

## A STUDY ON ADSORPTION OF HEAVY METALS IN AQUEOUS SOLUTIONBY USING BIOMASS AS ADSORBENT

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## ABSTRACT

This study explores the adsorption capacity of various biomass materials as eco-friendlyadsorbents for the removal of heavy metals from aqueous solutions. The specific biomasstypes investigated include rice husk, coconut waste, and sugarcane waste, which were selected for their availability and potential environmental benefits. A series of batch adsorption experiments were conducted to evaluate the effectiveness of these materials inremoving specific heavy metals, such as lead (Pb), cadmium (Cd), and chromium (Cr), from the solutions.

Key parameters influencing adsorption performance, including contact time, initial heavymetal concentration, pH of the solution, and the quantity of biomass used, were systematically examined. These factors were optimized to determine the conditions underwhich the maximum adsorption of heavy metals occurs. Adsorption kinetics were studied to understand the rate and mechanism of metal uptake, while isotherm models were applied to analyze the equilibrium data, providing insights into the interaction between the biomass surface and heavy metal ions.

The findings revealed that each type of biomass exhibited varying efficiencies in heavy metal adsorption, with one adsorbent often outperforming the others under specific conditions. Rice husk demonstrated a particularly high capacity for adsorbing lead ions, while coconut waste showed commendable efficiency in removing cadmium. Sugarcanewaste also proved effective, highlighting its potential as a sustainable solution for heavymetal remediation.

This research underscores the viability of using agricultural waste as an alternative to conventional adsorbents in wastewater treatment applications. The results suggest that these biomass materials not only offer an effective means of mitigating heavy metal contamination in water bodies but also promote environmental sustainability through the recycling of agricultural by-products. The findings contribute to ongoing efforts to develop cost-effective and eco-friendly strategies for water purification, addressing bothpollution and waste management challenges.

Keywords: Heavy metals, Biomass, Agricultural waste, cadmium (Cd), and chromium (Cr)

## 1. INTRODUCTION

Water pollution, particularly from heavy metals, has become a pressing environmental issue globally, with significant implications for public health and ecosystems (1). In the context of India, the Yamuna River is one of the most heavily polluted water bodies, particularly near Haryana, where industrial effluents and agricultural runoff contribute to the accumulation of heavy metals such as cadmium, lead, chromium, and arsenic (2). These contaminants pose substantial risks, as they can lead to serious health problems including neurological damage, cancer, and developmental delays in children (3; 4). Thesituation is exacerbated by the river's use as a primary source of drinking water and irrigation for agricultural lands, raising concerns regarding food safety and public health(5).

Heavy metals are defined as metallic elements that have high densities and are toxic or poisonous at low concentrations, including elements such as lead (Pb), cadmium (Cd), mercury (Hg), and arsenic (As) (6). They are commonly found in the environment due toboth natural processes and human activities, including industrial discharges, mining operations, agricultural runoff, and the use of certain consumer products (7). Heavy metalpollution has been a growing concern worldwide, particularly in developing countries where regulatory measures may be lax or absent (8).

The environmental impacts of heavy metals are profound, affecting soil quality, water resources, and overall ecosystem health. They can disrupt biological processes in flora and fauna, leading to decreased biodiversity and altered food webs (9). Human health is also at significant risk, as exposure to heavy metals can result in neurological damage, developmental issues, and various chronic diseases (10). For instance, studies have shownthat heavy metal exposure can cause cognitive impairments in children and increased risk cancers in adults (11).

In the context of India, the Yamuna River has been identified as one of the most pollutedrivers globally, with alarmingly high concentrations of heavy metals. Reports indicate thatlead and cadmium levels in some areas of the Yamuna exceed the permissible limits set by the World Health Organization (WHO) (12). According to the Central Pollution Control



Board (CPCB), certain stretches of the river show iron concentrations as high as 2,000  $\mu$ g/L and mercury levels above 0.5  $\mu$ g/L, indicating severe contamination (13).

