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Removal Efficiency and Adsorption aspects of Sand & Bagasse for Residual Surfactant from Laundry Wastewater (LW)

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Abstract: ***Techno-economic, sustainable and eco-friendly approaches for removal of the residual surfactants from laundry wastewater (LW) had always been a prime necessity of environment especially for floral diversity. In the present study, river sand and bagasse were used as adsorbents for removal of residual surfactant from LW via adsorption. Anionic content of surfactant of LW (treated and untreated) was determined by hyamine solution. The effect of adsorbent size, mass of adsorbent and duration of adsorption on removal efficiency was studied. Results revealed that 90 micrometer (µm) particle size, 9 grams (g) adsorbent mass and 6 minutes duration for adsorption by sand as an adsorbent reflected 97.6% removal efficiency for surfactants from LW. On the other hand, 150 µm particle size showed 99.2% removal efficiency at 0.1 g adsorbent mass for 2 minutes duration of adsorption using bagasse as an adsorbent. The cementing aspects of treated LW were also investigated and it was found that treated LW by both adsorbents was superior in all the studied properties of cementing parameters. On comparison, bagasse was much better adsorbent with respect to quantity (mass of adsorbent) as well as duration of adsorption to remove residual surfactant from LW.***

Keywords: ***River sand, bagasse, laundry wastewater, adsorption, hyamine solution, normal consistency, compressive strength, setting time.***

I. INTRODUCTION

Normally laundry wastewater (LW) is composed of dirt, dust, lint, and grease along with complex structured anionic surfactants. Organic materials are degradable in nature but degradation of surfactants is difficult.[1-9] Therefore, evacuation of residual surfactants is required to maintain the sustainability of the nature. Numerous researches had applied various processes associated with aerobic and anaerobic degradation, biodegradation and sorption.[10-18] Adsorbents like activated carbon, silica gel, clay, soil, kaolinite, sand stone and rubber granules surface have been explored for the removal of anionic surfactant from the surfactant solution.[19-29]

In this project, authors have chosen easily available, environmental friendly, techno-economic and widely abundant ordinary sand and bagasse obtained from river and local sugar industry, as an adsorbent, respectively.

River sand is first and foremost composed of feldspar ($KAlSi_3O_8$ - $NaAlSi_3O_8$ - $CaAl_2Si_2O_8$), microcline ($KAlSi_3O_8$) and mica along with various other minerals in varying proportions (e.g. ≥99.3% SiO_2, ≤0.04% Fe_2O_3).

Sugarcane bagasse contains silica and carbon 9.78% and 90.22%, respectively.[30] Carbon is present in the sugarcane bagasse in the form of cellulose 45-55%, hemicelluloses 20-22.5%, lignin 18-24%, ash 1-4% and waxes <1%.[31]

II. MATERIALS AND METHODS

Materials

River sand was collected from construction site of Jaypee University of Engineering and Technology, Guna and bagasse was collected from local sugar industry situated in Janjali (Guna).

Hyamine solution (0.004M, LOBA CHEM), chloroform (SDFL), methylene blue (MERK), anhydrous sodium sulphate (SDFL), sulphuric acid (98% pure, MERK) were purchased for the experimental work.

For the physical test to study the cementing aspects 200 g of Portland Pozzolana Cement (PPC) and various types of standard sands were used like Grade 1: particle size; 1mm-2mm, Grade 2: particle size; 0.5mm-1.0mm, and Grade 3: particle size ;90µm-500 µm. The amount required for standard sand was 200 g of each type of grade every time.

Preparation of adsorbent

The sand was first sieved to remove larger particles and washed quite a few times with distilled water, followed by settling and decanting. The washed sand was dried at 104 ° C for 24 h in oven.

The bagasse was first passed through the ball mill to reduce larger particles to smaller particles and then ASTM series of sieves were applied to exclude undesired particle size (> 250 µm) of bagasse and washed quite a lot of times with distilled water, followed by filtration process with ordinary filter paper. The filtered bagasse was exposed to sunlight for 5h and then placed in oven for 2 h at 104°C.

Grain size analysis

Grain size analysis was done by sieve technique using the series of ASTM sieves. The ASTM Sieve series were used to collect various sizes (250 µm, 180 µm, 150 µm, and 90 µm) of sand and bagasse particles. The amount of sand used for sieve analysis was 20 kg of sand whereas 900 g was the quantity used for bagasse. The sand weight percent (w/w) analysis for 90 µm was 3%, for 150 µm 12%, for 180 µm 9%, and for 250 µm 14%.

