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EVALUATION OF DAIRY EFFLUENT DETOXIFICATION AND REMOVAL EFFICIENCY IN AN INTEGRATED WASTEWATER TREATMENT SYSTEM USING LOW-COST ADSORBENTS

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ABSTRACT

Dairy effluent typically contains lipids, lactose, and whey proteins, all of which contribute to a rise in biological oxygen demand, chemical oxygen demand, and other water parameters. Physicochemical characteristics of wastewater can be reduced by biological, chemical, and Physicochemical treatments. The adsorption technique is attractive for the removal of organic compounds in wastewater among the numerous Physicochemical treatment methods. Two low-cost adsorbents were chosen for this work, and a comparative analysis was performed. The goal of this study was to find a new application of rice husk ash and sugarcane bagasse ash. When rice husk ash and sugarcane bagasse ash were employed, the removal of organic pollutants, biological oxygen demand, chemical oxygen demand and other parameters from dairy effluent were evaluated and compared. The organic pollutants, color, biological oxygen demand, and chemical oxygen demand have all been removed from dairy effluent using rice husk ash and sugarcane bagasse ash as adsorbents. At room temperature, rice husk ash adsorbents were reported to remove up to 73.11 % of biological oxygen demand, with a maximum dose of 800mg/L, whereas sugarcane bagasse adsorbents were removed 78.17 % with the same dose. The Chemical oxygen demand removal efficiency was also evaluated and compared to rice husk ash and sugarcane bagasse ash which were 89.12% and 81.23%, respectively with a dosage of 800 mg/L at 7.4 pH.

Keywords: Dairy Effluent, Adsorbent, Rice Husk Ash, Sugarcane Bagasse, Physicochemical Parameters

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INTRODUCTION

The dairy industry is the fastest growing industry in the world. Dairy effluent is more easily contaminated with high levels of organic substances, pollutants, and microbes. The dairy industry is sensitive to water and requires a large volume of water for various operations such as heating, cooling, cleaning, etc.[1] In milk processing, a large effluent discharge volume of 03 liters per liter of milk has been reported.[2-4] The present investigation was carried out for the detoxification of organic contaminants, color, Turbidity, BOD (Biological oxygen demand), COD(Chemical oxygen demand), and degree of efficiency of dairy effluents using low-cost adsorbents like rice husk ash (RHA) and sugarcane bagasse ash (SBA), which were obtained from rice and sugar mill individually. During monsoon, dairy effluent was collected from the dairy plant (CMP) Kannauj, U.P., India. In the present investigation, the adsorption technique is used for detoxification and removal of color, odor. During the investigation, various Physicochemical parameters i.e. pH, BOD, COD, TDS (Total dissolved solids), TSS (Total suspended solid), etc. were analyzed.

The biological, chemical and Physicochemical treatments are ways to reduce the Physicochemical properties of effluent[5,6] to the desired values. The adsorption technique was shown to be the most effective at removing organic compounds and reducing COD in wastewater among the other

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Physicochemical treatment methods.[7] Commercial activated carbon is successful in removing organic contamination, but it comes at a high initial cost and its regeneration problem in system.[8] Therefore, rice husk ash and sugarcane bagasse ash were chosen as low-cost adsorbents in this study. Rice husk ash has been widely used as an efficient adsorbent for filtration to filter solid-liquid systems such as colloids, highly compatible fine solid particles, or difficult-to-filter materials.[9] Recent studies on RHA have shown excellent adsorption properties which help in reducing the color, odor, COD, BOD and organic contaminants.[10] RHA is compared to sugarcane bagasse, which generally possesses biosorption of organic compounds due to high-quality fibers and surface, while rice husk ash material exhibits both physical adsorptions for removal of organic compounds and adsorption chemistry (ion exchange) to remove some ions and metals. The physical adsorption of RHA is due to its porous structure and high surface area.[11]
SBA is a by-product sugarcane industry. In addition to this SBA are a low-cost absorbent and high availability. After crushing and extracting the sugarcane juice, a fibrous residue from the sugarcane stalks remains.[12] Which we call SBA. SBA is a form of industrial waste that contains 50% cellulose, 25% hemicellulose, and 25% lignin.[13] These agricultural wastes pave the path to use as low-cost adsorbents which effectively reduce the cost of the process for reducing the wastewater contamination.[14] Bagasse from sugarcane exhibits biosorption characteristics. Bio absorption is a kind of adsorption that can be used to remove contaminants from biological materials that are not metabolically active.[7] The biosorption process has several advantages over traditional treatment methods, including cheap cost, high efficiency, reduced chemical use, no need for extra nutrients, biosorbent regeneration capacity, and metal recovery.[12] Sugarcane bagasse ash has a porous character due to its specific gravity, structure, and vesicular consistency.[15]