#### Specific Concerns in the Yamuna River

Numerous studies have investigated heavy metal contamination in the Yamuna River, revealing alarming concentrations that threaten both ecological and human health (14). For instance, a recent study reported that levels of chromium (Cr) and nickel (Ni) in the river water are significantly elevated, impacting aquatic life and the livelihoods of local communities reliant on fishing (15). The implications for agriculture are also significant; irrigation with contaminated water can lead to heavy metal accumulation in crops, affecting food safety and human health (16).

The local communities along the banks of the Yamuna are particularly vulnerable, as many rely on the river for drinking water and agricultural purposes (17). The loss of biodiversity in the river ecosystem not only undermines the environmental sustainability of the region but also diminishes the socio-economic potential of local populations dependent on healthy ecosystems for their livelihoods (18).

#### **Materials And Methods Of Biosorption**

Biosorption is a sustainable process that utilizes biological materials to adsorb heavy metals from wastewater. It operates on the principles of ion exchange, chemisorption, and physisorption (19). The process is favored due to its cost-effectiveness and the potential use of agricultural waste as biosorbents, reducing both waste and pollution simultaneously (20).

Rice husks, coconut waste, and sugarcane waste are promising biosorbents because of their high surface area and availability (21). Rice husks contain silica and lignin, which enhance their metal-binding capacity (22). Coconut waste is rich in cellulose and hemicellulose, contributing to its adsorption properties (23). Sugarcane waste, particularly bagasse, possesses functional groups that facilitate heavy metal removal, making it an effective material for biosorption (24).

#### **Previous Studies on Biosorption**

Numerous studies have demonstrated the efficiency of various agricultural waste materials in removing heavy metals from contaminated water. For instance, rice husks have shown significant capability in adsorbing lead and cadmium, with reported removalefficiencies exceeding 90% under optimal conditions (25). Comparative studies indicate that while coconut waste is effective in removing copper and chromium, sugarcane wasteexhibits superior efficiency for zinc and lead (26). These findings underscore the potential of utilizing indigenous biosorbents for effective heavy metal remediation.

#### **Sustainability Aspects**

The use of agricultural waste as biosorbents contributes to environmental sustainability by reducing waste and lowering the carbon footprint associated with traditional wastewater treatment methods (27). Additionally, utilizing locally available materials canmake biosorption economically feasible for rural and developing regions, where resourcesmay be limited (28). The dual benefit of waste management and heavy metal removal presents a viable solution for enhancing water quality and promoting sustainable practices within these communities (29).

In the quest for effective remediation strategies, biosorption using agricultural waste hasemerged as a sustainable and eco-friendly alternative for the removal of heavy metals from wastewater (30). Various biomass materials, particularly rice husks, coconut waste, and sugarcane waste, have demonstrated significant potential as adsorbents due to their high surface area, natural abundance, and ability to bind metal ions effectively (31). For instance, rice husks are rich in silica and contain functional groups that facilitate interaction with metal ions, making them especially suitable for adsorption processes (32). Similarly, coconut waste, known for its lignocellulosic structure, enhances the adsorption capacity for several heavy metals, providing an effective means of remediatingcontaminated waters (33).

Research has shown that the effectiveness of these biosorbents can vary based on various factors, including pH, contact time, and biomass dosage, which can be optimized for maximum metal removal efficiency (34). Moreover, the utilization of agricultural waste

not only helps in mitigating pollution but also reduces environmental burden by promoting waste recycling (35). This dual benefit is crucial in addressing the mounting waste management challenges posed by agricultural byproducts.

This study aims to explore the efficiency of rice husks, coconut waste, and sugarcane waste as biosorbents for heavy metals in aqueous solutions, with a focus on their application in treating wastewater from the Yamuna River. By systematically evaluating the adsorption capacities under varying conditions, this research seeks to contribute to the development of effective, sustainable solutions for heavy metal remediation, ultimately promoting cleaner water resources and healthier ecosystems (36).



## 2. MATERIAL & METHODS

Standard methods were followed to purify and dry all of the solvents used in the work [37]. Every reagent used was of the highest purity grade and was obtained from Merck orSigma-Aldrich Co.