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On the other hand, the bagasse weight percent analysis for 90 µm was 0.9%, for 150 µm 2.4%, for 180 µm 2.2%, and for 250 µm 6.1%. For 90 µm size bagasse particle, the weight percent was too low i.e. 0.9%. Therefore, in the case of bagasse as an adsorbent only three particle sizes i.e. 250, 180, 150 µm were used for adsorption.

$$\text{Weight percent(w/w)} = \frac{\text{Amount collected (g)}}{\text{Total weight taken (g)}} \times 100 \quad \text{….(1)}$$

Laundry wastewater (LW)

Laundry wastewater was collected from the laundry of Jaypee University of Engineering and Technology, Guna. Consumption aspects of surfactant (Tide powder, made by Procter & Gamble) are as 1 kg of surfactant dissolved in 250 L water for washing of 40 kg of cloth load. The sodium dodecyl sulphate (SDS) is the main anionic surfactant present in the Tide power. The percentage of active ingredient (SDS) present in Tide powder is 5 – 10%[32]. Structure of SDS is indicated in Fig.1.

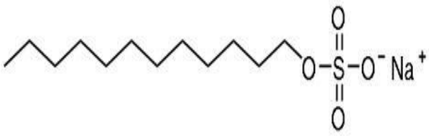

Fig.1. Structure of sodium dodecyl sulphate ($C_{12}H_{25}SO_4Na$)

Methods

Determination of anionic matter in LW

The anionic matter of LW was determined as per IS: 584 (Part II), 1964, pp 35 – 38.

Apparatus

Volumetric flasks: 1000, 500, and 250 mL

Graduated cylinder with stopper: 100 mL

Burette: 50 mL

Pipette: 10 mL

Reagents

Chloroform

Laundry wastewater

Standard Benzethonium Chloride (Hyamine) solution: Hyamine solution of 0.004 M procured from LOBA chemicals was further diluted to 0.0004 M. The structure of the Benzethonium Chloride is as follows (Fig.2):

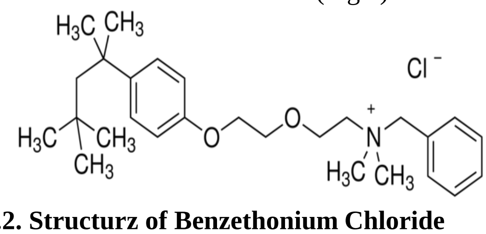

Fig.2. Structurz of Benzethonium Chloride ($C_{27}H_{24}ClNO_2$)

Methylene blue solution (0.005%): 0.05 g of methylene blue, 50 g of sodium sulphate and 6.8 mL of sulfuric acid (H_2SO_4) were dissolved in 1000 mL of volumetric flask and the solution was made up to volume of 1 litre with distilled water.

Procedure

Determination of anionic matter in LW: Pipette 10 mL of LW and transferred into 100 mL graduated cylinder provided with a glass stopper. Add 15 mL of chloroform and 25 mL of methylene blue reagents to the cylinder and shake well. The chloroform layer shall colored blue.

Benzethonium chloride solution was slowly added from the burette, initially in portion of 0.2 mL. After each addition, the cylinder was stoppered and allowed the phases to separate. Initially, the chloroform phase was blue in color. Towards the end point the color would start migrating to the aqueous layer. Reading was noted when the color intensity in both the phases was the same when viewed under standard conditions of light.

Calculation

$$\text{Anionic active matter percent by mass} = \frac{V1 * 288.38 * T2 * 5}{w} \times 100 \quad \text{….. (2)}$$

Where,

V_1 = Volume of hyamine solution used in the titration (mL)

T_2 = Molarity of hyamine solution (0.0004 M)

W = mass of Tide powder (2.0 g)

III. EXPERIMENTAL

For the optimization of mass of an adsorbent and to study the effect of time on removal efficiency experimental works were classified in following heads:

Optimization of mass of an adsorbent

The various amounts of sand with respect to their particle size and 100 mL of LW were introduced in 250 mL of Erlenmeyer flask and then kept over the magnetic stirrer (Manufactured by Remi Equipments Pvt. Ltd.). Batch process was applied for 10 minutes at maximum speed (rpm) of magnetic stirrer to optimize the mass of various particle sized adsorbent. After 10 minutes, treated LW was passed through ordinary filter paper. The filtrate treated LW was titrated against the hyamine solution to calculate removal efficiency.

