^{c}
	18	3.706 ± 0.0030^{c}	2.272 ± 0.0015^{e}	4.363 ± 0.0030^{b}	5.351 ± 0.0035^{a}	3.184 ± 0.0030^{d}
	24	1.054 ± 0.0020^{b}	0.282 ± 0.0015^{d}	0.229 ± 0.0015^{e}	0.535 ± 0.0015^{c}	2.794 ± 0.0026^{a}
Sawdust (doped)	6	6.456 ± 0.0045^{e}	9.162 ± 0.0055^{d}	11.520 ± 0.0069^{c}	12.150 ± 0.0055^{b}	17.289 ± 0.0096^{a}
	12	3.493 ± 0.0025^{d}	1.285 ± 0.0036^{e}	6.844 ± 0.0035^{c}	6.986 ± 0.0052^{b}	7.7863 ±0.0050^{a}
	18	1.549 ± 0.0026^{d}	0.342 ± 0.0020^{e}	1.557 ± 0.0032^{c}	3.012 ± 0.0030^{b}	3.883 ± 0.0040^{a}
	24	0.057 ± 0.0015^{e}	0.282 ± 0.0020^{d}	0.706 ± 0.0020^{a}	0.546 ± 0.0020^{c}	0.660 ± 0.0020^{b}
Sawdust (Undoped)	6	2.319 ± 0.0015^{e}	2.482 ± 0.0020^{d}	10.127 ± 0.0045^{c}	13.818 ± 0.0096^{a}	12.918 ± 00070^{b}
	12	1.632 ± 0.0015^{d}	1.152 ± 0.0015^{e}	6.938 ± 0.0045^{c}	8.691 ± 0.0065^{a}	7.618 ± 0.0052^{b}
	18	0.199 ± 0.0015^{e}	0.419 ± 0.0015^{d}	1.516 ± 0.0026^{c}	3.931 ± 0.0030^{a}	2.125 ± 0.0036^{b}
	24	0.080 ± 0.0010^{e}	0.282 ± 0.0010^{d}	0.833 ± 0.0010^{b}	1.946 ± 0.0030^{a}	0.316 ± 0.0010^{b}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan's multiple range test at $p < 0.05$.

Table 6.4: DMRT on different metal ion concentration on biosorption of Cd onto PAni doped/undoped sugarcane bagasse and sawdust.

Initial ion concentration (in ppm)	**Biosorbent**			
	Sugarcane (doped)	**Sugarcane (Undoped)**	**Sawdust (doped)**	**Sawdust (Undoped)**
10	0.522 ± 0.0010^{b}	1.054 ± 0.0020^{a}	0.057 ± 0.0015^{d}	0.080 ± 0.0010^{c}
20	0.840 ± 0.0010^{a}	0.282 ± 0.0015^{b}	0.282 ± 0.0020^{b}	0.282 ± 0.0010^{b}
30	0.513 ± 0.0010^{c}	0.229 ± 0.0015^{d}	0.706 ± 0.0020^{b}	0.833 ± 0.0010^{a}
40	1.738 ± 0.0015^{b}	0.535 ± 0.0015^{c}	0.546 ± 0.0020^{c}	1.946 ± 0.0030^{a}
50	1.205 ± 0.0015^{b}	2.794 ± 0.0026^{a}	0.660 ± 0.0015^{c}	0.316 ± 0.0010^{d}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan's multiple range test at $p < 0.05$.

Table 6.5: ANOVA on contact time and initial concentration on biosorption of Pb onto PAni doped and undoped sugarcane bagasse.

ANOVA

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	168.2001755	1	168.2002	1.403617	0.243111	4.084746
Columns	4432.858553	4	1108.215	9.24796	2.18E-05	2.605975
Interaction	148.5959759	4	37.14899	0.310005	0.869588	2.605975
Within	4793.336567	40	119.8334			
Total	9542.991271	49				

From the above **Table 6.5,** we can conclude that at samples variations the FCrit > FStats and P-value is greater than 0.05 that means we are fail to reject null hypothesis, which means as there is no difference between the doped sugarcane bagasse and undoped sugarcane bagasse as per this hypothetical data. Additionally at columns variations the FCrit < FStats and p-value is very smaller than 0.05 that means there is significant difference and alternate hypothesis will be accepted thus we can say that there is lot of significant difference among the PAni doped sugarcane bagasse and undoped sugarcane bagasse. And in interaction it shows that FCrit > FStats and p-value is greater than 0.05. So, we are going to accept the null hypothesis, and there is no significant difference among the uptake capacity of Pb ions and PAni doped sugarcane bagasse and PAni undoped sugarcane bagasse.

Table 6.6: ANOVA on contact time and initial concentration on biosorption of Pb onto PAni doped and undoped sawdust.

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Sample	18.75941	1	18.75941	0.141007	0.709266	4.084746
Columns	4784.564	4	1196.141	8.990931	2.81E-05	2.605975
Interaction	41.26444	4	10.31611	0.077542	0.988718	2.605975
Within	5321.545	40	133.0386			
Total	10166.13	49				

From the above **Table 6.6,** we can conclude that at samples variations the FCrit > FStats and P-value is greater than 0.05 that means we are fail to reject null hypothesis, which means as there is no difference between the doped sugarcane bagasse and undoped sugarcane bagasse as per this hypothetical data. Additionally at columns variations the FCrit < FStats and p-value is very smaller than 0.05 that means there is significant difference and alternate hypothesis will be accepted thus we can say that there is lot of significant difference among the PAni doped sugarcane bagasse and undoped sugarcane bagasse. And in interaction it shows that FCrit > FStats and p-value is greater than 0.05. So, we are going to accept the null hypothesis, and there is no significant difference among the uptake capacity of Pb ions and PAni doped sawdust and PAni undoped sawdust.

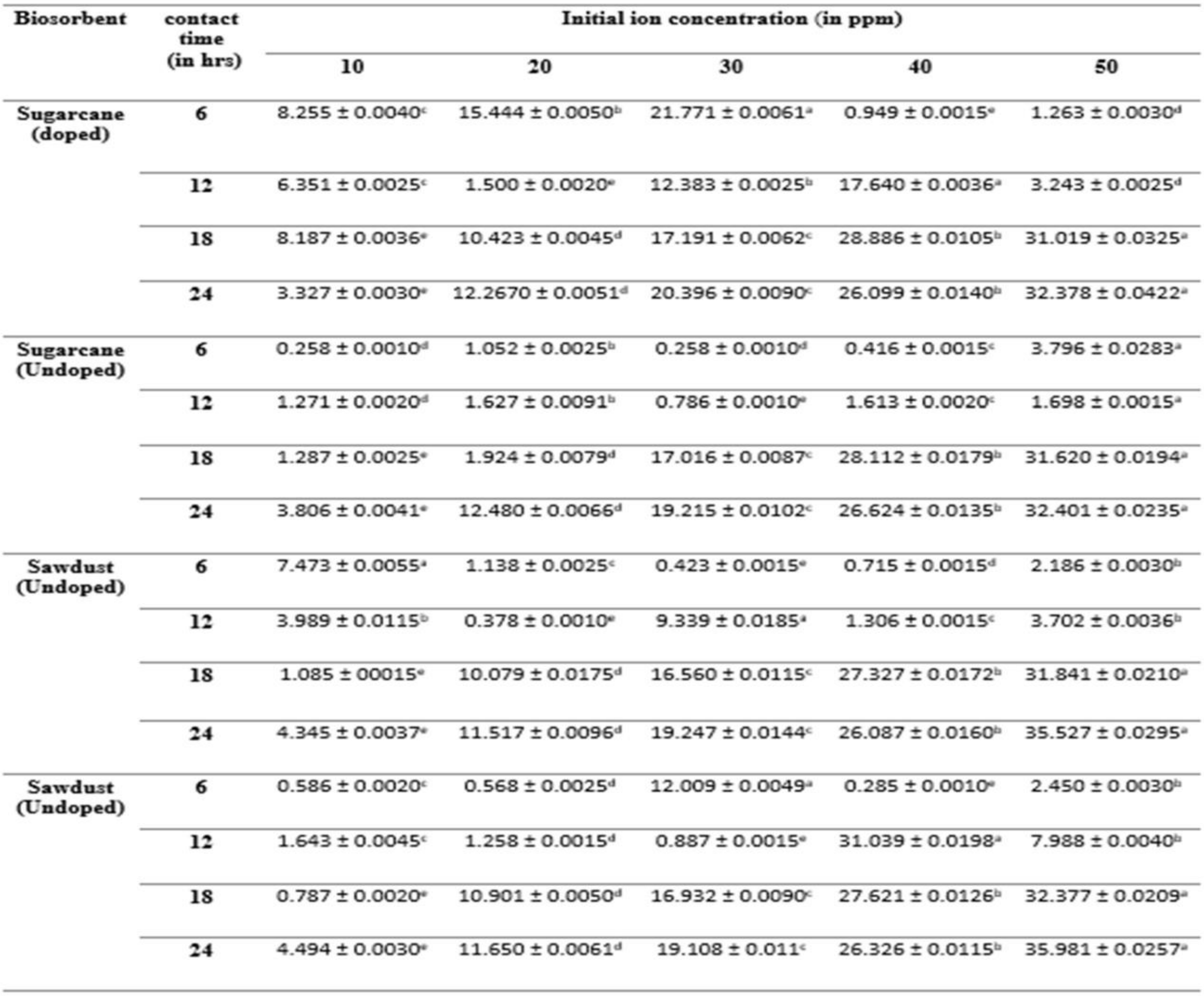
Table 6.7: DMRT on different metal ion concentration on biosorption of Pb onto PAni doped/undoped sugarcane bagasse and PAni doped/undoped sawdust.

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ

Initial ion concentration (in ppm)	**Biosorbent**			
	Sugarcane (doped)	**Sugarcane (undoped)**	**Sawdust (doped)**	**Sawdust (undoped)**
10	3.327 ± 0.0030^{d}	3.806 ± 0.0041^{c}	4.345 ± 0.0037^{b}	4.494 ± 0.0030^{a}
20	12.267 ± 0.0051^{b}	12.480 ± 0.0066^{a}	11.517 ± 0.0096^{d}	11.650 ± 0.0061^{c}
30	20.396 ± 0.0090^{a}	19.215 ± 0.0102^{c}	19.247 ± 0.0144^{b}	19.108 ± 0.011^{d}
40	26.099 ± 0.0140^{c}	26.624 ± 0.0135^{a}	26.087 ± 0.0160^{c}	26.326 ± 0.0115^{b}
50	32.378 ± 0.0422^{d}	32.401 ± 0.0235^{c}	35.527 ± 0.0295^{b}	35.981 ± 0.0257^{a}

significantly according to the Duncan’s multiple range test at $p < 0.05$.