Sample collection from areas adjacent to the Yamuna River in Haryana involved selecting appropriate containers (preferably hard glass or amber-colored) to avoid contamination. Techniques included grab sampling for homogeneous sources, composite sampling for heterogeneous matrices, and integrated sampling for varied sampling points, ensuring representative data for analysis.

Selection of sampling points is crucial and should reflect the study's objectives, using locations representative of the source, treatment plants, and discharge points. Reference points upstream help assess background quality, while integrated sampling techniques ensure representative samples. Proper labeling with essential details is vital for tracking. Five 250ml composite samples are treated with nitric acid and filtered for analysis via X-Ray Fluorescence. Techniques for determining heavy metals include FAAS, ETAAS, ICP-OES, and others. Each analytical step, from sampling to result evaluation, is criticalfor accuracy; errors at any stage can compromise results. Sample preparation is particularly important for wastewater analysis.

Reduced pressure distillation was used to preserve liquid reagents, which were then keptin dark, airtight amber bottles. The solids were utilized as given.

Prior to completely cleaning with a 2% aqueous solution of lab detergent (Rankleen hi power) and rinse with water that was running once more, every piece of equipment used in the experiment was carefully cleaned with concentrated chromic acid.

The impacts of heavy metals on adsorption rate and capacity, were examined in relation to pH, starting concentration, adsorbent dose, contact length, agitation speed, and temperature etc

#### **Preparation of Biomass**

Agricultural wastes such as rice husks, coconut fiber dust, and sugarcane bagasse were collected, cleaned, and dried at 70°C for 24 hours to prepare biomass materials. After drying, the samples were crushed and sieved to 0.5 to 2.0 mm. An acid treatment using 1M sulfuric acid was performed on 50 g of each biomass sample for 2 hours, followed by neutralization with 0.5 M sodium bicarbonate, thorough washing, and drying again at 70°C. The dried adsorbents were ground to a fine powder, sieved to 0.5 mm, and stored in airtight containers. Batch adsorption experiments evaluated capacities at 20°C, 30°C, and 40°C across contact times of 10, 20, 30, 60, and 120 minutes, with 1 g of adsorbent in 100 mL of adsorbate solution agitated mechanically. After filtering, UV-Vis spectroscopy analyzed the adsorbate concentration. Each experiment was replicated thriceto ensure data reliability, calculating adsorbed quantities using specific formulas.

## Effect of pH

To evaluate the effect of pH on biomass adsorption capacity for heavy metals, HCl and NaOH were utilized to adjust the pH of metal solutions to levels of 2, 4, 6, 8, and 10, verified with a calibrated pH meter. Batch adsorption experiments involved adding knownmasses (1, 2, and 5 g) of biomass to 100 mL of heavy metal solution in Erlenmeyer flasks, agitated at 150 rpm for 2 hours at approximately 25 °C. Post-treatment, samples were filtered using Whatman No. 1 filter paper, and residual metal concentrations were analyzed using UV-Vis spectrophotometry or atomic absorption spectrophotometry (AAS). The amount of heavy metal adsorbed was calculated using the formula relating initial and final concentrations, solution volume, and biomass mass.

## Effect of starting material

In batch adsorption experiments, a fixed biomass mass (e.g., 2 g) was measured in 100 mL beakers, followed by the addition of heavy metal solutions at desired concentrations, with pH adjustments as needed. After 60 minutes of mixing on a magnetic stirrer, solutions were filtered, and remaining metal concentrations were analyzed using UV-Vis spectrophotometry to calculate adsorption capacity and removal efficiency.

## Effect of adsorbent dose

For evaluating the effect of adsorbent dose, a series of beakers containing different biomass doses (1 g, 2 g, 3 g, 5 g) were prepared with a constant heavy metal solution volume of 100 mL. After adjusting pH if necessary, the mixtures were stirred for 60 minutes, then filtered. Residual heavy metal concentrations were analyzed using UV-Vis spectrophotometry, recording both initial and final concentrations.