Optimization of duration of adsorption

The optimized amount of sand with respect to their particle size and 100 mL of LW were introduced in 250 mL of Erlenmeyer flask and then kept over the magnetic stirrer with maximum agitation speed. At each one minute interval, samples taken from Erlenmeyer flask were passed through ordinary filter paper. The filtrate treated LW was titrated against the hyamine solution to calculate removal efficiency by applying Equation 2.

Evaluation of removal efficiencies

The removal efficiency was calculated from the following expression,

$$\eta_R = \frac{C_0 - C_f}{C_0} \times 100 \quad \text{…. (3)}$$

Where,

η_R = removal efficiency of anionic surfactant from the laundry wastewater

C_0 = initial concentration of anionic surfactant in the laundry wastewater

C_f = final concentration of anionic surfactant in the laundry wastewater after adsorption process.

IV. RESULTS AND DISCUSSION

Four different particle sizes viz. 250, 180, 150, and 90 µm were studied for sand as an adsorbent. But in the case of bagasse as an adsorbent only three particle size were studied 250, 180, and 150 µm, respectively. In the case of bagasse sieve analysis aspect for 90 µm size was very poor (already mentioned in materials and methods 2.1.2 Grain size analysis).

Effect of adsorbent (sand and bagasse) masses for various particle size and its removal efficiency

The quantity of adsorbent plays an important role in the adsorption and simultaneously enhancing the removal efficiency of used adsorbent. Therefore, an extensive study has been carried out to establish a correlation between mass of adsorbent and its removal efficiency. The removal efficiency of various particle size of sand as an adsorbent indicated in Fig.3.

On perusal of Fig.3, it is indicated that decrease in the particle size increases the removal efficiency and the maximum removal efficiency observed was 97.6% for 90 µm size sand particle and 8g mass of the adsorbent. With increase in particle size to 250 µm, the maximum surfactant removal took place when 12 g of sand was used and removal efficiency was found to be 73.9%. In the case 180 µm size sand particle, removal efficiency increased as compared to 250 µm size and amounted to 95.8% but mass of the adsorbent was only 10 g as compared to 12 g used in case of 250 µm size particle.

The correlation of removal efficiency and adsorbent mass for bagasse are depicted in Fig.4. The results indicated that decrease in the particle size increases the removal efficiency and the maximum removal efficiency observed was 99.2% for 150 µm size bagasse particle and mass of the adsorbent was 0.1 g. When particle size was 250 µm then maximum surfactant removal took place when 0.3 g of bagasse was used and removal efficiency was 99.2%. In the case 180 µm size sand particle, removal efficiency increased to 99.2%as compared to 250 µm size but mass of the adsorbent was only 0.2 g as compared to 0.3 g used in case of 250 µm size particle.

When sand particle size was 150 µm then 9 g of sand had shown 96.7% removal efficiency. Maximum removal efficiency was observed in the case of minimum particle size (90 µm) with only 8 g mass of adsorbent i.e. sand. The reason for maximum removal efficiency for smallest size particle could be largest surface area available when particle size was smallest. In all these experiments volume of LW was 100 mL and the duration of adsorption was 10 minutes. When bagasse particle size was 150 µm then 0.1 g of sand had shown 99.2% removal efficiency. Maximum removal efficiency was observed in the case of minimum part1icle size (150 µm) with only 0.1 g mass of adsorbent i.e. bagasse. The reason for maximum removal efficiency for smallest size particle could be largest surface area available when particle size is smallest.[33]

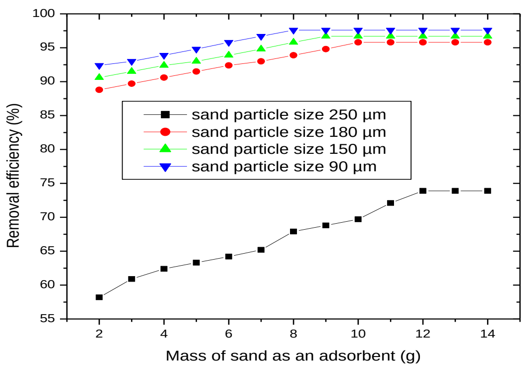

Fig.3 Effect of mass of sand as an adsorbent with respect to their adsorbent particle size on removal efficiency

