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A study on adsorption of heavy metals industrial effluents' in aqueous solution by using biomass as adsorbent from Mohan Nagar Ghaziabad

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Abstract

The elimination of heavy metal ions from wastewater is crucial for maintaining human health and a clean environment. Various described techniques were used to remove heavy metal ions from different types of wastewater. These techniques can be divided into treatments based on adsorption, membranes, chemicals, electricity, and photocatalysis. The employed agents/adsorbents, removal efficiency, operating circumstances, and advantages and disadvantages of each technique are all covered in-depth and critically in this paper's assessment and discussion of these approaches. In addition, a summary of the principal discoveries from earlier research is provided in the literature. It is generally observed that adsorption techniques have been the subject of the majority of current investigations. The capacity to remove many ion types simultaneously, long retention times, and adsorbent cycling stability are the main challenges facing adsorption techniques. The large-volume sludge generation and post-treatment requirements are crucial problems that must be resolved for chemical procedures, even though the membrane and chemical processes are feasible. Further advancements in membrane separation may result from fouling and scaling inhibition. Pre-treatment and routine membrane cleaning, however, come at an extra expense. Electrical-based techniques have also been found to be effective; however, in addition to addressing the problem of large-volume sludge development, industrial-scale separation is required. Techniques based on electricity and photocatalysis are still in their infancy. Real wastewaters should be used more often in heavy metals removal research rather than simulated ones. Future investigations ought to concentrate on sustainable, affordable, and environmentally friendly materials and procedures.

Keywords: Heavy metal, photocatalysis, wastewater, adsorption, sustainable

Introduction

Water is the foundation of life. Without water, humans cannot survive. It is necessary for many biological functions, including feeding cells, getting rid of waste, shielding joints and tissues, and controlling body temperature. Water, on the other hand, is equally vital to plants. Water is necessary for plants to survive and flourish. Through a process known as photosynthesis, plants use carbon dioxide (CO2) and water to make food. Water also facilitates the transfer of nutrients across plants. Seeds cannot germinate without water.

The yearly increase in water demand can be attributed to several reasons such as population growth, industrialization, climate change effects, and variations in consumption habits. Water use will continue to rise in tandem with growing home and industrial demand. Industrialization is expected to increase the amount of water required by industry globally by 4% every year. Consequently, it is projected that the industry would account for 38% of global water consumption by 2040, up from 21% at present. Power plants are the main source of water use, which is why they are increasingly being built along the shore to draw in seawater.

Water contamination is attributed to large-scale, unplanned urbanization and industrialization processes that change the chemical composition of the atmosphere. These processes are also connected to organic evolution.

Water scarcity affects a great deal of people on the earth now, at least sporadically annually. Everyone has the right to utilize clean water for daily domestic chores that protect human health. A country's capacity to grow economically and demographically is reliant on its availability of freshwater. About 21 major Indian cities are facing a water crisis that would affect hundreds of millions of people and

the GDP by 2020 due to the groundwater level plummeting to zero. The limited amount of fresh water on Earth is raising doubts about the sustainability of human life. The author has discussed the details of India's water supply, quality, and sustainability.

With the expansion of human activity and industry, such as the plating and electroplating sector, batteries, pesticides, mining, rayon, tanning, fluidized bed bioreactors, textile, metal smelting, petrochemical, paper, and electrolysis applications, the amount of heavy metals in wastewater has been rising. Wastewater tainted with heavy metals seeps into the environment, endangering both the ecology and human health. Because heavy metals are not biodegradable and may cause cancer, their presence in water at excessive concentrations may have a detrimental effect on the health of living things.

Lead (Pb), zinc (Zn), mercury (Hg), nickel (Ni), cadmium (Cd), copper (Cu), chromium (Cr), and arsenic (As) are the most commonly occurring heavy metals. These heavy metals are still dangerous even when traces of them can be found. A summary of some heavy metals is provided in Table 1, with an emphasis on the main sources, health consequences, and allowable levels in drinking water. The metals listed above as well as others that are frequently found in wastewater, such as cobalt (Co), silver (Ag), iron (Fe), manganese (Mn), molybdenum (Mo), boron (B), calcium (Ca), antimony (Sb), and so on, must be eliminated.

Some heavy metal ion removal techniques, like electrocoagulation (EC), adsorption using artificial and natural adsorbents, magnetic field application, sophisticated oxidation procedures, membranes, etc., have been the subject of recent studies. This research focused on the benefits and drawbacks of a particular wastewater treatment technique, which included heavy metal removal. There is still no clear picture of how heavy metals are removed from wastewater resources. As a result, the current analysis analyzes the many methods that can effectively remove heavy metal ions from wastewater in a thorough and critical manner. Furthermore, it is crucial to select the best approach depending on the removal efficiency, additional chemicals or adsorbents, starting concentration, ideal treatment pH value, and further operational parameters.