EXPERIMENTAL

Sample Collection

Samples were collected from the Cow milk plant (CMP) Kannauj, U.P. (India). After sample collection, the discharge rate of wastewater was also measured from the dairy plant's outlet. The flow rate of wastewater from the plant was measured by a differential pressure flow meter. The sample was collected in a sterile 5L container from the identified site. The container was washed with alcohol and distilled water and dried in a hot air oven for 15 minutes at 30ºCand was allowed to cool at room temperature. After sample collection, the cap of the container was tightly locked and placed below 4ºC to avoid any physicochemical change in the effluent.[16] An antibiotic (Chloramphenicol 500 mg/L) was added to the influent to inhibit bacterial growth and incubated for 3 days at room temperature (27ºC).[17]

Preparation of Rice Husk Ash

Rice husk ash was obtained from a local rice mill of Kannauj, Uttar Pradesh, India. It was washed with distilled water, dried for 2 hours at 60^0C, washed again with acetone and NaOH (0.3M) to remove dirt and other impurities, and then dried for 4 hours at 60^0C.[18] RHA was obtained by heating rice husk samples at 500^0C for 6 hours in a muffle furnace. Obtain RHA was grey in color because it was completely burned. The average particle size of RHA is 0.20mm and has a specific gravity of 2.10.[19]

Preparation of Sugarcane Bagasse Ash

Sugarcane was obtained from a mill in Sitapur, Uttar Pradesh, India. It was cleaned with distilled water to remove dirt and suspended impurities, then dried for 2 hours at 80°C, cooled, then washed again with acetone and distilled water to remove any remaining contaminants, and dried for 4 hours at 100°C to remove moisture. After drying, 250g bagasse was burned in a muffle furnace at 1200ºC for 5 hours to generate SBA.[20] The average particle size of SBA is 0.30mm, and the specific gravity is 1.95.[21]

Chemicals and Instrumentation

Analytical reagent grade (AR) chemicals were used in this study. Chemical oxygen demand (COD) was analyzed with COD Digestion Unit, KHERA KI-162, BOD by BOD Incubator KHERA KI-216, double beam UV–visible spectrophotometer (Systronics 2203), FTIR spectrophotometer (Perkin-Elmer RX1) as KBr pellets and pH by digital pH meter.

General Procedure

The adsorbent dosage for each batch of RHA and SBA was changed between 200mg/L to 1000mg/L at 27ºC for each experiment. In 1000 mL of dairy wastewater, the desired amount of adsorbent was added. At 27ºC, this mixture was shaken at a constant speed of 150 rpm in a temperature-controlled shaker for the necessary amount of time. At the end of the set time interval, the absorbent was filtered from treated water and Physicochemical parameters were analyzed.[18] For data consistency, all experiments were repeated twice. In all of the experiments, the standard deviations for duplicate experiments were less than 5%. The characteristics of the effluent and treated water are shown in Table-1. The percentage of removal was calculated using the following formula:

$$\% \text{ Removal Efficiency} = \frac{Ci - Ct}{Ci} x\ 100 \quad (1)$$

Where Ci is the initial concentration of waste water, Ct is after 't' time concentration.

RESULTS AND DISCUSSION

Characterization of Dairy Wastewater

Initial sets of experiments were performed with untreated dairy wastewater and obtained results of physicochemical parameters and percentage of removal were summarized in Table-1. The untreated wastewater was light grey in appearance with an unpleasant odor, after adsorbent treatment water was clear without odor. Some variation in color and odor of the effluent is due to the biosorption property of rice husk ash or bagasse ash, which plays an important role in the removal of impurities.