Table 6.8: DMRT on different contact time on biosorption of Pb onto PAni doped/undoped sugarcane bagasse and PAni doped/undoped sawdust.



Biosorbent	contact time (in hrs)	Initial ion concentration (in ppm)				
		10	20	30	40	50
Sugarcane (doped)	6	8.255 ± 0.0040^{c}	15.444 ± 0.0050^{b}	21.771 ± 0.0061^{a}	0.949 ± 0.0015^{e}	1.263 ± 0.0030^{d}
	12	6.351 ± 0.0025^{c}	1.500 ± 0.0020^{e}	12.383 ± 0.0025^{b}	17.640 ± 0.0036^{a}	3.243 ± 0.0025^{d}
	18	8.187 ± 0.0036^{e}	10.423 ± 0.0045^{d}	17.191 ± 0.0062^{c}	28.886 ± 0.0105^{b}	31.019 ± 0.0325^{a}
	24	3.327 ± 0.0030^{e}	12.2670 ± 0.0051^{d}	20.396 ± 0.0090^{c}	26.099 ± 0.0140^{b}	32.378 ± 0.0422^{a}
Sugarcane (Undoped)	6	0.258 ± 0.0010^{d}	1.052 ± 0.0025^{b}	0.258 ± 0.0010^{d}	0.416 ± 0.0015^{c}	3.796 ± 0.0283^{a}
	12	1.271 ± 0.0020^{d}	1.627 ± 0.0091^{b}	0.786 ± 0.0010^{e}	1.613 ± 0.0020^{c}	1.698 ± 0.0015^{a}
	18	1.287 ± 0.0025^{e}	1.924 ± 0.0079^{d}	17.016 ± 0.0087^{c}	28.112 ± 0.0179^{b}	31.620 ± 0.0194^{a}
	24	3.806 ± 0.0041^{e}	12.480 ± 0.0066^{d}	19.215 ± 0.0102^{c}	26.624 ± 0.0135^{b}	32.401 ± 0.0235^{a}
Sawdust (Undoped)	6	7.473 ± 0.0055^{a}	1.138 ± 0.0025^{c}	0.423 ± 0.0015^{e}	0.715 ± 0.0015^{d}	2.186 ± 0.0030^{b}
	12	3.989 ± 0.0115^{b}	0.378 ± 0.0010^{e}	9.339 ± 0.0185^{a}	1.306 ± 0.0015^{c}	3.702 ± 0.0036^{b}
	18	1.085 ± 00015^{e}	10.079 ± 0.0175^{d}	16.560 ± 0.0115^{c}	27.327 ± 0.0172^{b}	31.841 ± 0.0210^{a}
	24	4.345 ± 0.0037^{e}	11.517 ± 0.0096^{d}	19.247 ± 0.0144^{c}	26.087 ± 0.0160^{b}	35.527 ± 0.0295^{a}
Sawdust (Undoped)	6	0.586 ± 0.0020^{c}	0.568 ± 0.0025^{d}	12.009 ± 0.0049^{a}	0.285 ± 0.0010^{e}	2.450 ± 0.0030^{b}
	12	1.643 ± 0.0045^{c}	1.258 ± 0.0015^{d}	0.887 ± 0.0015^{e}	31.039 ± 0.0198^{a}	7.988 ± 0.0040^{b}
	18	0.787 ± 0.0020^{e}	10.901 ± 0.0050^{d}	16.932 ± 0.0090^{c}	27.621 ± 0.0126^{b}	32.377 ± 0.0209^{a}
	24	4.494 ± 0.0030^{e}	11.650 ± 0.0061^{d}	19.108 ± 0.011^{c}	26.326 ± 0.0115^{b}	35.981 ± 0.0257^{a}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan’s multiple range test at $p < 0.05$.

6.5.2. Biosorbent dosage

One-way anova is performed for dosages for all the biosorbents separately and then DMRT is also conducted for different dosages to check the statistical difference within the biosorbents.

Table 6.9: ANOVA on different dosage on biosorption of Cd onto PAni doped/undoped sugarcane bagasse and PAni doped/undoped sawdust.

Sugarcane (doped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34.53792	1	34.53792	9.911063	0.034574	7.708647
Within Groups	13.93914	4	3.484785			
Total	48.47706	5				

Sugarcane (undoped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.777888	1	0.777888	3.236288	0.146414	7.708647
Within Groups	0.961457	4	0.240364			
Total	1.739345	5				

Sawdust (doped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.407047	1	2.407047	17.80106	0.013487	7.708647
Within Groups	0.540877	4	0.135219			
Total	2.947924	5				

Sawdust (undoped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.382208	1	1.382208	5.440249	0.080038	7.708647
Within Groups	1.016283	4	0.254071			
Total	2.398491	5				

Based on the information provided in **Table 6.9**, we can conclude that the sugarcane doped samples, the analysis of variance shows that the $F_{stat} > F_{crti}$ and the p-value is less than 0.05. The test results are statistically significant, and the alternative hypothesis is accepted. For undoped sugarcane, the Fstat<Fcrti and the p-value is greater than 0.05. Therefore, the test is not statistically significant and the null hypothesis is accepted. In addition, the Fstat>Fcrti and the p- value is less than 0.05 for the sawdust doped condition. Conversely, the Fstat<Fcrti and the p- value is greater than 0.05 for the sawdust undoped condition. Therefore, the test results indicate that the sawdust doped has a significant effect, leading to the acceptance of the alternative hypothesis. Conversely, the analysis of variance test results shows that the sawdust undoped does not have a significant effect, resulting in the rejection of the alternative hypothesis.

The statistical analysis reveals that the impact of different dosage on the biosorption of Cd ions onto PAni-doped/undoped sugarcane bagasse and PAni-doped/undoped sawdust is significantly different.

Table 6.10: DMRT on different dosage on biosorption of Cd onto PAni DP/UD sugarcane bagasse and sawdust.

Dosage (in g)	**Sugarcane (doped)**	**Sugarcane (Undoped)**	**Sawdust (doped)**	**Sawdust (Undoped)**
0.1	7.144 ± 0.0090^{a}	1.416 ± 0.0070^{d}	1.893 ± 0.011^{b}	1.848 ± 0.0051^{c}
0.25	5.985 ± 0.0184^{a}	1.356 ± 0.0145^{c}	1.755 ± 0.014^{b}	1.380 ± 0.0085^{c}
0.5	2.117 ± 0.0115^{a}	0.238 ± 0.0074^{d}	1.003 ± 0.0086^{b}	0.502 ± 0.0085^{c}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan's multiple range test at $p < 0.05$.

Table 6.11: ANOVA on different dosage on biosorption of Pb onto PAni doped/undoped sugarcane bagasse and PAni doped/undoped sawdust**.**

Sugarcane (doped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34.53792	1	34.53792	9.911063	0.034574	7.708647
Within Groups	13.93914	4	3.484785			
Total	48.47706	5				

Sugarcane (undoped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.777888	1	0.777888	3.236288	0.146414	7.708647
Within Groups	0.961457	4	0.240364			
Total	1.739345	5				

Sawdust (doped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	2.407047	1	2.407047	17.80106	0.013487	7.708647
Within Groups	0.540877	4	0.135219			
Total	2.947924	5				

Sawdust (undoped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	1.382208	1	1.382208	5.440249	0.080038	7.708647
Within Groups	1.016283	4	0.254071			
Total	2.398491	5				

Sugarcane (doped)

Based on the information provided in **Table 6.11**, we can conclude that for sugarcane doped samples, the analysis of variance shows that the $F_{stat}<F_{crti}$ and the p-value is greater than 0.05 and for undoped sugarcane, the $F_{stat}<F_{crti}$ and the p-value is greater than 0.05. Therefore, the tests are not statistically significant and the null hypothesis is accepted.

In addition, the $F_{stat}>F_{crti}$ and the p-value is less than 0.05 for the sawdust doped condition and for sawdust undoped condition the $F_{stat}>F_{crti}$ and the p-value is less than 0.05. Therefore, the test results indicate that there is a significant difference, leading to the acceptance of the alternative hypothesis and rejection of null hypothesis for both doped and undoped condition of sawdust.

The statistical analysis reveals that the impact of different dosage on the biosorption of Pb ions onto PAni-doped/undoped sugarcane bagasse and PAni-doped/undoped sawdust is significantly different.

Table 6.12: DMRT on different dosage on biosorption of Pb onto PAni DP/UD sugarcane bagasse and sawdust.

Dosage (in g)	**Sugarcane (doped)**	**Sugarcane (Undoped)**	**Sawdust (doped)**	**Sawdust (Undoped)**
0.1	2.306 ± 0.0053^{c}	3.265 ± 0.0085^{a}	2.056 ± 0.013^{d}	2.870 ± 0.0075^{b}
0.25	1.464 ± 0.0135^{c}	2.956 ± 0.0125^{a}	1.477 ± 0.0120^{c}	2.414 ± 0.0102^{b}
0.5	0.451 ± 0.0140^{d}	1.109 ± 0.0111^{c}	1.272 ± 0.0105^{b}	2.281 ± 0.0075^{a}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan's multiple range test at $p < 0.05$.

6.5.3. pH

One-way ANOVA is performed for pH for all the biosorbents separately and then DMRT is also conducted for different pH to check the statistical difference within the biosorbents.

Table 6.13: ANOVA on different pH on biosorption of Cd onto PAni doped / undoped sugarcane bagasse and PAni doped / undoped sawdust.

Sugarcane (doped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	26.30073	1	26.30073	4.010924	0.080177	5.317655
Within Groups	52.4582	8	6.557274			
Total	78.75893	9				

Sugarcane (undoped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	34.95629	1	34.95629	5.583877	0.045742	5.317655
Within Groups	50.08174	8	6.260217			
Total	85.03802	9				

Sawdust (doped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	52.33343	1	52.33343	10.29833	0.012441	5.317655
Within Groups	40.65393	8	5.081741			
Total	92.98736	9				

Sawdust (undoped)

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	24.4935	1	24.4935	3.371369	0.103659	5.317655
Within Groups	58.1212	8	7.26515			
Total	82.6147	9				

Based on the information provided in **Table 6.13**, we can conclude that for sugarcane doped samples, the analysis of variance shows that the $F_{stat}<F_{crti}$ and the p-value is greater than 0.05 and for undoped sugarcane, the $F_{stat}>F_{crti}$ and the p-value is smaller than 0.05. Thus, the test misses statistical significance for the sugarcane dope, although it does possess statistical significance for the sugarcane undoped. The null hypothesis is rejected for the case where sugarcane is doped, and accepted for the condition where sugarcane is undoped.