Materials and Methods

In this study, the levels of heavy metals in the Hindon River in Uttar Pradesh, India, were measured throughout the monsoon and non-monsoon seasons. Additionally, the potential source of the contamination and the health risk it posed were evaluated. All elements, including iron (Fe), nickel, copper, lead, mercury, and cadmium, were part of the study.

Samples were taken from all along the Hindon River; no specific authorization was required. Thirteen sampling locations were chosen for this study in order to track and evaluate the spread of metal pollution along the whole Hindon stretch. Using the grab method, one litre of water was sampled from the centre of the river at a level of 30 to 50 cm. River levels fall during the non-monsoon season when there is little to no rainfall and then rise during the monsoon season because of rain. Water with different concentrations of metals can be caused by variations in rainfall in monsoon and non-monsoon seasons.

Further, there are numerous techniques for treating heavy metals in water, but comparison between synthetic activated carbons and biomass absorbents is necessary as wastewater treatment technologies become more efficient and affordable. Due to their low cost, biomass absorbent materials such as lignite and coconut husk charcoal are gaining popularity; nonetheless, their effectiveness is inferior to that of synthetic activated carbon absorbents like polymeric resins. Because of organic matter and heavy metals, biomass absorbents can generate more pollutants than synthetic materials. Therefore, it is necessary to analyze the efficiency, cost, and environmental impact of biomass and synthetic absorbents in order to choose the most economical and environmentally responsible wastewater treatment techniques. Motivated by the same, the present research work aimed to examine the effect of biomass material on the adsorption of heavy metals present in water under various parameters like pH, starting concentration, adsorbent dose, contact length, agitation speed, and temperature. Different biomasses are prepared by physical, chemical and thermal methods. For example Coconut fiber dust may be used to remove metals from water by adsorption. (CFD). Different types of coconut fiber dust were examined in terms of their surface physicochemical properties. More fluoride, cadmium, chromium, and arsenic ions may be adsorbed to the surfaces of CFD-3 and CFD-2 because their surface areas and total pore volumes are both higher than those of CFD-1, suggesting that the pore walls are rougher as well as there are more active sites responsible for adsorption. The effects of pH, starting concentration, adsorbent dose, contact length, agitation speed, as well as temperature on fluoride, cadmium, chromium, and arsenic, adsorption rate and capacity were investigated. CFD-1 has a neutral charge of 6.1, CFD-2 has a neutral charge of 6.6, and CFD-3 has a neutral charge of 7.1. When compared to alternative isotherm models, the experimental data were best captured by the Langmuir isotherm.

Rice husk dust may be used to remove metals from water by adsorption. (RHD). Physicochemical characteristics were examined to learn more about the surface nature of the distinct rice husk dust forms. Surface area and total pore volume are greater for RHD-3 and RHD-2 than for RHD-1, meaning that the pore walls are rougher and there are more active sites for adsorption of heavy metal ions. We investigated the effects of pH, starting concentration, adsorbent dose, contact length, agitation speed, as well as temperature on the adsorption rate as well as the ability for heavy metals.

Sugarcane bagasse's were industrially produced for use in a batch technique to precipitate heavy metals out of water in this investigation. The adsorption of fluoride, cadmium, chromium, and arsenic, were found to be lower when the pH in the aqueous solution was raised above 6.0. In the temperature range of 303-333 K, it was shown that fluoride, and other metals monolayer adsorption is negatively correlated with temperature, and that the adsorption process showed good agreement with the Langmuir adsorption isotherm. Adsorption was found to be best described by a pseudo-second-order kinetic model.

Heavy metal adsorption on activated carbon made from sugarcane bagasse's is physisorption, exothermic in nature,

and enthalpy driven, according to the available thermodynamic data.
The adsorption studies will be analysed under chemical kinetics called Langmuir Adsorption Isotherm.

Experimentation

To track the adsorption process, a sequential mode operation was chosen. One gramme of the required kind of adsorbent, such as sugarcane, and husk, combined with fifty milliliters of the adsorbate mixture name as triphenyl-methane and xanthene in aqueous solution of the required starting amount, temperature, and pH in a separate glass bottle as a shaker thermostat operating at a steady 130 revolutions per minute. Before beginning every test run, the pH of the adsorption material solution was corrected by adding diluted HCl or the appropriate concentration of NaOH. Up until saturation was reached, the rate of adsorption was tracked at various intervals.
The suspended matter was removed and filtered at periodically, and the amount of leftover dye was determined by analysing the supernatant liquid using a Shimadzu spectrophotometer (Phamaspac UV-1700). To determine the background adsorption and whether any corrections needed were made, blanks were run under identical concentrations, temperatures, and pH conditions in each case.
For all dye, an adsorbance vs. wavelengths plot was created by noting the absorbance at a specific wavelength. The wavelength related to the greatest adsorbance, or λmax, was ascertained. The resultant λmax values for Triphenyl-methane and Xanthene were determined. All dye concentration measurements were conducted at these respective λmax values.