#### Effect of contact length/contact time

To investigate the effect of contact time, batch adsorption experiments were conducted with a fixed initial heavy metal concentration in separate reactors, adding 1 g of dried biomass to 100 mL of solution. Varying contact times (0, 15, 30,



60, 120, 180 minutes) were maintained at consistent temperature and pH (5-7). Samples were filtered after eachinterval, and residual metal concentrations were analyzed spectrophotometrically to calculate the amount adsorbed per gram of biomass. For agitation studies, 0.5 g of biomasswas stirred with 100 mL of metal solution at 150 rpm for similar time intervals before filtration.

#### Effect of Agitation time

In a 250 mL Erlenmeyer flask, 0.5 g of each biomass material was combined with 100 mL of a heavy metal solution. The mixtures were agitated at constant speed (150 rpm) forvarying time intervals of 15, 30, 60, 120, and 180 minutes, followed by filtration to separate the biomass from the liquid phase.

#### **Effect of Temperature**

Adsorption experiments were conducted in batch mode at temperatures of 20°C, 25°C, 30°C, 35°C, and 40°C. In 250 mL Erlenmeyer flasks, 1 g of biomass was added to 100 mL of metal solution, agitated at 100 rpm for 2 hours in a temperature-controlled water bath, followed by filtration using Whatman filter paper to separate biomass from the solution.

## **4 RESULTS AND DISCUSSION**

#### 4.1 Heavy metal concentration in Yamuna River

A total of 160 water samples from different regions of Delhi and Haryana were collected from Yamuna River and was evaluated for presence of heavy metals. The following resultwas found and each samples S1-S16 are represented as mean of 10 samples.

Heavy metal concentration in Yamuna river (the values are mean of 10 samples)											
Sampl	les		Conce	ntration mg/	L						
Sample No (Mean of10)	SamplingStation	Fluoride	Cadmium	Chromium	Arsenic						
S1	Hathnikund	0.33	0.01	3.1	0.05						
S2	Kalnor	0.79	0.01	2.5	0.01						
\$3	Kundaghat	0.76	0.01	0.1	0.03						
S4	Manglora bridge	0.39	0.01	1.3	0.04						
S5	Kairana	0.08	0.01	1.1	0.01						
\$6	Khojkipur	0.07	0.01	2.0	0.01						
S7	Mimarpur Ghat	0.09	0.01	1	0.03						
S8	Garh Bridge	0.87	0.01	1.5	0.02						
S9	Bairabakipur	0.24	0.01	1.4	0.04						
S10	Palla ghat	0.94	0.01	1.9	0.03						
S11	Wazirabad	0.57	0.02	1.7	0.01						
S12	Okhla	3.33	0.20	1.1	0.03						
S13	Dadasiya	3.48	0.01	1.6	0.02						
S14	Chhaynsa	1.12	0.13	2.9	0.01						
S15	Mohana	2.00	0.15	4.6	0.02						
S16	Hassanpur	0.13	0.16	3.9	0.01						

#### 4.2 Preparation of Biomass

The preparation of biomass materials from agricultural wastes, such as rice husks, coconutwaste, and sugarcane waste, involved drying, crushing, and acid treatment. The drying process effectively reduced moisture content from approximately 10-15% (w/w) to less than 5% (w/w). Post-crushing particle sizes averaged between 0.5 and 2.0 mm, specifically 1.2 mm for rice husks, 1.5 mm for coconut waste, and 0.8 mm for sugarcanewaste. Acid treatment enhanced cellulose content, with rice husks' ash content decreasingfrom 15% to 5%, coconut waste's volatile matter increasing by 8%, and sugarcane waste'sfixed carbon rising from 25% to 35%. Elemental analysis showed an increase in carbon content: rice husks (40% to 44% C), coconut waste (44% to 48% C), and sugarcane waste

(38% to 42% C). FTIR analysis revealed new functional groups, including pronounced carboxylic and hydroxyl groups, indicating beneficial structural modifications for adsorption applications.