In addition, the $F_{stat}>F_{crti}$ and the p-value is less than 0.05 for the sawdust doped condition and for sawdust undoped condition the $F_{stat}>F_{crti}$ and the p-value is greater than 0.05. Therefore, the test results indicate that there is a significant difference for sawdust doped and fails for the sawdust undoped, leading to the acceptance of the alternative hypothesis and rejection of alternative hypothesis for doped sawdust and undoped sawdust conditions respectively.

The statistical analysis reveals that the impact of different pH on the biosorption of Cd ions onto PAni-doped/undoped sugarcane bagasse and PAni-doped/undoped sawdust is significantly different.

Table 6.14: DMRT on different pH on biosorption of Cd onto PAni DP/UD sugarcane bagasse and sawdust.

pH	**Sugarcane (doped)**	**Sugarcane (Undoped)**	**Sawdust (doped)**	**Sawdust (Undoped)**
2	5.876 ± 0.105^{a}	1.870 ± 0.001^{c}	2.065 ± 0.003^{b}	2.155 ± 0.004^{b}
4	2.044 ± 0.003^{b}	1.123 ± 0.003d	1.373 ± 0.004^{c}	5.444 ± 0.002^{a}
6.5	2.669 ± 0.004^{b}	1.999 ± 0.053^{c}	1.274 ± 0.004^{d}	4.885 ± 0.009^{a}
8	1.396 ± 0.004^{d}	1.704 ± 0.005^{b}	1.638 ± 0.004^{c}	1.916 ± 0.051^{a}
10	2.297 ± 0.004^{b}	5.108 ± 0.006^{a}	1.273 ± 0.004^{c}	0.449 ± 0.014^{d}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan's multiple range test at $p < 0.05$.

Table 6.15: ANOVA on different pH on biosorption of Pb onto PAni doped/undoped sugarcane bagasse and PAni doped/undoped sawdust.

Sugarcane (doped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	33.26684	1	33.26684	5.745671	0.043378	5.317655
Within Groups	46.31918	8	5.789897			
Total	79.58602	9				

Sugarcane (undoped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	26.83175	1	26.83175	4.627958	0.063649	5.317655
Within Groups	46.38201	8	5.797752			
Total	73.21376	9				

Sawdust (doped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	39.71172	1	39.71172	7.273983	0.027199	5.317655
Within Groups	43.67535	8	5.459419			
Total	83.38707	9				

Sawdust (undoped)

Source Variation	*ofSS*	*df*	*MS*	*F*	*P-value*	*F crit*

Between Groups	40.97183	1	40.97183	6.611605	0.03306	5.317655
Within Groups	49.57566	8	6.196957			
Total	90.54749	9				

Based on the information provided in **Table 6.15**, we can conclude that for sugarcane doped samples, the analysis of variance shows that the $F_{stat}>F_{crti}$ and the p-value is less than 0.05 and for undoped sugarcane, the $F_{stat}<F_{crti}$ and the p-value is greater than 0.05. Thus, the test statistical significance for the sugarcane dope, although it does not possess statistical significance for the sugarcane undoped. The alternative hypothesis is accepted for the case where sugarcane is doped, and rejected for the condition where sugarcane is undoped.

In addition, the $F_{stat}>F_{crti}$ and the p-value is less than 0.05 for the sawdust doped condition and for sawdust undoped condition the $F_{stat}>F_{crti}$ and the p-value is greater than 0.05. Therefore, the test results indicate that there is a significant difference for sawdust doped and fails for the sawdust undoped, leading to the acceptance of the alternative hypothesis and rejection for doped sawdust and undoped sawdust conditions respectively.

The statistical analysis reveals that the impact of different pH on the biosorption of Pb ions onto PAni-doped/undoped sugarcane bagasse and PAni-doped/undoped sawdust is significantly different.

Table 6.16: DMRT on different pH on biosorption of Pb onto PAni DP/UD sugarcane bagasse and sawdust.

pH	**Sugarcane (doped)**	**Sugarcane (Undoped)**	**Sawdust (doped)**	**Sawdust (Undoped)**
2	2.391 ± 0.0101^{b}	1.541 ± 0.0160^{d}	1.714 ± 0.0115^{c}	3.627 ± 0.0076^{b}
4	2.164 ± 0.0043^{d}	4.505 ± 0.0075^{a}	2.536 ± 0.0067^{c}	3.797 ± 0.0057^{b}
6.5	1.708 ± 0.0120^{b}	3.468 ± 0.0116^{a}	1.512 ± 0.0122^{c}	1.106 ± 0.0120^{d}
8	1.437 ± 0.0075^{b}	2.918 ± 0.0125^{a}	1.264 ± 0.0081^{c}	0.608 ± 0.0125^{d}
10	4.561 ± 0.0075^{a}	1.688 ± 0.0075^{c}	3.546 ± 0.0100^{b}	1.120 ± 0.0075^{d}

Data shown are Mean ± S.D. Values in the same row sharing the different letters differ significantly according to the Duncan's multiple range test at $p < 0.05$

6.6. To study the adsorption kinetics to understand the variations of uptake of Cd with time.

An investigation was conducted to evaluate the influence of adsorption contact duration on the removal of Cd ions using PAni-doped and undoped sugarcane bagasse and sawdust composites, as depicted in Figures 6.9 and 6.10. The study found that the adsorption of Cd ions increased with contact time initially and then declined until equilibrium was reached after 24 hours for both PAni-doped and undoped sugarcane bagasse and sawdust. This adsorption behavior is primarily due to the abundance of surface binding sites during the early stages of the adsorption process. As these sites become occupied, the number of vacant active sites diminishes, making it more challenging to adsorb additional Cd ions due to electrostatic repulsions between the remaining Cd ions in solution and those already adsorbed on the surfaces of the biosorbents [3].

To further understand the kinetics of Cd ion adsorption, the study employed pseudo-first-order (PFO) and pseudo-second-order (PSO) models. The mathematical equations and corresponding parameters for these kinetic models were derived using non-linear regression analysis, with results summarized in Tables 6.17 and 6.18 for PFO and PSO, respectively. The regression coefficient (R^2) for the PSO model for PAni-doped sugarcane bagasse at different Cd ion concentrations (10, 20, 30, 40 ppm) were 0.820, 0.987, 0.995, and 0.998, respectively. In contrast, the R^2 values for the PFO model for the same bio-composite were significantly lower, at 0.051, 0.043, 0.034, and 0.034, respectively. These results indicate that the PSO model better fits the experimental adsorption data. Furthermore, the estimated uptake capacities (qe) from the PSO model showed a strong agreement with the experimentally obtained values (qe exp.).

Supporting these findings, Hsini et al. (2020) conducted a study on the removal of OG dye and Cr (VI) using PAni-doped almond shell and found that the R^2 values for the PSO kinetic model were 0.940 for OG dye and 0.985 for Cr (VI). This further confirms that the PSO model best corresponds to the adsorption experimental data, demonstrating its reliability and applicability in describing the kinetics of biosorption processes [3].

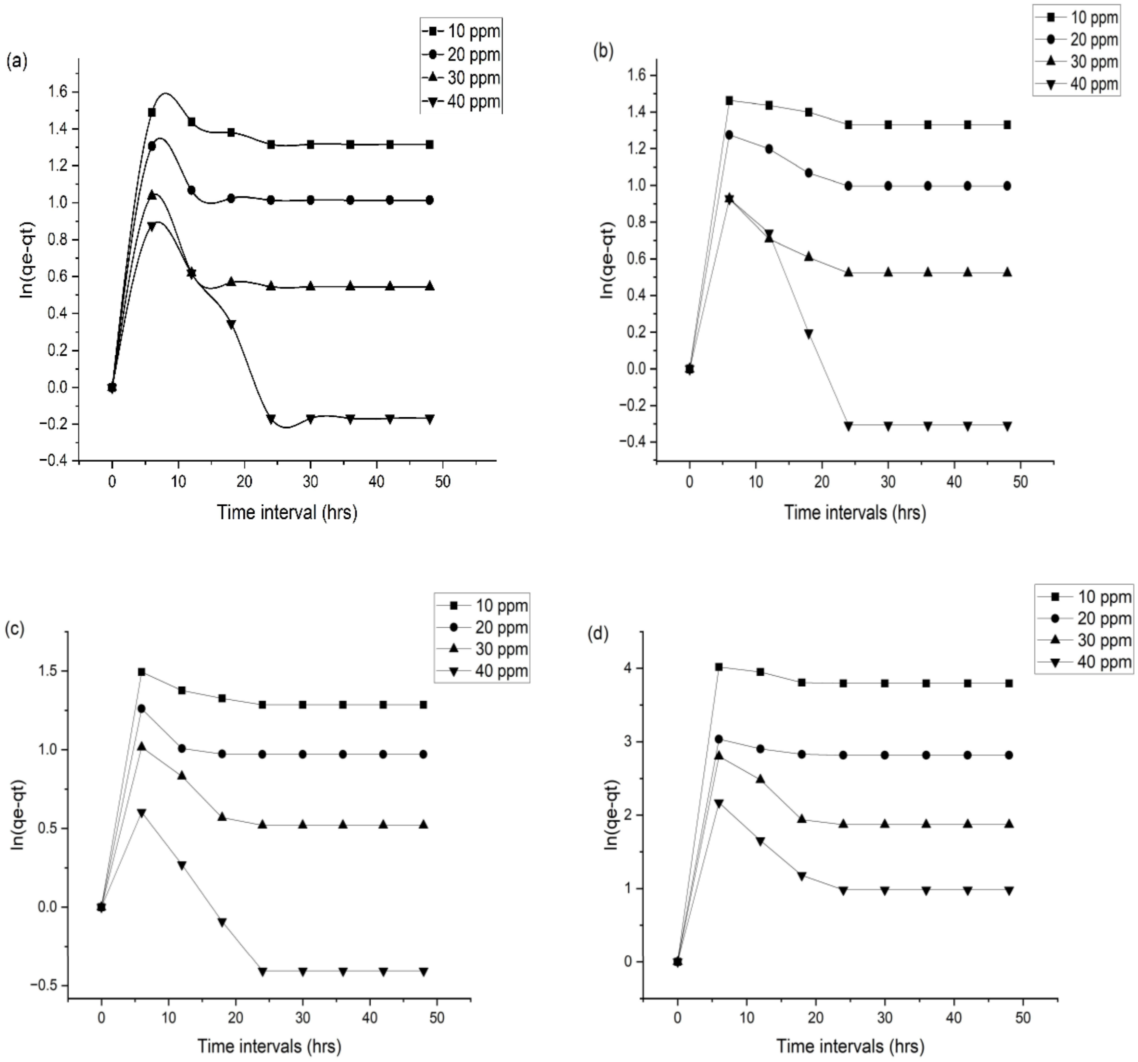
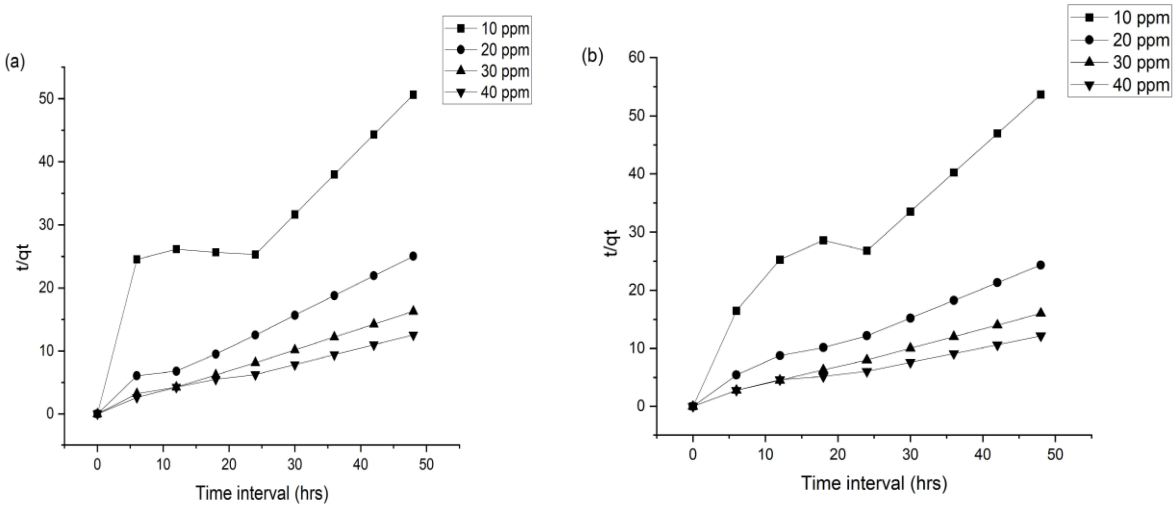