Characterization of Treated Dairy Wastewater

The experiments were carried out using two selected adsorbents RHA and SBA for the treatment process. The contact time of wastewater and adsorbent was taken as 12 hrs. The obtained values of the Physicochemical parameter of treated dairy wastewater are summarized in Table-1. RHA and SBA as adsorbents leads to the removal of total suspended solids and consequently in the color reduction[22]. The treated water was used for the characterization of the Physicochemical parameters. Results show that the color and value of other Physicochemical parameters of dairy effluent were changed. This change may be attributed to the biosorption of organic materials by the adsorbents.

Characterization of Adsorbents

The absorption bands for such adsorbent materials are usually broad and diffuse, according to IR spectra studies of rice husk ash and Sugarcane bagasse. It was determined which chemical groups matched the wavenumber of bands cm^{-1}. The Sugarcane bagasse has an OH group in cellulose (1261 cm^{-1}) and a presence of β-glycosidic linkage (910 cm^{-1}) in addition to the normal bands ester carbonyl (l730 cm^{-1}) groups, while in rice husk had (3400 cm^{-1}) OH groups, 2926 cm^{-1} (C-H groups), and 1641–1738 cm^{-1} (C = O) groups were observed.

Adsorbent Dosage

The experiments were done under Constant temperature (27°C), agitation speed (250 rpm), constant pH approximately 6.0, and varying adsorbent dosage (200, 400, 600, 800, and 1000 mg/L) were used. As seen in figure1, the percentage removal of parameters varies with adsorbent dosage. It was observed that as the dosage was increased the percentage of removal was also increased. The release of soluble organic molecules contained in plant products may be responsible for the growth in COD, BOD and other parameters value. In RHA, the percentage removal was fairly high, reaching 800 mg/L after 4 hours, whereas in SBA, it was only 600 mg/L. After that, up to 1000 mg/L, there was no more decline. It should be mentioned that trials were carried out for dosages of more than 1000 mg/L, yet adsorption and desorption did not change. Although these adsorbent materials are porous in nature, the porous volume is coupled with multiple minute pores, resulting in extra diffusion resistance and a reduction in removal.

pH

The pH of the effluent is an important parameter that determines the effectiveness of bioadsorption investigations. This affects not only the surface charge of the biosorbent, but also the type and concentration of organic molecules in effluent solution, as well as the degree of dissociation of functional groups in the active site of the adsorbent. The pH was changed between 6.6 and 7.81 in the range from acidic to strongly alkaline, while other parameters were maintained such as the dosage of the adsorbent from 200 mg/L to 1000 mg/L, temperature 27° C and rotation speed 250 revolutions per minute. Removals of organic components from the samples were increased with increasing pH. This shows that the removal of organic products is more effective at more than 7 pH. The adsorbent surface is negatively charged at higher pH values due to the dissociation of functional groups, while at lower pH values it has a net positive charge. The surface of the rice hulls and sugarcane bagasse ash protonate and become positive at low pH values, and the surface is linked by hydrogen ions, which represent the interactions between organic molecules and binding sites through attractive interactions.

Total Dissolve Solid

SBA has a higher total dissolved solid removal power (88.15%) than RHA (87.10%). The presence of organic and inorganic compounds in the effluent produces high amount of TDS. Water contains a large number of solids, as we all know. Both RHA and SBA have Oxygen atoms in various forms, each with a lone pair of electrons. Hardness is caused by the presence of cation in water. The interaction of these cations with the negative charge of adsorbents helps in the removal of TDS.

Turbidity

The removal efficiency of RHA and SBA were tested after 2hrs. and 4 hrs. of treatment by the filtration process. It was observed that after the addition of RHA and BSA, turbidity drastically changed with the increased amount of dosage as shown in Table-1. For the observation of turbidity, various amounts of adsorbents were used such as 200mg, 400mg, 600mg, 800mg,1000mg in 250mLof effluent at 6.37 pH which was the original pH of the effluent. The turbidity of RHA and SBA treated water was observed with different dosages and time and it was found that SBA treated water has more % removal efficiency (87.28%) with a dose 600mg at 7.52 pH after 4 h, while in RHA treated water % removal efficiency (80.21%) with dose 600mg at 7.1 pH after 4 h which was less than SBA. The Turbidity Removal Efficiency of sugarcane bagasse is high due to the presence of high-grade fibres and surface area, while in RHA physical adsorption occurs due to porous structure and surface area.[23-25]