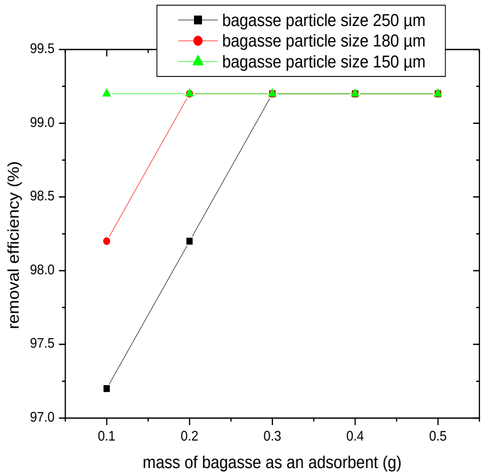

Fig.4 Effect of mass of bagasse as an adsorbent with respect to their adsorbent particle size on removal efficiency

Effect of duration of adsorption to enhance removal efficiencies

Duration of adsorption (time provided to adsorb surfactant molecules on adsorbent) is second important parameter to enhance removal efficiencies. Various durations (measured in minutes) were studied for both the adsorbents for various particle sizes. A general trend had observed that on increase of duration there is an enhancement in the removal efficiencies had noticed up to certain duration. Results of experiments had indicated that 12 g is optimized amount of sand for 250 µm, 10 g is for 180 µm, 9 g and 8 g is for 150 µm and 90 µm. The optimization of duration of adsorption for sand for all particle size with optimized quantity of mass was studied and results are depicted in Fig.7.

The results of Fig.5 reflect that, for 250 µm size and optimized 12 g quantity, ten different durations were studied. Maximum efficiency i.e. 73.9% required 10 minutes of duration for adsorption. The 180 µm size sand with 10 g quantity, 95.6% removal efficiency was observed when duration was 8 minutes. When particle size was 150 µm with optimized mass 9 g, the removal efficiency was found maximum for 6 min duration with a removal efficiency of 96.7%. On the other hand, highest removal efficiency and lowest duration of adsorption was observed at 5 minutes for sand. Analytical approach to the results clearly indicated that smallest size particle i.e. 90 µm size for sand showed highest removal efficiency with lowest duration of adsorption i.e. 5 minutes. The reason of highest removal efficiency with lowest duration for smallest particle size is again maximum surface area availability which could enhance the removal efficiency in the short duration of time.

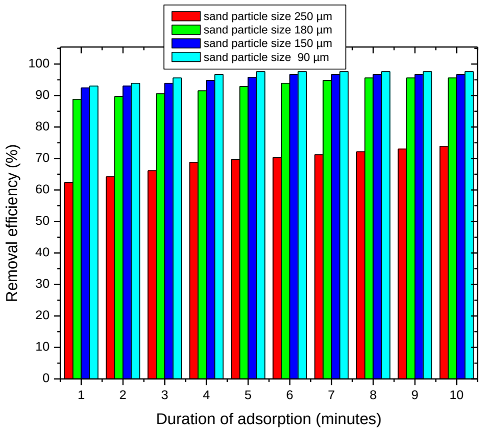

Fig.5 Effect of duration on removal efficiency for various particle size of sand

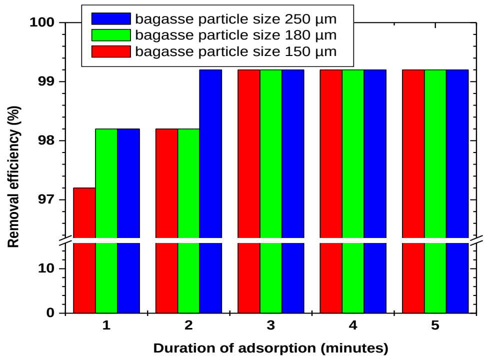

Fig.6 Effect of duration on removal efficiency for various particle size of bagasse

Three particle sizes for bagasse were also studied for optimization of lowest duration required for highest removal efficiency. The optimization of duration of adsorption for bagasse for all particle size with optimized quantity of mass was studied and results are depicted in Fig.6.

