

Research Article

Biotechnological Valorization of Solid Waste–Derived Adsorbents for Sustainable Removal of COD, BOD, and TDS from Dairy Wastewater

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Abstract

The dairy industry is one of the most important sectors among the food process industries. But it generates a significant amount of wastewater due to more quantity of water usage in various processing units, i.e., pasteurization, homogenization, equipment cleaning, and sanitation. On an average, about 2.5 to 10 liters of wastewater are generated for each liter of milk processed. This wastewater contains a large concentration of pollutants like carbohydrates, proteins, oil, greases, suspended solids and other nutrients. Because of these, the concentration of BOD and COD in the waste water was pretty high. If it is dumped directly to the water resources without appropriate treatment, it may serious problems like, polluted water, bad smells, even damaged aquatic life. In this study, an environmental-friendly approach was adopted by transforming agricultural waste materials like dried guava leaves and coconut shells into granular activated carbon for the wastewater treatment. To simulate actual industrial conditions, synthetic dairy wastewater was generated in laboratory scale. Then it was treated using these low-cost adsorbents. Their performance was evaluated by measuring the reduction in COD, BOD, and TDS concentrations. Activated carbon derived from guava leaves achieved the removal efficiencies of 76% for COD, 78% for BOD, and 65% for TDS. In comparison, the coconut shell derived activated carbon performed somewhat better, achieving 84% removal of COD, 80% of BOD, and 68% of TDS. The study demonstrates that converting waste into valuable resources through biotechnological processes provides a sustainable and eco-friendly solution for the efficient treatment of dairy wastewater.

Keywords

Dairy Waste Water, BOD, COD, TDS, Activated Carbon

1. Introduction

Industrialization is considered as an important parameter for economic growth of country [1]. Based on data reported by the Food and Agriculture Organization's Corporate Statistical Database (FAOSTAT), India has held the top position in global milk production since 1998 [2]. Now it is contributing

25% of global milk production. Dairy industry in the world is growing 2% per annum [3]. In dairy industries, more amount of water is used in different steps of processing starting from milk receiving station to packaging station [4]. It produces

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11.217 million m³ of waste water per year [5]. It has been reported that, 2.5-10 L of waste water is generated for 1L milk processing in India. Dairy Waste water disposal remains a major challenge for the industry [6]. It contains high concentration of COD, BOD due to the presence of organic compounds

along with increased level of TDS, TSS contents [7]. Hence, adequate treatment is essential before its discharge to the environment [8].

Table 1. Regulatory Standards for Physicochemical Parameters in Dairy Industry Effluents.

Parameter	World Bank Report CPCB, India	Maximum Value (mg/l)
TSS	150	50
COD	-	250
BOD5	100 (based on BOD5)	50
Oil & Grease	10	10
pH	6.5-8.5	6-9
Temperature Rise	-	< = 30°C
Coliform Bacteria	-	400 MPN/ 100 ml

2. Materials and Methods

2.1. Materials Required

Granular activated carbon derived from coconut shells (CGAC) was prepared using discarded coconut shells collected from a temple. The shells were thoroughly cleaned to eliminate surface impurities and then dried under sunlight before further processing. It was then carbonized in a furnace at 400 °C for 15 minutes, followed by cooling and grinding to obtain particles of approximately 1 mm in size. After carbonizing the material, it was treated with hydrochloric acid to boost its surface area and adsorption abilities [9-11].

To make GGAC, guava leaves was used. It is easy to find and usually considered agricultural waste. We let the leaves were dried in the sun for about two weeks. After drying, it was ground with a hammer mill and shifted the particles to get a size of roughly 1 mm. Next, powder was carbonized in a furnace with a temperature ranged from 600 to 1000 °C all in about 20 minutes, then let it cool down. Finally, cooled material was washed with sodium hydroxide, which helped create pores and turned it into granules [12].

2.2. Experimental Procedure

The adsorption studies were carried out using a batch column setup. As-prepared CGAC and GGAC were used as the adsorbents. To evaluate the effect on adsorption performance,

five different bed heights, i.e., 2 cm, 4 cm, 6 cm, 8 cm, and 10 cm were set up in individual cylindrical columns, each with an internal diameter of 5 cm [13]. The experiments were carried out separately for CGAC and GGAC to provide a clear and reliable comparison of their performance.



Figure 1. Experimental Set-up.

The wastewater was allowed to enter from the top of each adsorption column in downward direction through the CGAC and GGAC beds under gravity. 20-minute contact time was fixed for each experimental run to enhance adsorption efficiency. Samples of untreated and treated water collected from various bed heights were subsequently analyzed for COD, BOD and TDS to evaluate the treatment efficiency of CGAC and GGAC.