COD

The COD of dairy wastewater samples treated with two different adsorbents RHA and SBA is calculated. It indicates a continuous removal of organic pollutants by adsorption on the surface of rice husk ash and sugarcane bagasse ash. Table-1 showed that the COD concentration decreased with adsorbent dosage. Equation-1 was used to compute the percentage of COD removed. Table-1 shows that the % removal increases gradually as the time and the dosage increase. It can be attributed to the fact that greater time (4 h) becomes available for the organic substances to stick with the adsorbent surface, as well as surface adsorption increases with dosage. At the 27°C, the maximum percentage removal in COD using RHA and SBA were found to be 89.12%, 83.17%, respectively. RHA was found to be highly efficient for removing organic pollutants from dairy wastewater. The percentage removal of 89.12% within 4h using a dose of 800mg/L was obtained at 7.4 pH.

BOD

Figure-1 shows the effect of adsorbent dose on the reduction of BOD. It may be seen that the % of BOD removal efficiency an increases with increase in the adsorbent dose up to some extent and thereafter for further increase in the adsorbent dose for 4 h contact time. The % removal of BOD was higher in the case of SBA(89.20%) followed by RHA(73.11%) due to their Physicochemical adsorption properties and high-grade fibers. The removal of BOD by SBA has sharply increased from 36.33% to 89.20% with an adsorbent dose from 200mg to 1000mg. However, with a further increase in the adsorbent dose, there was no appreciable increase in the BOD removal. Maximum BOD removal by SBA, RHA was found to be 89.20%, 73.11%, respectively with an adsorbent dose of 800mg/L. Hence SBA has great ability to remove the BOD of dairy wastewater.