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editor@ijprems.com 4.3 Effect of pH on Adsorption

рН	Adsorption Capacity for Cadmium (mg/g)	Adsorption Capacityfor Fluoride (mg/g)	Adsorption Capacity for Chromium (mg/g)	Adsorption Capacity for Arsenic (mg/g)
	Coconut Waste	Sugarcane Waste	Rice Husk	Coconut Shell
2	12.5	10.3	8.0	8.3
4	20.2	15.7	12.4	15.2
6	25.8	22.4	18.3	22.0
8	18.5	16.1	14.0	18.0
10	10.6	8.3	6.5	9.4

The results demonstrate that pH is a key factor influencing the adsorption process, with optimal capacities observed around neutral pH (6). The decrease in adsorption at extremepH levels can be attributed to changes in ionic forms of heavy metals and alterations in the functional groups on biomass surfaces. This indicates potential application for water treatment against heavy metal contamination using biomass materials.

HeavyMetal	Biomass Material	Adsorption Capacity (qemg/g)	Removal Efficiency(%)	
Cadmium	Coconut ShellPowder	0.15	60	
Cadmium	Coconut ShellPowder	0.35	70	
Cadmium	Rice Husks	0.75	75	
Cadmium	Sawdust	62.5		
Fluoride	Coconut ShellPowder	0.20	80	
Fluoride	Rice Husks	0.50	100	
Chromium	Coconut ShellPowder	0.80	80	
Arsenic	Rice Husks	1.50	75	

#### 4.4 Adsorption Capacity and Removal Efficiency of Heavy Metals

#### 4.5 Effect of Adsorbent dose

Adsorbent	Dose(g)	Cadmium(Cd) Removal (%)	Fluoride (F) Removal (%)	Chromium (Cr) Removal (%)	Arsenic (As) Removal (%)
Rice Husk	1	55	60	50	45
Rice Husk	2	70	75	65	60
Rice Husk	3	82	85	78	75
Rice Husk	5	90	92	88	85
Sugarcane Waste	1	50	55	48	42
Sugarcane Waste	2	68	70	60	58
Sugarcane Waste	3	75	80	72	68
Sugarcane Waste	5	85	90	83	80
Coconut Waste	1	40	45	42	38
Coconut Waste	2	67	72	65	62
Coconut Waste	3	75	76	70	68
Coconut Waste	5	82	85	80	78

The effect of adsorbent dose on the removal efficiency of heavy metals significantly underscores the relationship between biomass quantity and pollutant uptake capability. As observed in the study, an increase in the adsorbent dose directly correlates with enhanced removal percentages across all tested heavy metals, indicating that greater biomass availability provides more active sites for adsorption. For instance, rice husk demonstrated remarkable efficiency in



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cadmium removal, with percentages rising from 55% at 1 g to 90% at 5 g, suggesting that the adsorption capacity ramps up with dose due higher binding site accessibility. However, this trend also hints at a saturation point, where further increments in adsorbent quantity render diminishing returns in removal efficiency, highlighting the importance of optimizing adsorbent dosage for effective watertreatment. Ultimately, these findings emphasize the critical role of biosorbent dose in maximizing heavy metal uptake, which is crucial for developing efficient remediation strategies in contaminated water bodies

Contact Time	Rice Husk	Sugarcane Waste	Coconut Waste	Rice Husk	Sugarcane Waste	Coconut Waste	Rice Husk(As	Sugarcane Waste	Coconut Waste
(min)	(Cd	(Cdrug/g)	(Cdm a/a)	(Cr	(Come ala)	(Creation of a)	mg/g)		
	mg/g)	(Cung/g)	(Cung/g)	mg/g)	(Cring/g)	(Cring/g)		(Asing/g)	(Asing/g)
0	0	0	0	0	0	0	0	0	0
15	2.5	1.2	0.8	1.0	0.5	0.3	0.4	0.1	0.2
30	4.5	2.1	1.4	1.5	0.8	0.6	0.7	0.3	0.4
60	6.0	3.5	2.0	2.0	1.2	0.9	1.0	0.5	0.6
120	7.5	4.8	3.0	2.5	1.5	1.2	1.5	0.7	0.8
180	8.0	5.2	3.5	3.0	1.7	1.5	1.8	0.9	1.0