Fig 6.9: pseudo-first-order kinetics model for Cd onto PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD [Agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=6.5, temperature= 298.15 K].

Table 6.17: Pseudo-first-order kinetic model parameters for the adsorption of Cd onto PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD.

Bio-composite	**qe(exp.)**	**qe (mg/g)**	**k1**	**R^2**
Sugarcane (doped)	0.7013	2.4934	0.0003	0.0519
	1.8907	2.0877	0.0002	0.0435
	2.9089	1.6734	0.0000	0.0349
	3.2595	1.6555	-0.0003	0.0345
Sugarcane (undoped)	0.6294	2.4769	0.0003	0.1016
	1.7728	2.1572	0.0002	-0.0182
	2.5637	1.6677	0.0000	-0.1356
	3.4649	1.7139	-0.0004	0.4240
Sawdust (doped)	0.8451	2.4456	0.0002	0.0758
	1.9658	2.0213	0.0002	0.0244
	2.8446	1.7557	0.0000	-0.1427
	3.6988	1.3263	-0.0004	0.5510
Sawdust (undoped)	0.9802	2.4456	0.0002	0.0758
	1.9581	2.0213	0.0002	0.0244
	2.8484	1.7557	0.0000	-0.1427
	3.6069	1.3263	-0.0004	0.5510



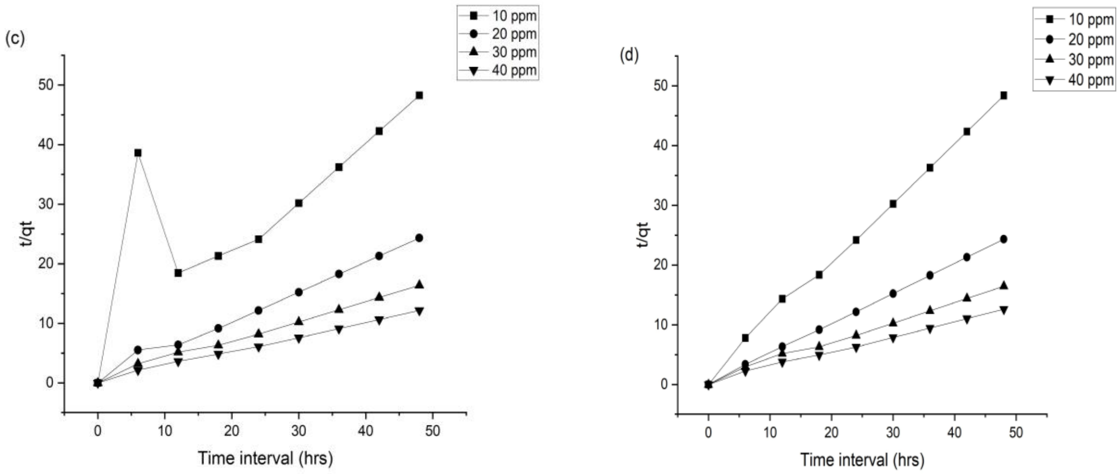


Fig 6.10: Pseudo-second-order kinetics model for Cd onto PAni dope SC, PAni UD SC, PAni SD dope and PAni UD SD [Agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=6.5, temperature= 298.15 K].

Table 6.18: Pseudo-second-order kinetic model parameters for the adsorption of Cd onto PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD.

Bio-composite	qe (exp.)	qe (mg/g)	qe^2	R^2	k2
Sugarcane (doped)	0.701	1.235	1.525	0.820	0.065
	1.891	2.025	4.099	0.987	0.227
	2.909	3.051	9.308	0.995	0.245
	3.260	4.101	16.814	0.988	0.079
Sugarcane (undoped)	0.629	1.056	1.115	0.921	0.121
	1.773	2.131	4.541	0.984	0.139
	2.564	3.089	9.543	0.998	0.246
	3.465	4.307	18.553	0.978	0.060
Sawdust (doped)	0.845	1.449	2.100	0.538	0.039
	1.966	2.064	4.260	0.990	0.273
	2.845	3.079	9.477	0.993	0.157
	3.699	4.098	16.791	0.997	0.150
Sawdust (undoped)	0.980	1.020	1.041	0.998	0.846
	1.958	1.991	3.965	1.000	1.268
	2.848	3.045	9.274	0.994	0.182
	3.607	3.963	15.706	0.996	0.146

6.7. To study the adsorption kinetics to understand the variations of uptake of Pb ions with time.

An investigation was conducted to evaluate the influence of adsorption contact duration on the removal of Pb ions using PAni-doped and undoped sugarcane bagasse and sawdust composites, as depicted in Figures 6.11 and 6.12. The study found that the adsorption of Pb ions increased initially with contact time, eventually reaching equilibrium after 24 hours for both PAni-doped and undoped sugarcane bagasse and sawdust. This adsorption behavior is attributed to the abundance of surface binding sites available during the early stages of the adsorption process. As these sites become occupied, the number of vacant active sites decreases, making it more challenging to adsorb additional Pb ions due to the electrostatic repulsions between the remaining Pb ions in the solution and those already adsorbed on the biosorbent surfaces [3].

To further understand the kinetics of Pb ion adsorption, the study employed both pseudo-first-order (PFO) and pseudo-second-order (PSO) models. The mathematical equations and parameters for these kinetic models were derived using non-linear regression analysis, with the results summarized in Tables 6.19 and 6.20 for the PFO and PSO models, respectively. For PAni-doped sugarcane bagasse, the regression coefficient (R^2) values for the PSO model at different Pb ion concentrations (10, 20, 30, 40 ppm) were 0.272, 0.967, 0.983, and 0.979, respectively. In contrast, the R^2 values for the PFO model for the same bio-composite were significantly lower, at 0.134, 0.273, 0.286, and 0.550, respectively. These results indicate that the PSO model better fits the experimental adsorption data for Pb ions. Additionally, the estimated uptake capacities (qe) from the PSO model showed strong agreement with the experimentally obtained values (qe exp.).

Mishra et al. (2022) conducted a study on the removal of fluoride ions using beads composed of polyether sulfone impregnated with doped and undoped PAni. They observed the adsorption kinetics using both the PFO and PSO models, concluding that the fitting parameter R^2 ranged from 0.99 to 1, which was highest for the PSO model. This further confirms the reliability and applicability of the PSO model in accurately describing the kinetics of adsorption processes, including the removal of Pb ions using PAni-doped and undoped biosorbents [5].