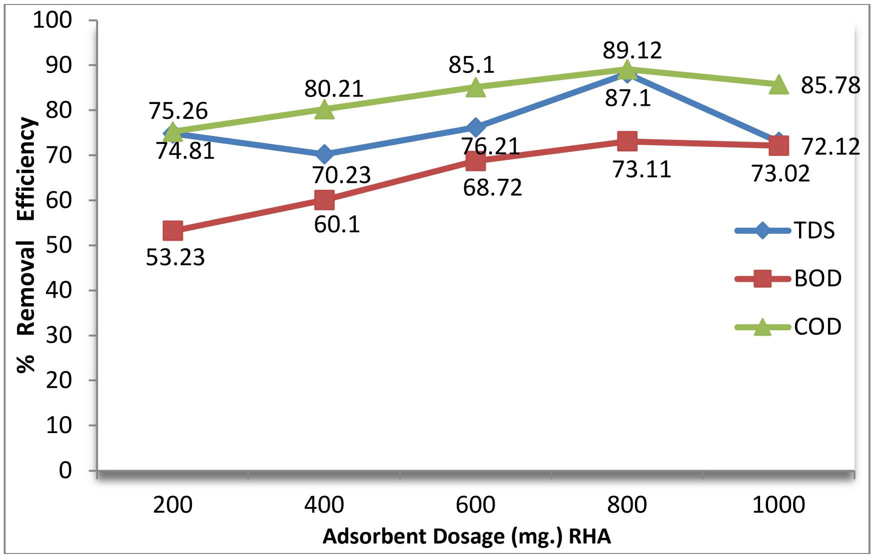

Fig.-1: % RHA's Removal Efficiency for BOD, COD, and TDS is measured in %

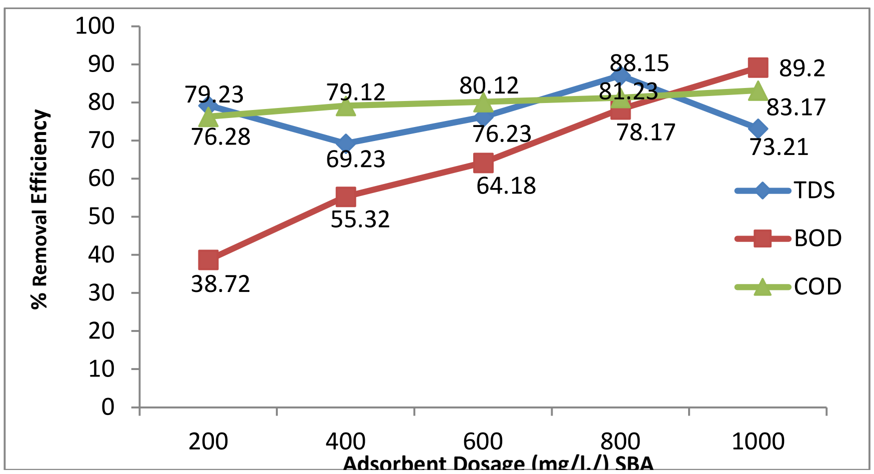

Fig.-2: SBA's Removal Efficiency for BOD, COD, and TDS is measured in %

Table-1: Analysis of Physicochemical Parameters of Dairy Effluent Control and after Treatment

Parameters		pH	Turbidity (NTU)	TDS (mg/L)	TSS (mg/L)	BOD3	COD
Control	Grey in Color	6.37 ± 0.08	1147.37 ± 1.12	1706.08 ± 0.80	736.24 ± 0.41	1093.24 ± 0.68	2318.59 ± 0.05
Doasage (mg.)	Time (Hrs.)	(RHA) Adsorbent + Effluent (Removal Efficiency in % Except pH)					
200mg.	2	6.6	68.84	71.23	72.1	48.66	70.19
	4	6.8	70.01	74.81	75.1	53.23	75.26
	6	6.8	70.1	74.81	76.12	53.2	75.21
400mg.	2	6.9	73.85	68.71	70.21	58.23	76.78
	4	7.1	77.25	70.23	74.23	60.1	80.21
	6	7.1	77.4	70.38	74.2	61.89	80.2
600mg.	2	6.9	79.32	73	76.18	63.28	82.32

	4	7.1	80.21	76.21	77.18	68.72	85.1
	6	7.1	80.21	76.78	77.2	69.21	86.21
800mg.	2	7.4	81.43	83	85.1	68.72	86.2
	4	7.4	81.56	87.15	90.2	73.11	89.12
	6	7.39	81.52	87.15	90.12	73.1	89.01
1000mg.	2	7.2	80.01	73.02	78.02	68.7	84.98
	4	7.3	79.56	73.02	79.18	72.12	85.78
	6	7.31	80.12	73.1	80.01	72.12	86.13
		(SBA) Adsorbent + Effluent (Removal efficiency in % Except pH)					
200mg.	2	7.81	73.21	79.93	72.18	36.33	75.98
	4	7.9	75.26	79.23	73.28	38.72	76.28
	6	7.89	75.32	80.1	73.25	37.85	77.21
400mg.	2	7.56	77.24	70.12	70.2	51.78	78.72
	4	7.71	79.58	69.23	74.23	55.32	79.12
	6	7.66	79.5	69.2	74.21	55.32	79.1
600mg.	2	7.48	74.51	76.2	75.23	64.21	76.48
	4	7.52	87.28	76.23	77.18	64.18	80.12
	6	7.5	86.32	74.52	77.21	64.19	80.11
800mg.	2	7.3	66.11	86.5	80.1	76.01	77.23
	4	7.37	65.72	88.15	82.12	78.17	81.23
	6	7.35	65.85	88.14	81.89	78.1	81.19
1000mg.	2	6.9	62.71	71.78	72.28	80.38	72.01
	4	7.1	62.12	73.21	78.31	89.2	83.17
	6	7.11	62.12	73.21	78.31	89.2	83.17

CONCLUSION

The results obtained after using the RHA and SBA adsorbent for the treatment of dairy wastewater showed certain points in this investigation. The results reveal that SBA and rice husk may be utilized efficiently as adsorbents for the treatment of dairy effluents, as they can remove up to 89.2% and 73.11% of BOD_3 respectively, using an adsorbent dose of 800 mg/L, pH 7.37-7.4 at 27°C. This treatment method can be a very cost-effective and efficient way to handle CMP wastewater. The results also suggest that it is the best treatment after filtering, as all of the specified parameters have been significantly reduced. The pH regulates the electrostatic interactions between adsorptive-adsorbent, which have a significant impact on the adsorption process.

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