#### 4.6 Effect of contact length/contact time

The experimental results indicated significant variations in the adsorption capacities of different biomass materials for heavy metals, highlighting the potential of agricultural wastes for environmental remediation. Rice husk demonstrated particularly effective adsorption for cadmium, surpassing the performance of sugarcane and coconut waste, which can be attributed to its higher surface area and the presence of functional groups that facilitate metal ion binding. Additionally, the data showed that adsorption efficiencygenerally improved with increased contact time, suggesting that equilibrium was reachedafter a certain period, beyond which minimal additional uptake occurred, indicating saturation of active sites. Notably, differences in adsorption profiles among the various heavy metals could be explained by their ionic sizes and charges, impacting their termoval from contaminated water, promoting sustainable practice in waste management and environmental conservation. Future research could delve into the regeneration of these adsorbents and the underlying mechanisms governing metal adsorption to further enhance practical applications in watertreatment.

#### 4.7 Effect of Agitation time

Agitatio n Time	Rice Husk	Sugarcan e Waste	Coconu t	Rice Husk	Sugarcan e Waste	Coconu t	Rice Husk	Sugarcan e Waste	Coconu t Waste	Rice Husk	Sugarcan e Waste	Coconu t Waste
(min)	(Cd mg/g	(Cd mg/g)	Waste (Cd mg/g)	(Cr mg/g	(Cr mg/g)	Waste (Cr mg/g)	(As mg/g	(As mg/g)	(As mg/g)	(F mg/g	(F mg/g)	(F mg/g)
0	0	0	0	0	0	0	0	0	0	0	0	0
15	2.5	1.2	0.8	1.0	0.5	0.3	0.4	0.1	0.2	0.5	0.2	0.3
30	4.5	2.1	1.4	1.5	0.8	0.6	0.7	0.3	0.4	0.8	0.4	0.5
60	6.0	3.5	2.0	2.0	1.2	0.9	1.0	0.5	0.6	1.0	0.6	0.7
120	7.5	4.8	3.0	2.5	1.5	1.2	1.5	0.7	0.8	1.5	0.8	0.9
180	8.0	5.2	3.5	3.0	1.7	1.5	1.8	0.9	1.0	2.0	1.0	1.2

#### Effect of agitation speed

Agitatio n	Rice Husk	Sugarcan e Waste	Coconut Waste	Rice Husk	Sugarcan e Waste	Coconut Waste	Rice Husk	Sugarcan e Waste	Coconut Waste	Rice Husk	Sugarcan e Waste	Coconut Waste(F
Speed (rpm)	(Cd mg/g	(Cd mg/g)	(Cd mg/g)	(Cr mg/g	(Cr mg/g)	(Cr mg/g)	(As mg/g	(As mg/g)	(As mg/g)	(F mg/g	(F mg/g)	mg/g)
50	3.0	1.5	1.0	1.2	0.6	0.4	0.5	0.2	0.3	0.6	0.3	0.4
100	5.0	2.5	1.8	1.8	1.0	0.7	0.9	0.4	0.5	1.0	0.5	0.6



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	150	7.0	3.8	2.5	2.5	1.5	1.0	1.2	0.6	0.7	1.5	0.7	0.8	
	200	8.5	4.5	3.2	3.0	1.8	1.4	1.6	0.8	0.9	1.7	0.9	1.0	
	250	9.0	5.0	3.8	3.5	2.0	1.6	1.8	1.0	1.2	2.0	1.0	1.2	

The results indicate that agitation time significantly affects the adsorption capacity of ricehusk, sugarcane waste, and coconut waste for heavy metals such as cadmium, chromium, arsenic, and fluoride. As agitation time increased, the adsorption capacity generally improved for all biomass materials, reaching a plateau at around 180 minutes, which suggests that the active sites on the biomass were becoming saturated. Rice huskconsistently demonstrated the highest adsorption capacities across all heavy metals, likelydue to its larger surface area and higher availability of functional groups that facilitate metal ion binding. Sugarcane waste and coconut waste exhibited lower adsorptioncapacities, which may be attributed to their different structural properties and chemical compositions. The increasing trend in adsorption capacity with time highlights the importance of optimizing contact time in practical applications for water treatment usingbiomass adsorbents. These findings support the potential of using agricultural waste materials as effective and sustainable solutions for the removal of heavy metals from contaminated water sources. Further investigations could explore the regeneration of these biomass materials and their performance in real wastewater treatment scenarios.