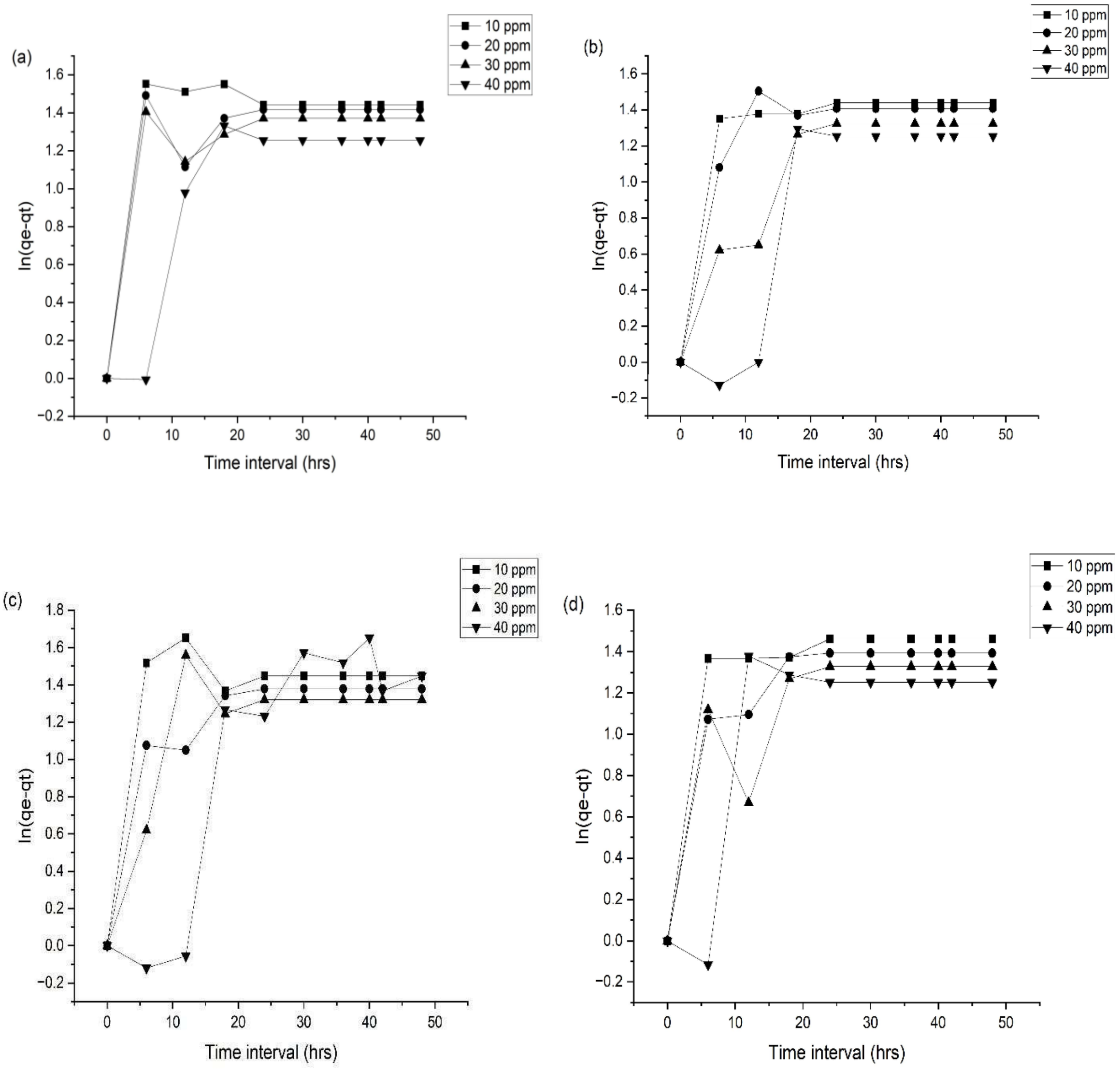
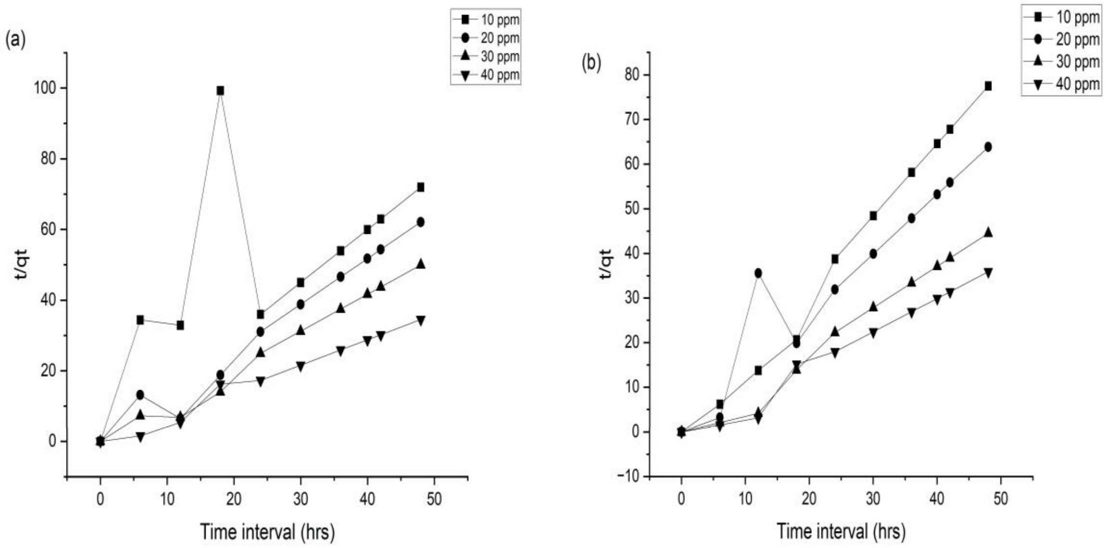


Fig 6.11: Pseudo-first-order kinetics model for Pb onto (a) PAni dope SC, (b) PAni UD SC,(c) PAni dope SD and (d) PAni UD SD [Agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=6.5, temperature= 298.15 K].

Table 6.19: Pseudo-first-order kinetic model parameters for the adsorption of Pb onto PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD.

Bio-composite	qe (exp.)	qe (mg/g)	k_1	R^2
Sugarcane (doped)	0.8813	2.6473	0.0003	0.1344
	1.8577	2.2869	0.0003	0.2739
	2.8809	2.2191	0.0003	0.2860
	3.8114	1.4056	0.0005	0.5503
Sugarcane (Undoped)	0.8713	2.3333	0.0003	0.2875
	1.8076	2.2165	0.0004	0.3196
	2.8984	1.5448	0.0005	0.6701
	3.8888	1.0572	0.0007	0.6337
Sawdust (doped)	0.8713	2.6205	0.0003	0.1401
	1.8076	1.9756	0.0004	0.4668
	2.8984	1.9234	0.0004	0.3598
	3.8888	0.9939	0.0008	0.7121
Sawdust (Undoped)	0.8213	2.3299	0.0004	0.3054
	1.8090	2.0046	0.0004	0.4580
	2.8068	1.8106	0.0004	0.4865
	3.8379	1.4876	0.0005	0.4085



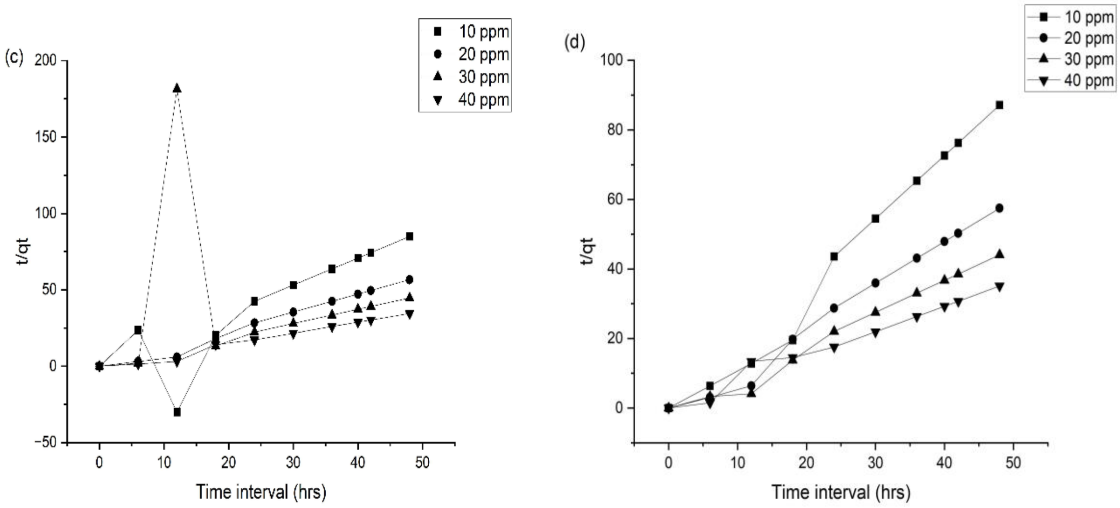


Fig 6.12: Pseudo-second-order kinetics model for Pb onto (a) PAni dope SC, (b) PAni UD SC, (c) PAni SD dope SD and (d) PAni UD SD [Agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 0.3g/30 mL metal solution, pH=6.5, temperature= 298.15 K].

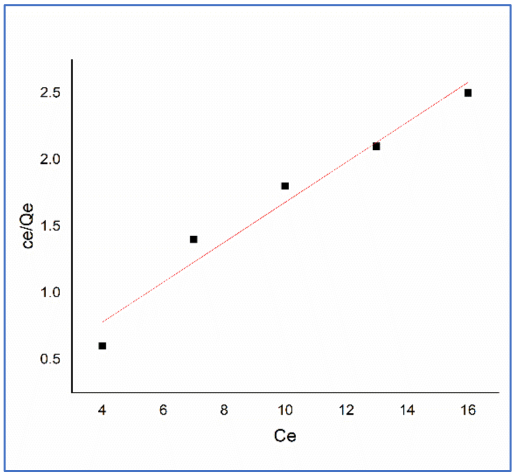
Table 6.20: Pseudo-second-order kinetic model parameters for the adsorption of Pb onto PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD

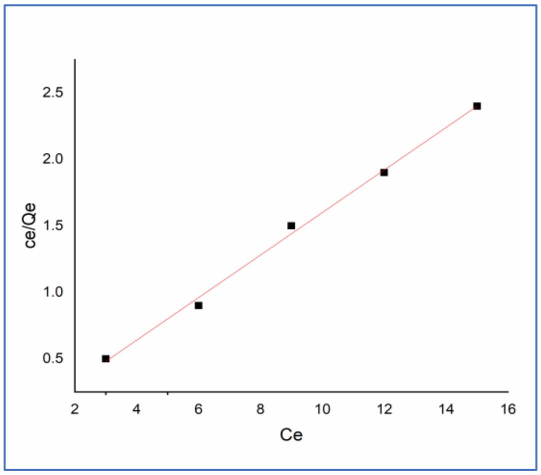
Bio-composite	qe (exp.)	qe (mg/g)	qe^2	R^2	k_2
Sugarcane (doped)	0.881	1.025	1.050	0.272	0.039
	1.858	0.760	0.578	0.967	-1.273
	2.881	0.926	0.858	0.983	-0.606
	3.811	1.333	1.776	0.979	-0.524
Sugarcane (undoped)	0.871	0.588	0.345	0.989	-0.724
	1.808	0.787	0.619	0.893	0.625
	2.898	0.995	0.990	0.983	-0.303
	3.889	1.250	1.563	0.975	-0.312
Sawdust (doped)	0.871	0.502	0.252	0.760	-0.372
	1.808	0.790	0.624	0.986	-0.429
	2.898	1.000	1.000	0.988	-0.331
	3.889	1.300	1.691	0.977	-0.297
Sawdust (Undoped)	0.821	0.514	0.264	0.980	-0.632
	1.809	0.780	0.608	0.987	-0.464
	2.807	1.016	1.033	0.983	-0.338

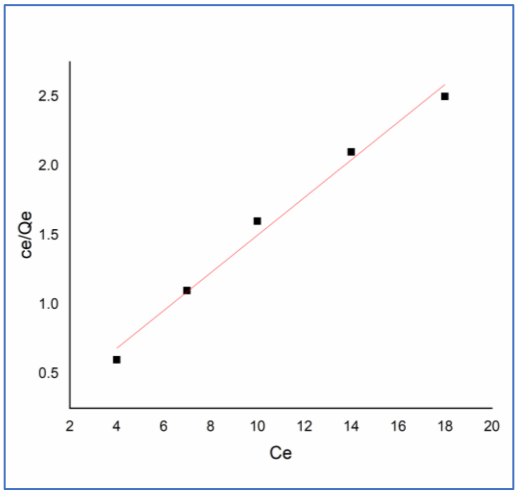
6.8. To examine the equilibrium between adsorbate concentration in the liquid phase and that on the adsorbent surface at a constant temperature using different adsorption isotherm models

Adsorption isotherms describe the relationship between the mass of adsorbate per unit weight of adsorbent and the liquid phase concentration of the adsorbate. Conducting isotherm studies is crucial for understanding the efficacy of metal ion biosorption on biosorbents, as it provides essential design data for adsorption systems. The data obtained from these studies were analyzed using the Langmuir and Freundlich isotherm models. This analysis helps determine the adsorption capacity and affinity of the biosorbent, offering valuable insights into the mechanisms of biosorption and aiding in the optimization and design of effective adsorption processes for metal ion removal.