2.3. Analytical Method

COD analysis was done using standard method for 11 samples (50 mL each) one untreated, five treated with CGAC, and five with GGAC. Each sample was mixed with potassium dichromate, put in a water bath to heat at 100 °C for 1 hour. It was allowed to cool for 30 minutes, then titrated with sodium thiosulphate by adding a known amount of potassium iodide and Sulphuric acid. In each sample, potassium dichromate was added and heated the mix at 100 °C for an hour [14, 15]. After cooling for half an hour, potassium iodide was added followed by sulfuric acid. Then it was titrated with sodium thiosulphate.

For BOD, 11 samples were put into BOD bottles and incubated them at 20 °C for five days. Once the incubation was done, the BOD values were recorded to see how well CGAC and GGAC worked. For TDS, a 50 mL sample was filtered to remove suspended particles. The clear water was collected in a clean evaporating dish [16, 17]. Then, it was evaporated by the help of water bath. The solid residue was dried at 103–105 °C with the help of an oven. After cooling the dish in a

desiccator, it was weighed to determine the final mass of the residue.

3. Result

The initial test result of the sample before any treatment was found as COD at 785.67 mg/L, BOD at 438.67 mg/L, and TDS at 1200 mg/L. It was a serious level of contamination. Then the expected treatment process was conducted. The sample was flown through cylindrical columns filled with various beds of adsorbents. Proper operating conditions was maintained to obtain a consistent and meaningful result. After passing through the different beds, different parameters were analyzed. The removal efficiencies for COD, BOD, and TDS under these various conditions were obtained as shown in Table 2. The adsorbent bed used made a major difference in cleaning up the wastewater. This comparison gives a good result of the method worked best and the variation in adsorbent quantity impacted the results.

Table 2. COD, BOD and TDS Removal Efficiency.

Bed Ht (cm)	COD Removal % (CGAC)	COD Removal % (GGAC)	BOD Removal % (CGAC)	BOD Removal % (GGAC)	TDS Removal % (CGAC)	TDS Removal % (GGAC)
2	30.28	32.17	22.54	26.95	28.40	30.15
4	45.15	49.11	31.76	37.16	40.22	43.87
6	50.61	54.92	54.99	58.24	52.63	55.14
8	61.49	63.66	61.83	66.14	60.85	62.73
10	66.03	73.46	77.12	81.18	68.00	65.00

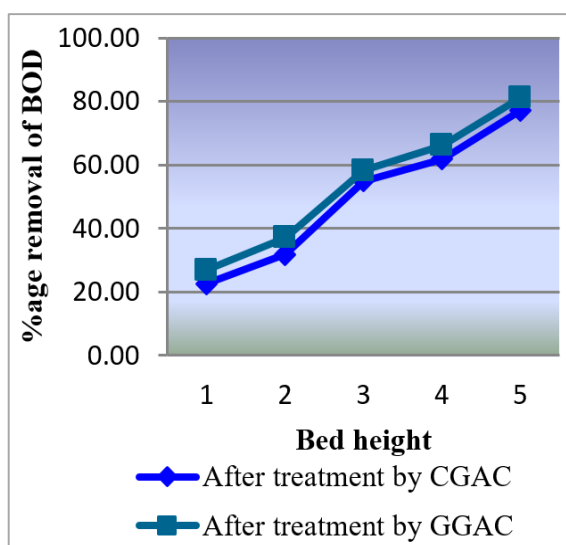


Figure 2. Comparative graph: removal of BOD.

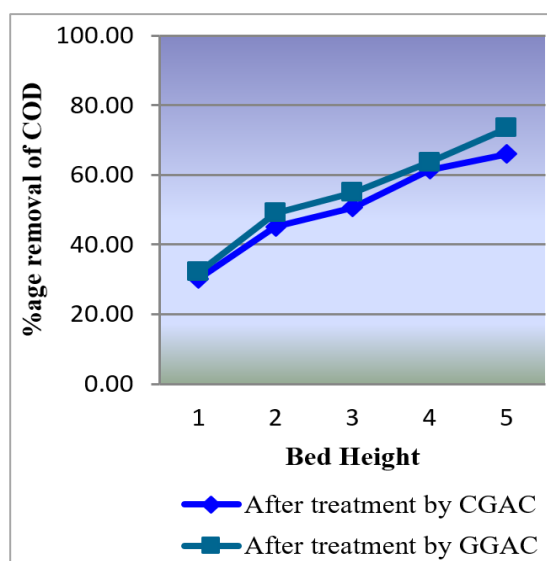


Figure 3. Comparative graph Removal of COD.