Results of adsorption

Temperature's effect

Adsorption and, consequently, the removal of coloured species from water and waste water are significantly influenced by temperature. Physical adsorption is invariably a process that is exothermic, and it follows that rising temperatures are detrimental to the degree of adsorption. The decreasing strength of the adsorption forces among the adsorbent and adsorbate as well as among the adjacent sides of the adsorbed phase is responsible for a reduction in adsorption density. As a result, as temperature rises, the rate at which adsorbate species are absorbed reduces. Regarding the treatment of waste water and water using adsorption, environmentalists have discovered that the temperature of the adsorbate adsorbent system is a critical factor.
In the majority of completed studies, the rate at which adsorbate species are absorbed generally decreases as temperatures increase. The reduction in the escape propensity of dye molecules from the solid state to the bulk phase with rising temperatures is caused by a decrease of the adsorptive forces among the active sites of adsorbent molecules in the adsorbed phase.
Determining how quickly the elimination of pollutants reaches a state of thermal equilibrium is crucial for comprehending the adsorbent process, which determines how long the adsorbent and adsorbate are retained. However, there are additional documented instances where the system's temperature rises and causes an increase in the absorption of ions or molecules. As a result, the composition of the adsorbent-adsorbate system determines how the adsorbent changes with temperature. This study examined how temperature affected the elimination of xanthene and triphenyl-methane dyes utilizing activated sugarcane, risk husk, and coconut as adsorbents at different temperatures.
Tables present the findings of time rate investigations on the absorption of triphenylmethane and xanthene by rice husk ash and activated charcoal at varying temperatures. The image makes it evident that while dye uptake is very quick in the early phases of the adsorption process, it slows down and eventually reaches saturation in later stages. The data collected at various temperatures indicate that while temperature has a significant impact on adsorption rate and amount absorbed by the various adsorbents to varying degrees, it has no effect on the saturation duration.
The table indicates that the adsorption of triphenyl-methane and xanthene through rice husk ash as well as activated sugarcane and coconut has a maximum adsorption time of 140 minutes for rice husk ash and 120 minutes for active carbon. This is evident from the values of 1.0 to 1.5 at initial adsorption concentrations of 45 mg/L, adsorption particle size <60 μm, and pH 4.5. Temperature increases have no effect on the contact time. When the temperature is raised from 20 to 40 °C, the absorption of triphenyl-methane by various adsorbents at the point of saturation time ranges has been presented in table.
Rice husk ash absorbs less triphenyl-methane form the dye solution after 140 minutes after contact than activated sugarcane and coconut does. Based on the aforementioned observation, rice husk ash is a more effective method of removing triphenyl-methane from dye solutions than activated sugarcane and coconut.

Table 1: Temperature-dependent time variation of triphenyl-methane adsorption: case of rice husk

Contact duration in min	Temperature					
	20 ºC		30 ºC		40 ºC	
	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption
10-20	0.1526	33.77	0.1781	36.43	0.21968	40.40
20-40	0.2377	45.55	0.2888	54.46	0.3211	59.85
40-60	0.2811	56.50	0.3274	65.72	0.3606	72.93
60-100	0.3044	59.96	0.3555	70.45	0.3890	77.51
100-120	0.3121	60.12	0.3448	72.88	0.3846	78.74
120-140	0.3211	63.32	0.3751	74.44	0.4266	83.33
140-160	0.3211	63.32	0.3751	74.44	0.4266	83.33

Table 2: Temperature-dependent time variation of triphenyl-methane adsorption: case of sugarcane

Contact duration in min	Temperature					
	20 °C		30 °C		40 °C	
	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption
10-20	0.1336	31.37	0.1571	34.33	0.1977	38.30
20-40	0.2166	43.45	0.2559	53.36	0.3017	56.64
40-60	0.2667	55.00	0.3274	65.72	0.3606	72.93
60-100	0.2990	57.66	0.3345	68.43	0.3685	74.41
100-120	0.3011	58.88	0.3224	70.66	0.3654	76.54
120-140	0.3100	61.12	0.3555	72.22	0.4076	81.43
140-160	0.3120	61.99	0.3588	72.98	0.4086	81.96

Table 3: Temperature-dependent time variation of triphenyl-methane adsorption: case of coconut