6.8.1. Langmuir model for Cadmium biosorption onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped).







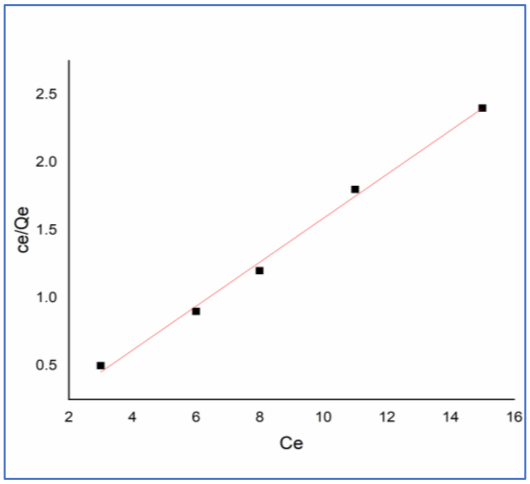


Fig.6.13. Langmuir isotherm model for Cadmium onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped). [agitation speed= 110 rpm, contact time=24 hrs, biosorbent dose=0.5 g/50 mL metal solution, pH=6.5, temperature= 298.15K]

The Langmuir isotherm model for Cd(II) sorption onto PAni-doped and undoped sugarcane bagasse and sawdust was investigated by plotting Ce/qe against Ce, as shown in Figure 6.13. This model assumes monolayer adsorption on a homogeneous surface with a finite number of active sites. The correlation coefficient (R^2) value for PAni-doped sugarcane bagasse was found to be 0.9475, with a maximum sorption capacity (qmax) of 5.55 mg/g and a Langmuir constant (b) of 0.833 L/mg, indicating a strong affinity between the sorbent and Cd(II) ions. The calculated RL values for initial Cd(II) concentrations of 10, 20, 30, 40, and 50 mg/L were 0.107, 0.056, 0.038, 0.029, and 0.023, respectively, suggesting favorable biosorption ($0 < RL < 1$).

For PAni-undoped sugarcane bagasse, the Langmuir isotherm model yielded an R^2 value of 0.99, with a qmax of 10 mg/g. The high R^2 value indicates a strong fit to the Langmuir model. Similarly, the PAni-doped sawdust had an R^2 value of 0.98, a qmax of 7.246 mg/g, and a b value of 0.985 L/mg, with RL values of 0.092, 0.048, 0.032, 0.024, and 0.0 for the same initial Cd(II) concentrations, further confirming favorable biosorption.

In contrast, the Langmuir isotherm plot for PAni-undoped sawdust showed a high R^2 value of 0.9939, but the maximum sorption capacity (qmax) was found to be -28.58 mg/g, which is an anomaly. The Langmuir constant (b) was 4.637 L/mg, and the RL values were 0.022, 0.01, 0.007, 0.0054, and 0.0043 for the initial concentrations, indicating favorable conditions ($0 < RL < 1$). However, the negative qmax suggests that the adsorption may not predominantly follow monolayer adsorption, as assumed by the Langmuir isotherm. The model presumes a homogeneous adsorbent surface with uniform energy and no interaction between adsorbed molecules, but these conditions may not be fully met in the case of PAni-undoped sawdust, where transmigration of adsorbate on the surface could occur.

Table.6.21. Isotherm constants and regression data for Langmuir adsorption isotherm models for Cd(II) biosorption onto PAni sugar cane bagasse(doped),sugarcane(undoped), Sawdust(doped), sawdust(undoped)

Bio-composite	qmax (mg g^{-1})	K_L	R^2
Sugarcane(doped)	5.555	1.2	0.9475
Sugarcane(Undoped)	10	0.625	0.995
Sawdust(doped)	7.246	1.014	0.983
Sawdust(Undoped)	28.5	0.215	0.993

6.8.2. Freundlich model for Cadmium biosorption onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped).

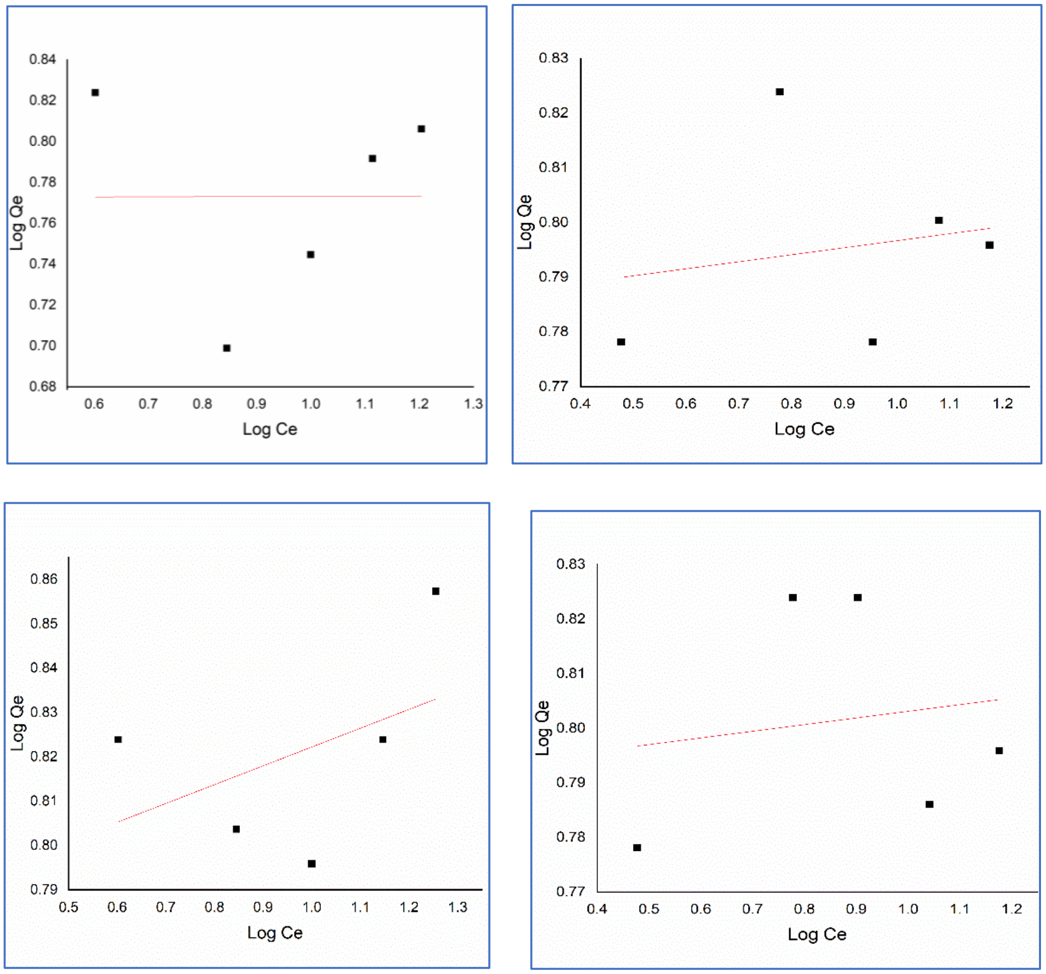


Fig.6.14. Freundlich isotherm model for Cadmium onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped). [agitation speed= 110 rpm, contact time=24 hrs, biosorbent dose=0.5 g/50 mL metal solution, pH=6.5, temperature= 298.15K]

The Freundlich isotherm model provides valuable insights into the adsorption of Cd(II) onto various PAni-doped and undoped biosorbents, as illustrated in Figure 20. For PAni-doped sugarcane bagasse, the plot of log qe against log Ce yielded a Freundlich constant (Kf) value of 5.922. This indicates that the biosorption process allows for easy separation of Cd(II) from solution, suggesting a high sorption rate. The model exhibited a correlation coefficient (R^2) of 0.33, indicating a reasonably good fit of experimental data to the model. The adsorption intensity parameter (n) was calculated as 0.00061, falling within the range ($1 < n < 10$), characteristic of favorable adsorption. This low value of n suggests that the adsorption onto PAni-doped sugarcane bagasse is predominantly physisorption, indicating that the interaction between Cd(II) ions and the biosorbent surface involves weak Van der Waals forces.

Similarly, for PAni-undoped sugarcane bagasse, the Freundlich isotherm model showed a lower R² value of 0.286 compared to the Langmuir isotherm, indicating multilayer adsorption on a heterogeneous surface. The Kf value was 6.078, and the calculated n value was 0.012, both suggesting a highly heterogeneous surface with a tendency towards physisorption. The n value being closer to zero further confirms the heterogeneous nature of the biosorbent surface, where multiple layers of adsorption are possible due to varied surface energies and active sites. Despite the lower R² value, the Freundlich model demonstrates that Cd(II) biosorption onto PAni-undoped sugarcane bagasse is favorable under the experimental conditions studied.

For PAni-doped sawdust, the Freundlich isotherm plot also exhibited a lower R² value of 0.053 compared to the Langmuir isotherm model, indicating its suitability in describing the adsorption process. The calculated Kf value of 6.022 and n value of 0.0424 further highlight the heterogeneous nature of the biosorbent surface. The n value being between 1 and 10 suggests that physisorption dominates the adsorption process, where weak interactions between Cd(II) ions and the PAni-doped sawdust surface occur. This model confirms that Cd(II) biosorption onto PAni-doped sawdust is feasible and effective under the studied conditions, despite the higher heterogeneity indicated by the n value.

Lastly, for PAni-undoped sawdust, the Freundlich isotherm plot with an R² value of 0.302 demonstrated a good fit to the experimental data, indicating multilayer adsorption of Cd(II). The Kf value of 6.179 and the n value of 0.0122 further reinforce the heterogeneous nature of the biosorbent surface, where multiple layers of Cd(II) ions can be adsorbed due to varied surface energies. The n value being within the range of 1 to 10 confirms that physisorption predominates in the adsorption process onto PAni-undoped sawdust. Overall, the Freundlich isotherm model provides valuable insights into the complex adsorption behavior of Cd(II) onto PAni-doped and undoped biosorbents, highlighting their effectiveness and suitability for metal ion removal applications.

Table.6.22. Isotherm constants and regression data for Freundlich adsorption isotherm models for Cd (II) biosorption onto PAni sugar cane bagasse(doped), sugarcane(undoped), sawdust(doped), sawdust(undoped).