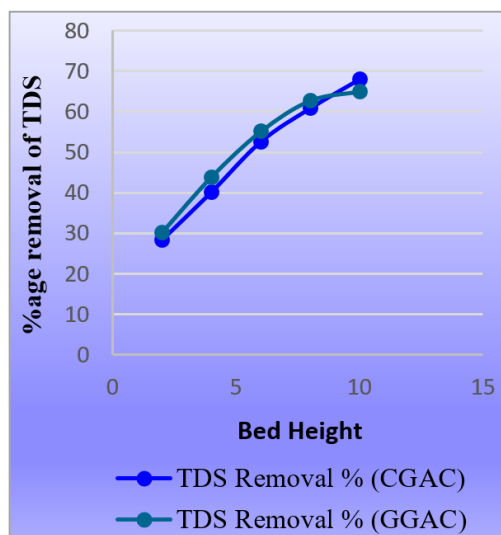


Figure 4. Comparative graph: Removal of TDS.

4. Discussion

Table 2 shows that more the height of adsorbent bed, the cleaner the sample will be. COD, BOD, and TDS removal efficiencies improve as the bed height increases. At a height of 10 cm, COD removal efficiency was obtained 66.03% for CGAC, while 73.46% for GGAC. The same trend was observed for BOD. At 10 cm bed height, BOD removal efficiency was obtained 77.12% for CGAC and 81.18% for GGAC. For TDS, the numbers peak at the highest bed height tested, with CGAC removing 68% and GGAC removing 65%. With variation of adsorbent bed height, two different variables like surface area and the contact time will vary. The water sample has more contact time with the adsorbent to get more cleaned up. This exposure helps to remove more pollutants, leading to better treatment process.

5. Conclusion

The best removal of COD, BOD, and TDS was observed at the adsorbent bed of height 10 cm. Comparing the performance of both adsorbents, GGAC performed better than CGAC in the adsorption process. These results show real promise for scaling up the method. It fits right into continuous industrial wastewater treatment systems.

Abbreviations

COD	Chemical Oxygen Demand
BOD	Biochemical Oxygen Demand
TDS	Total Dissolved Solid
TSS	Total Suspended Solid

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Author Contributions

Suman Mishra: Conceptualization, Resources, Data curation, Writing – original draft

Santosh Kumar Bindhani: Data curation, Supervision, Methodology, Resources, Methodology, Writing – review & editing

Hora Mohan Jena: Supervision, Writing – review & editing

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Data Availability Statement

The data supporting the outcome of this research work has been reported in this manuscript.

Conflicts of Interest

The authors declare no conflicts of interest.

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Biography



Suman Mishra is working in the field of Chemical Engineering as a teacher and researcher. She completed her M. Tech from Biju Patnaik University of Technology and is currently pursuing her Ph.D. in wastewater treatment. Her areas of interest include mass transfer, environmental engineering, wastewater treatment, and sustainable process development.

She has been actively involved in teaching, student guidance, and curriculum-related activities. Her research mainly focuses on adsorption studies, process optimization, and the use of eco-friendly materials for industrial wastewater treatment. Along with academics and research, she also contributes to project guidance, technical writing, and other educational activities in Chemical Engineering. She has more than 15 publications with in reputed Scopus Journals.



Santosh Kumar Bindhani is an Associate Professor in Chemical Engineering at GIET University, Gunupur. He completed his M. Tech from Anna University, Chennai and PhD from BPUT, Rourkela. He is an experienced teacher and researcher. With more than 18 years of academic and research experience, he has been involved in teaching, guiding students, and contributing to various research and development activities. His areas of interest include thermo-dynamics properties, process design, separation processes, environmental engineering, and sustainable technologies. He has also worked on several sponsored projects supported by organizations like DST, SERB, etc. Along with research and academics, he actively participates in student development and institutional activities at the university. He has more than 15 publications with H-index 4 in reputed Scopus Journals.



Hora Mohan Jena is an Associate Professor in the Department of Chemical Engineering at NIT, Rourkela. He completed his PhD from NIT, Rourkela. He is a respected teacher and researcher. He has extensive experience in teaching and research, with specialization in fluidization engineering,

multiphase flow, computational fluid dynamics (CFD), reactor engineering, and wastewater treatment. Over the years, he has guided many students and research scholars and has published several research papers in reputed journals. He is also actively involved in academic and research activities related to Chemical Engineering. He has more than 70 publications with an H-index of 14 in reputed Scopus Journals.

Research Field

Suman Mishra: mass transfer, environmental engineering, wastewater treatment, and sustainable process development

Santosh Kumar Bindhani: thermo-dynamics properties, process

design, separation processes, environmental engineering, and sustainable technologies

Hora Mohan Jena: in fluidization engineering, multiphase flow, computational fluid dynamics (CFD), reactor engineering, and wastewater treatment