#### Effect of agitation speed

The results demonstrate that agitation speed significantly influences the adsorptioncapacity of rice husk, sugarcane waste, and coconut waste for various heavy metals. Increasing the speed enhances the interaction between the biomass and metal ions, leading to improved adsorption rates. Rice husk consistently shows the highest capacity, likely due to its superior surface area and structural properties. While both sugarcane and coconut wastes exhibited positive trends, they remained less effective than rice husk. Optimal agitation speeds resulted in maximum adsorption, underscoring the importance of effective mixing in maximizing the efficacy of agricultural waste as a sustainable solution for heavy metal remediation.

Temperatur e(°C)	Rice Hus	Sugarcan eWaste	Coconu tWaste	Rice Hus	Sugarcan eWaste (F	Coconu tWaste	Rice Hus	Sugarcan eWaste	Coconu tWaste	Rice Hus	Sugarcan eWaste	Coconu tWaste
	k(Cd mg/g	(Cdmg/g)	(Cd mg/g)	k(F mg/g	mg/g)	(F mg/g)	k(Cr mg/g	(Crmg/g)	(Cr mg/g)	k(As mg/g	(Asmg/g)	(As mg/g)
20	5.0	2.0	1.5	0.8	0.4	0.5	1.5	0.7	0.5	0.7	0.3	0.4
25	6.5	2.8	2.0	1.0	0.5	0.6	2.0	1.0	0.8	0.9	0.4	0.5
30	8.0	3.5	2.7	1.2	0.6	0.8	2.5	1.5	1.0	1.1	0.5	0.6
35	9.5	4.2	3.5	1.5	0.8	1.0	3.0	1.8	1.3	1.4	0.6	0.8
40	10.5	5.0	4.0	1.8	1.0	1.2	3.5	2.0	1.5	1.6	0.7	1.0

#### 4.8 Effect of Temperature

The outcomes of this study indicate a clear trend in the effect of temperature on the adsorption capacities of heavy metals by different biomassmaterials. As temperature increased from 20°C to 40°C, the adsorption capacities for cadmium, fluoride, chromium, and arsenic showed a consistent upward trend for all biomass materials assessed.

Rice husk exhibited the highest adsorption capacity across all temperatures, particularly for cadmium and chromium. This can be attributed to its larger surface area and favorable structural properties, which enhance the interaction with metal ions. Sugarcane waste and coconut waste also displayed increased adsorption with rising temperature; however, they remained less effective than rice husk in binding the heavymetals.

## 5 CONCLUSION

This study demonstrates the promising potential of agricultural biomass materials, including rice husks, coconut waste, and sugarcane waste, as effective adsorbents for removing heavy metals from contaminated water sources like the Yamuna River in Delhiand Haryana. Highlighting alarming levels of heavy metals in the water, the research underscores the urgent need for effective remediation strategies. The preparation methods involving drying, crushing, and acid treatment significantly enhance the biomass's physicochemical properties, resulting in improved adsorption capacities for metals such as cadmium, fluoride, chromium, and arsenic. Optimal adsorption conditions, particularlyat neutral pH levels, and a direct relationship between biomass dosage and heavy metal removal efficiency were established, with rice husks showing outstanding performance incadmium removal. Additionally, the findings indicate that prolonged contact time and increased agitation speed enhance metal uptake, while higher temperatures facilitate better metal ion diffusion



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and chemisorption. These insights suggest that agricultural wastes can be effectively tailored to optimize their use in water treatment applications. In conclusion, this research advocates for the utilization of agricultural biomass as sustainable and cost-effective solutions for heavy metal remediation, contributing valuable knowledge to environmental science and supporting the development of practical applications to tackle water contamination challenges. Future investigations should explore the regeneration capabilities of these biosorbents and conduct field trials to enhance their viability in environmental management practices.

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