Bio-composite	K_f (L g^{-1})	n	R^2
Sugarcane(doped)	5.922	0.00061	0.333
Sugarcane (Undoped)	6.078	0.012	0.286
Sawdust(doped)	6.022	0.0424	0.053
Sawdust (Undoped)	6.179	0.0122	0.302

6.8.3. Langmuir isotherm model for lead onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped).

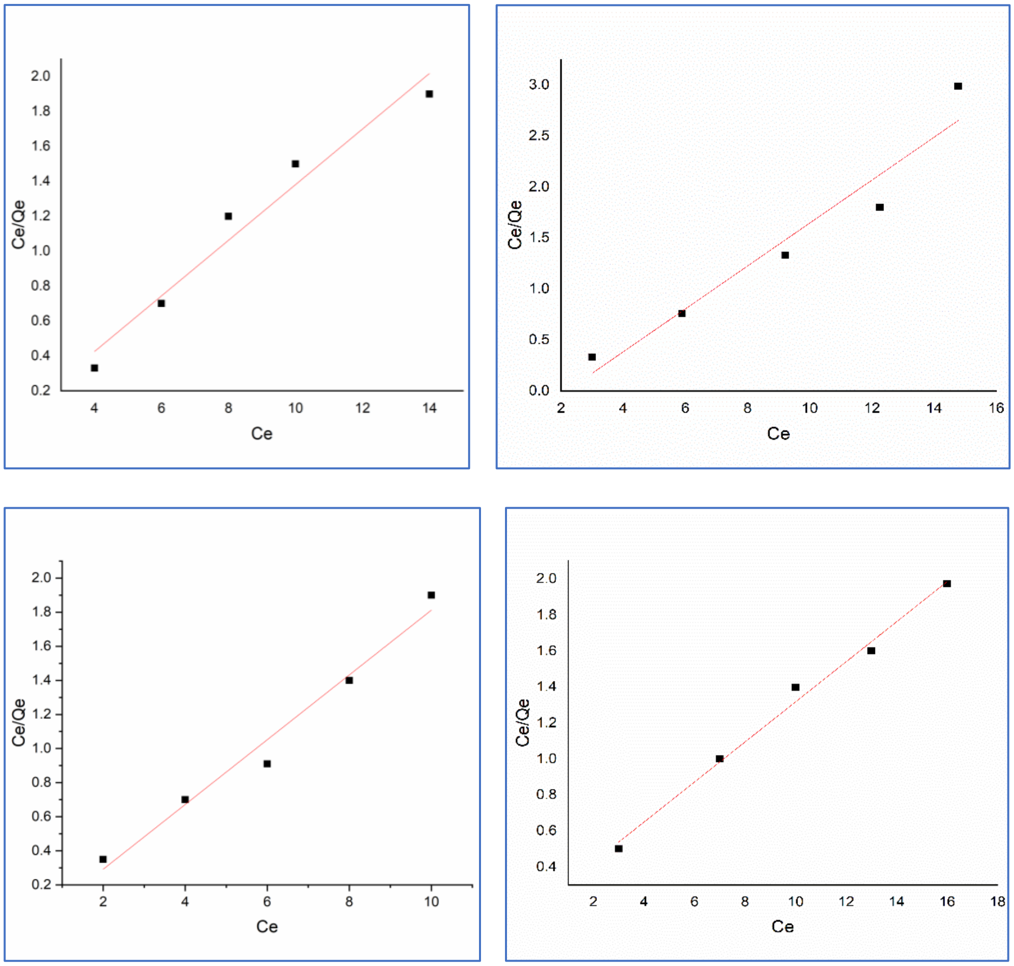


Fig.6.15. Langmuir isotherm model for lead onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped). [agitation speed= 110 rpm, contact time=24 hrs, biosorbent dose=0.5 g/50 mL metal solution, pH=6.5, temperature= 298.15K]

The Langmuir isotherm model was applied to evaluate the sorption of Pb(II) onto various PAni-doped and undoped biosorbents, as depicted in Figure 6.15. For PAni-doped sugarcane bagasse, the plot of Ce/qe against Ce yielded a high correlation coefficient (R^2) value of 0.95, indicating a strong agreement between the experimental data and the Langmuir model. The maximum sorption capacity (qmax) was determined to be 4.722 mg/g, with a Langmuir constant (b) of 0.752 L/mg, suggesting favorable affinity between the sorbent and sorbate. The RL values calculated ranged from 0.117 to 0.0259 for Pb(II) concentrations from 10 to 50 mg/L, indicating favorable biosorption where $0 < RL < 1$. These findings imply that Pb(II) ions form monolayer adsorption on a homogeneous surface with finite active sites on PAni-doped sugarcane bagasse, facilitating efficient removal of Pb(II) from aqueous solutions.

Similarly, for PAni-undoped sugarcane bagasse, the Langmuir isotherm exhibited a high R^2 value of 0.916, indicating a good fit of the data to the model. The qmax value obtained was 2.184 mg/g, with a Langmuir constant (b) of 0.459 L/mg, suggesting a lower sorption capacity compared to the doped counterpart. The RL values ranged from 0.178 to 0.041, further confirming favorable biosorption conditions for Pb(II) onto PAni-undoped sugarcane bagasse. These results suggest that while both doped and undoped forms show effective Pb(II) removal, the doped form exhibits higher sorption capacity due to enhanced surface interactions and active sites.

For PAni-doped sawdust, the Langmuir isotherm plot showed an R^2 value of 0.97, indicating a very good fit of experimental data to the model. The calculated qmax was 11.36 mg/g, with a Langmuir constant (b) of 2.159 L/mg, indicating strong affinity between the sorbent and Pb(II) ions. The RL values ranged from 0.044 to 0.009, indicating favorable monolayer adsorption where $0 < RL < 1$ across different initial Pb(II) concentrations. This suggests that PAni-doped sawdust is highly effective in removing Pb(II) ions from aqueous solutions due to its abundant active sites and strong adsorption capabilities.

In contrast, for PAni-undoped sawdust, the Langmuir isotherm exhibited a high R^2 value of 0.988, demonstrating excellent agreement between experimental data and the model. The qmax was found to be 4.90 mg/g, with a Langmuir constant (b) of 0.545 L/mg, indicating lower sorption capacity compared to the doped form. The RL values ranged from 0.155 to 0.035, confirming favorable biosorption conditions where $0 < RL < 1$. These results suggest that although PAni-undoped sawdust shows effective Pb(II) removal, the doped form offers superior sorption capacity and efficiency due to enhanced surface characteristics and interactions. Overall, the Langmuir isotherm model provides valuable insights into the monolayer adsorption behavior of Pb(II) onto various PAni-doped and undoped biosorbents, highlighting their potential for environmental remediation applications.

Table.6.23. Isotherm constants and regression data for Langmuir adsorption isotherm models for Pb(II) biosorption onto PAni sugar cane bagasse(doped), sugarcane(undoped), sawdust(doped), sawdust(undoped)

Bio-composite	qmax (mg g^{-1})	K_L	R^2
Sugarcane(doped)	4.72	1.32	0.95
Sugarcane (Undoped)	2.18	2.176	0.91
Sawdust(doped)	11.36	0.46	0.97
Sawdust (Undoped)	4.9	1.83	0.98

6.8.4. Freundlich isotherm model for lead onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped).

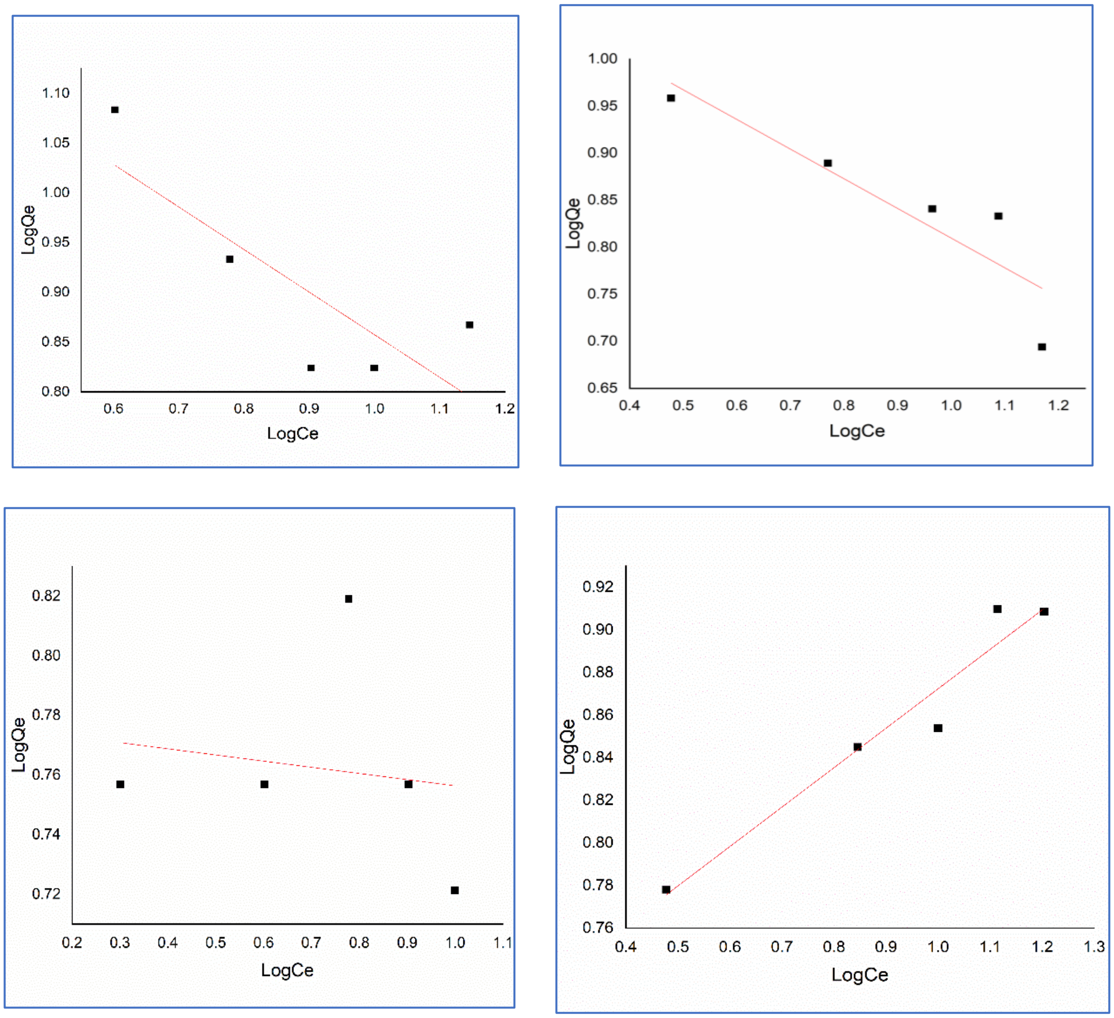


Fig.6.16. Freundlich isotherm model for lead onto PAni Sugarcane bagasse (doped), PAni sugar cane bagasse(undoped), PAni saw dust(doped) and PAni saw dust (undoped). [agitation speed= 110 rpm, contact time=24 hrs, biosorbent dose=0.5 g/50 mL metal solution, pH=6.5, temperature= 298.15K]

The Freundlich isotherm model was applied to analyze the adsorption of Pb(II) onto various PAni-doped and undoped biosorbents, as shown in Figure 6.16. For PAni-doped sugarcane bagasse, the plot of log qe against log Ce yielded a Kf value of 19.29, indicating a high sorption capacity and efficient removal of Pb(II) from solution. The high correlation coefficient (R^2) of 0.56 suggests a good fit of the experimental data to the Freundlich model, despite indicating an unfavorable adsorption intensity (n = 0.429). This suggests that while PAni-doped sugarcane bagasse exhibits strong sorption capacity due to its Kf value, the adsorption process is less favorable, possibly due to surface characteristics or competitive interactions with other species in solution.