For 250 µm size and optimized 0.3 g quantity, five different durations were studied. Maximum efficiency i.e. 99.2% required 10 minutes of duration for adsorption. The 180 µm size bagasse with 0.2 g quantity, 99.2% removal efficiency was observed when duration was 2 minutes. When particle size was 150 µm with optimized mass of 0.1 g, the removal efficiency was found maximum for 2 min duration with removal i.e 99.2%. On the other hand, highest removal efficiency and lowest duration of adsorption was 2 minutes. Bar graph illustration of Fig.8 clearly indicated that smallest size particle i.e. bagasse with 150 µm size showed highest removal efficiency with lowest duration of adsorption i.e. 2 minutes. The reason of highest removal efficiency with lowest duration for smallest particle size is again maximum surface area availability of small size that could enhance the removal efficiency in the short duration of time.

Performance evaluation of treated LW by sand and bagasse as an adsorbents

The performance evaluation of treated water has been studied for same particle size for both the adsorbent i.e. 150 µm. The comparison of NC, compressive strength, and setting time has been carried out with water because it is normally used for physical test determination of cement. The physical test viz. NC, compressive strength, and setting time essential for cementing aspects were studied as per BIS specification 4031. For NC, compressive strength and setting time, the room temperature was 27 ± 2°C and relative humidity was maintained at 65 ± 5%.

TABLE 1- The performance evaluation of Treated LW for both adsorbents for cementing aspects

Conditions:
Temperature: 27 ± 2°C
Relative humidity: 65 ± 5%

Sr No.	Physical properties of cement		Ordinary water	LW with sand LTWS)	LW with bagasse (LTWB)
1	NC* (%)		32.0	32.5	31.2
2	Compressive* strength (MPa)	3rd day	19.9	23.8	23.8
		14th day	32.9	30.1	30.1
		28th day	39.6	39.8	39.8
3	Setting time* (minutes)	Initial	210	205	210
		Final	270	280	285

*All the values of physical evaluations are as per Indian Standards.

Mathematical data given in TABLE 1 indicates that for determination of NC by using tap water is 32% whereas for sand treated LW it is 32.5%. Whereas, NC value for bagasse treated LW is little lower i.e. 31.2% as compared to tap water NC value.

Compressive strength is the main physical property of cementing aspects of cement. As per the Indian slandered 3rd day compressive strength is important and its good value is 16.31 MPa. In the present study, it was 19.9 MPa for ordinary water (water used for construction aspects) and 23.8 MPa for both the adsorbents treated LW i.e. laundry treated water by sand (LTWS) and laundry treated water by bagasse (LTWB). Compressive strength for 14th day and 28th day were also studied and found quite promising on comparison with tap water values. Setting time is also an important parameter for constriction and cementing of cement.

In the case of both the adsorbents setting time is also as per the value suggested by Indian cement standards.

Setting time determination indicated that the values obtained for LTWS and LTWB are quite matching with the values obtained for ordinary water alone.

V. CONCLUSIONS

Removal of residual surfactant from laundry wastewater is a very important issue from the point of view for environmentalists and wastewater treatment. Various authors had suggested different techniques viz. electrocoagulation – electroflotation and physico-chemical adsorption. The conclusions of the present research are as follows:

- Two adsorbents viz. sand and bagasse have been assessed for adsorption of residual surfactant from LW. Out of two adsorbents, bagasse was found remarkably superior with respect to mass of adsorbent and duration of adsorption.
- Bagasse of 150 µm particle size, 0.1 g of quantity and 10 minutes of adsorption duration showed 99.2% removal efficiency.

On the other hand, sand of 90 µm particle size, 8 g of quantity and 10 min of duration showed 97.6% removal efficiency. Therefore, 150 µm size of bagasse as an adsorbent showed maximum efficiency.

- On the basis of duration required for adsorption, bagasse was found more promising as compared to sand. Highest removal efficiency i.e 99.2% was observed for 150 µm size, 0.1 g quantity, and 2 minutes of duration.
- Adsorption by sand was found maximum with removal efficiency of 97.6% for 90 µm sizes, 8 g adsorbent mass at 5 minutes of duration.
- Sand treated LW when studied for physical properties of cement with comparison to ordinary water was found almost equal in all respects.

Identical studies were carried out for bagasse treated LW and comparison has been made for all physical properties like NC, compressive strength, and setting time which were quite identical with the results of ordinary water.

On the basis of present study, bagasse as an adsorbent was found to be much superior with respect to quantity (mass of adsorbent) as well as duration of adsorption to remove residual surfactant from LW.

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