Contact duration in min	Temperature					
	20 °C		30 °C		40 °C	
	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption
10-20	0.1121	29.88	0.1345	32.12	0.1885	37.12
20-40	0.2088	42.54	0.2459	51.26	0.2917	55.00
40-60	0.2585	54.85	0.3185	64.43	0.3596	71.23
60-100	0.2896	55.96	0.3252	67.96	0.3641	73.34
100-120	0.3010	57.98	0.3210	69.63	0.3543	75.52
120-140	0.3020	60.18	0.3498	70.12	0.3998	80.80
140-160	0.3078	60.85	0.3478	70.11	0.4010	80.96

Table 4: Temperature-dependent time variation of xanthene adsorption: case of rice husk

Contact duration in min	Temperature					
	20 °C		30 °C		40 °C	
	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption
10-20	0.1199	31.66	0.1008	22.96	0.0987	21.39
20-40	0.2288	43.25	0.1325	29.30	0.1328	28.21
40-60	0.2778	55.59	0.1754	37.88	0.1669	35.23
60-100	0.2999	58.89	0.2054	43.88	0.1931	38.27
100-120	0.3032	59.69	0.2262	48.04	0.293	40.87
120-140	0.3163	61.36	0.2390	50.64	0.3180	45.04
140-160	0.3128	61.28	0.2967	54.87	0.3432	49.58

Table 5: Temperature-dependent time variation of xanthene adsorption: case of sugarcane

Contact duration in min	Temperature					
	20 °C		30 °C		40 °C	
	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption
10-20	0.1210	25.32	0.1008	22.96	0.0987	21.39
20-40	0.1601	33.14	0.1325	29.30	0.1328	28.21
40-60	0.2150	44.12	0.1754	37.88	0.1669	35.23
60-100	0.2440	49.92	0.2054	43.88	0.1931	38.27
100-120	0.2672	54.56	0.2262	48.04	0.293	40.87
120-140	0.2902	59.06	0.2390	50.64	0.3180	45.04
140-160	0.2962	60.26	0.2967	54.87	0.3432	49.58

Table 6: Temperature-dependent time variation of xanthene adsorption: case of coconut

Contact duration in min	Temperature					
	20 °C		30 °C		40 C	
	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption	Quantity Adsorbed	Percentages of adsorption
10-20	0.1121	29.88	0.0647	12.65	0.0554	10.18
20-40	0.2088	42.54	0.0995	19.61	0.0818	18.54
40-60	0.2585	54.85	0.1336	26.43	0.1255	22.85
60-100	0.2896	55.96	0.1949	38.69	0.1888	35.86
100-120	0.3010	57.98	0.2044	40.59	0.1982	40.72
120-140	0.3020	60.18	0.2344	46.59	0.1810	36.85
140-160	0.3078	60.85	0.2694	53.59	0.2412	48.89

Conclusion

The selection of the best method for removing heavy metal ions from wastewater is contingent upon a number of important aspects, such as the cost of operation, the metal ions' initial concentration, the environmental impact, pH levels, chemicals added, removal efficiency, and economic viability. Chemical treatments (such as chemical precipitation, coagulation-flocculation, and flotation), electric treatments (such as electrochemical (reduction, EC, EF, and advanced oxidation) and ion exchange), membrane treatments (such as UF, nanofiltration, microfiltration, reverse osmosis, forward osmosis, and electrodialysis), and photocatalysis are the categories into which these techniques fall.

Owing to its low cost of reusability, robust application, high removal rate, and ease of operation, adsorption is the most promising technique for removing heavy metal ions from wastewater that has received extensive research. This choice is contingent upon the selection of inexpensive materials, high absorption rates, and effective regeneration mechanisms. The membrane approach is better developed technically than adsorption because it is more practicable; still, minimizing separation costs and membrane fouling remains difficult.

The chemical-based techniques, particularly chemical precipitation, are both realistic and well-developed technically. They are regarded as economical techniques as well. Unlike the electrochemical approach, which depends on additional elements like electrodes, electrical energy, and other fixed expenditures, they are dependent on the chemical used. They do, however, produce a lot of sludge and require sedimentation separation. Because of the high electrical energy consumption and electrode passivation, the electrochemical process is a relatively expensive technique. In addition, electric techniques are the least developed technology, with the exception of photocatalytic techniques. The advantage of the photocatalytic process is that it produces less sludge and uses no, or very little, chemicals, making it environmentally benign.

Chemical, adsorption, and membrane techniques are typically the most useful ones discussed in the literature. Given that the majority of research used synthetic wastewater that contained one or a few different metal types, it has been noted that there is a glaring information gap in the performance of treatment strategies for the removal of heavy metal ions from actual wastewater. Therefore, more study on removing various contaminants using actual wastewater treatment should be carried out. There should be more investigation into the introduction of affordable materials and techniques for the removal of heavy metals from wastewater. Future research ought to concentrate on the pilot-scale procedure as well. Future study should take into account the most effective methods currently being developed for low-cost, environmentally friendly metals recovery.

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