For PAni-undoped sugarcane bagasse, the Freundlich isotherm plot exhibited an R² value of 0.745, indicating a satisfactory fit to the model for multilayer adsorption. The calculated Kf value was 13.33, suggesting a lower sorption capacity compared to the doped counterpart, yet still effective in removing Pb(II) ions. The adsorption intensity parameter (n = 0.315) indicates a moderate favorability for the adsorption process, with a surface characterized by heterogeneous binding sites. The value of n being between 1 and 10 supports a predominantly physisorption mechanism, where Pb(II) ions interact physically with the biosorbent surface, aligning with experimental conditions favorable for effective Pb(II) removal.

Conversely, for PAni-doped sawdust, the Freundlich isotherm model showed an R² value of 0.29, indicating a lesser fit compared to the Langmuir model but still reasonable for understanding the adsorption behavior. The Kf value of 5.98 indicates moderate sorption capacity, while the low n value (0.02) suggests a highly heterogeneous surface with favorable adsorption characteristics. This indicates that although the fit to the Freundlich model is lower compared to Langmuir, the adsorption of Pb(II) onto PAni-doped sawdust is primarily physical in nature, facilitated by the biosorbent's surface properties.

Finally, for PAni-undoped sawdust, the Freundlich isotherm plot displayed an R² value of 0.92, indicating a very good fit to the model for multilayer adsorption. The Kf value of 4.86 and n value of 0.185 further support effective adsorption of Pb(II) ions, highlighting the heterogeneous nature of the biosorbent surface. The n value falling between 1 and 10 suggests a physisorption-dominated mechanism under the studied conditions, where Pb(II) ions form multiple layers on the PAni-undoped sawdust surface. Overall, the Freundlich isotherm analysis provides insights into the adsorption capacity and mechanism of Pb(II) onto various PAni-doped and undoped biosorbents, crucial for environmental remediation applications.

Table.6.24. Isotherm constants and regression data for various adsorption isotherm models for Pb (II) biosorption onto PAni sugar cane bagasse(doped),sugarcane(undoped), Sawdust(doped), sawdust(undoped).

Bio-composite	K_f (L g^{-1})	n	R^2
Sugarcane(doped)	19.29	0.429	0.56
Sugarcane (Undoped)	13.33	0.315	0.745
Sawdust(doped)	5.98	0.02	0.29
Sawdust (Undoped)	4.86	0.185	0.92

To carry out the regeneration studies, examining its effective removal efficiency and its durability.

6.9. Effect of Cd onto desorption of PAni dope SC, PAni UD SC, PAni dope SD and PAni UD SD.

Regeneration of the adsorbent is a necessary step in the large-scale waste water treatment systems. Two advantages of an adsorbent for its possible use in wastewater treatment are its high adsorption capacity and good recyclability. The selection of an efficient eluent for the desorption process in an essential aspect in regeneration study. In this regard, the desorption of Cd adsorbed on the PAni doped/UD sugarcane bagasse and sawdust was performed using different eluents such as NaOH, HCl. To study the adsorbent capacity of the different type of biosorbent the study is conducted for 5 cycles keeping all the parameters constant [agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dosage= 1g/100 mL metal solution, initial concentration of Cd ions= 10 ppm].

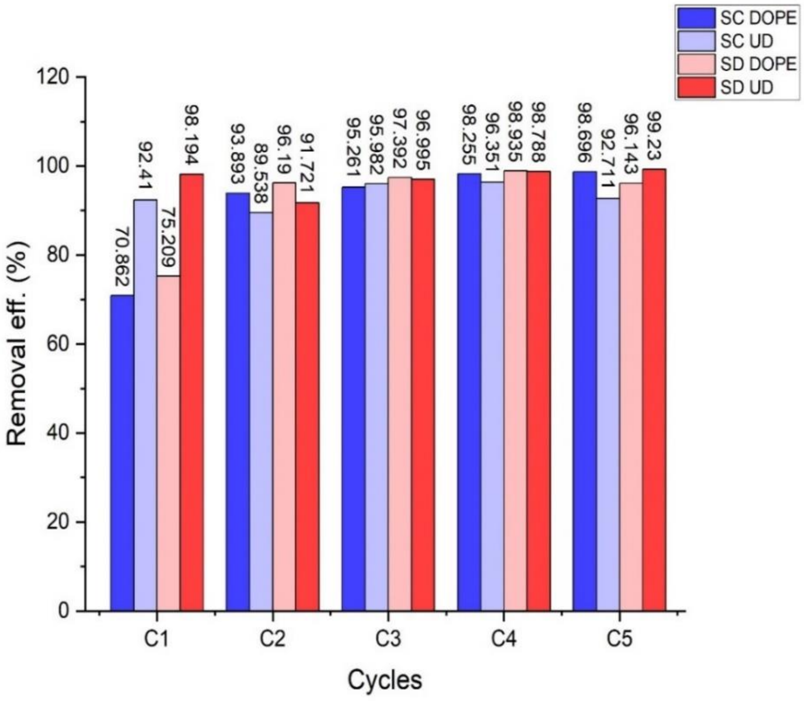


Fig 6.17: Effect of Cd on desorption onto PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD (agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 1g/100 mL metal solution, pH=6.5, temperature= 298.15 K).

From the above **Fig 6.17,** it is evident that the biosorbents i.e. PAni dope SC, PAni UD SC, PAni dope SD and PAni UD SD retains 98.69 %, 92.71 %, 96.14 % and 99.23 % respectively even after 5 cycles of adsorption. Also, we can conclude that PAni doped/UD sugarcane bagasse and sawdust biosorbent may be efficiently reused many times as an effective and affordable adsorbent to remove Cd ions from wastewater treatment. In the literature data there also evidence that the PAni doped almond shell retains around 92 % of Cr (VI) ions even after 5 cycles of adsorption [3].

6.10. Effect of Pb onto regeneration of PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD.

To suggest a good quality of biosorbent the regeneration is one of key aspects to know its adsorption capacity and effectively reused many times as an effective and economical biosorbent. The desorption of Pb ion from the PAni doped/UD sugarcane bagasse and sawdust is carried for 5 cycles. The desorption effluent also plays as important role in removal percentage from the biosorbent. In this study we have selected NaOH or HCl as a desorbing medium. The experiments are done keeping all other parameter constant [agitation speed= 110 rpm, biosorbent dosage= 1g/100 mL metal solution, contact time= 24 hrs, initial concentration= 10 ppm of Pb ions, temperature= 298.15 K].

From the **Fig 6.18,** we can clearly see that even after 5 cycles of adsorptions the biosorbents i.e. PAni dope SC, PAni UD SC, PAni dope SD, PAni UD SD retains removal efficiency of 96.92%, 94.34%, 97.63% and 97.81% respectively. Additionally, we can say that the PAni dope/UD sugarcane bagasse and sawdust may be used many a times effectively, ecofriendly and cost- efficient adsorbent for the removal of Pb ion for wastewater treatment. The same is also noticed in the literature PAni doped walnut shell composite remove Cr(VI) from the aqueous solutions and still kept about 88 % of removal efficiency after 5 cycles of adsorption [3].

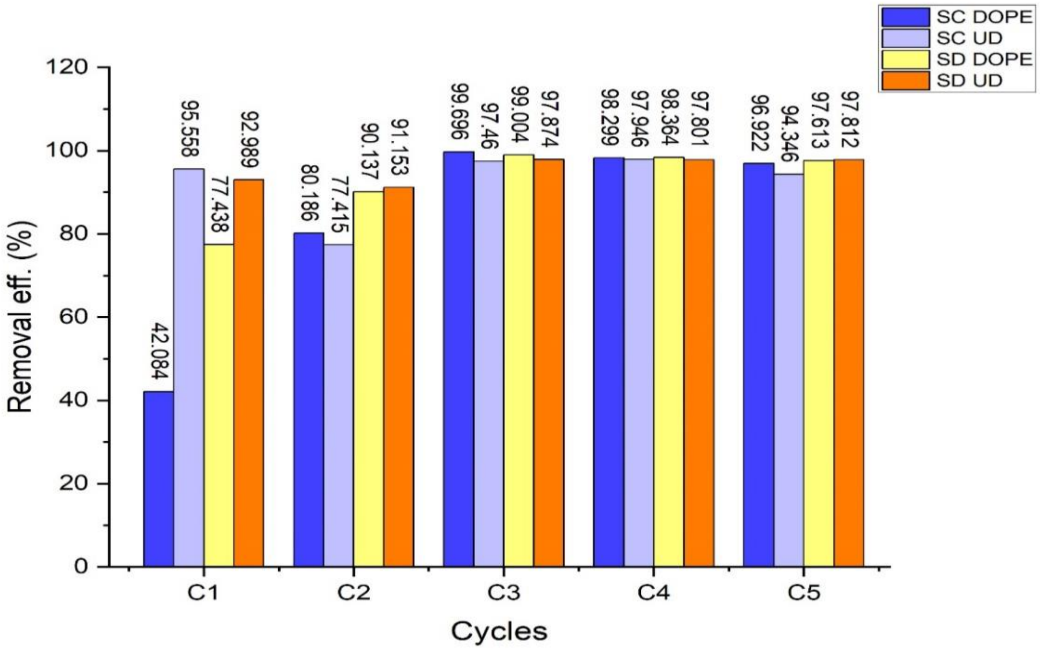


Fig 6.18: Effect of Pb on desorption PAni dope SC, PAni UD SC, PAni SD dope SD and PAni UD SD [agitation speed= 110 rpm, contact time= 24 hrs, biosorbent dose= 1g/100 mL metal solution, pH=6.5, temperature= 298.25]

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