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Research Article

Performance Evaluation and Effectiveness of Different Natural Bio-adsorbents for Wastewater Treatment

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Abstract

Augmentation of environmental pollution load for Swift industrialization in leather sector of Bangladesh is a major concerned issue in order to maintain the sterility of environmental water body. The direct discharge of toxic tanning industry wastewater into the environment causes irreversible threat to the aquatic life as well as human existence. Various high cost physio-chemical processes are available to treat these pollution load to ensure environmental sustainability and living which are difficult to afford for small or medium scale tanning industry. In this case, Bio-adsorption is an eco-friendly and effective treatment process due to the high availability of natural bio-adsorbent. From this point of view, the paper highlights the use of natural bio-adsorbent for tanning industry wastewater treatment and a comparative study to determine the percentage removal of suspended solids (SS), dissolved solids (DS) and turbidity. In that regard, banana peel, sugarcane bagasse and orange peel were used as natural bio-adsorbents. The methodology of this process was initiated with mixing of wastewater from different section of beam house operations (Soaking, Liming, Deliming and Bating, Chrome tanning) in tanning industry at definite ratio. The mixer takes nearly six hours to settle down. After sedimentation, the turbidity reduces to a reasonable amount from 4780.0 NTU to 1150.0 NTU. After that, the supernatant was taken for further treatment by using three different natural bio-adsorbents on the basis of amount, contact time and pH. The determined data for the percentage removal of different parameters like suspended solids, dissolved solids and turbidity for banana peel were 65.71%, 25.91%, 85.65%, for sugarcane bagasse were 62.02%, 24.05%, 86.07% and for orange peel were 64.03%, 20.73%, 85.48% respectively in optimum condition. The DO level increased to 5.89 mg/L for banana peel, 5.89 mg/L for sugarcane bagasse and 5.40 mg/L for the orange peel at 35.2°C from 0.22 mg/L at 35.2°C in raw sample. After comparing the performance of three natural bio-adsorbents, it was found that the removal efficiency of banana peel was better than other two bio-adsorbents.

Keywords: *Bio-adsorbent, banana peel, sugarcane bagasse, orange peel, sedimentation, pollution load.*

1. Introduction

The rapid growth of the leather sector in Bangladesh highlights itself a potential sector for investment. It is also one of the oldest industries in Bangladesh and plays a significant role in the national economy with a good worldwide reputation. This sector earning around $1.29 billion in 2013-14 fiscal year which representing around 4.2 percent of the country's total export income (Juel, *et al*, 2016). But this kind of investment potential sector is associated with burden in terms of environmental issues and for this reason, this sector is the major concern of focusing. There are reportedly around 220 tanneries in Bangladesh but in fact, only 113 tanneries are active in operation (Paul, *et al*, 2013).According to the Department of Environment, around 85000 tons of raw materials are processed daily in tanneries and 20000 m^3 of highly polluted tannery wastewater is directly discharged into the environment without any treatment (Human Rights Watch, 2012).

Wastewater generates from tanneries in the range of 30 - 35 L/kg skin or hide processed with variable pH and high concentrations of solids (Manivasagan, *et al*, 2011). This wastewater contained a high level of BOD, COD, suspended solids, dissolved solids, sulfide, chloride and chromium etc. The direct disposal of untreated tannery effluents into the water bodies or into the open lands without any treatment causes irreversible damage to the environment (Karim, *et al*, 2012). Due to the complex and variable nature of tannery effluents, different types of physio-chemical process are considered for the treatment of tanning industry wastewater. Coagulation, flocculation, ozonation, reverse osmosis and ion exchange are the widely used conventional processes (Chowdhury, *et al*, 2013).

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The process of separation and individual treatment of wastewater demands excessive cost, which is very difficult to afford for small or medium level tanning industry (Ram, *et al*, 1999). In sum, all of these conventional methods have some concerning disadvantages such as incomplete ion removal, production of toxic sludge or other waste products which consequentially demand further safe disposal (Reza, *et al*, 2011). As a result, this situation leads to an intensive search for the best available effective technology that can be implemented for the treatment of tanning industry wastewater. On the contrary, bio-adsorption is the widely used treatment process for the removal of both organic and inorganic compounds as well as heavy metals (Reza, *et al*, 2011).

Basically, bio-adsorption is the capacity conferred by the biological materials to aggrandize the solids as well as heavy metals from wastewater through the physio-chemical process (Hossain, *et al*, 2012). The process of adsorption arises due to the presence of unbalanced or residual forces at the surface of the liquid or solid phase. These unbalanced residual forces have a tendency to attract and retain the molecular species with which it comes in contact with the surface. Adsorption is essentially a surface phenomenon. The main noticing point of bio-adsorption is that it offers the system of energy saving in the form of a more efficient wastewater treatment system operating for fewer hours. Furthermore, it is attractive in terms of economy due to the inexpensive and widely available of waste biomass (Prabu, *et al*, 2012). In addition, fully operational bio-adsorption process requires the biological materials which have high metal binding capabilities and specific heavy metal selectivity and offers the minimization of chemical and biological sludge without any additional nutrients (Singhal, *et al*, 2014).

In the last few years, a great number of publications have been published in search of adsorption technique with different types of low-cost materials for industrial wastewater treatment (Reza, *et al*, 2011). A wide variety of bio-adsorbents has been used for the wastewater treatment namely as rice straw, banana peel, orange peel, wood and bark, tea-waste, maize-corn cob, sugarcane bagasse, tamarind hull, sawdust, rice husk (Abbasi, *et al*, 2013). Out of the wide range of adsorbents, the aim of this research work was to conduct the laboratory batch experiment in order to find out the removal capacities of solids as well as turbidity by using banana peel, sugarcane bagasse and orange peel on the basis of optimum conditions like amount of adsorbent, effect of contact time and pH. A comparison was also studied between three of these adsorbents to highlight the removal efficiency of suspended solids, dissolved solids and turbidity.

2. Materials and Methods

2.1 Collection of wastewater

Wastewater samples were collected from a renowned tanning industry nearby KUET campus. Wastewater from different sections of beamhouse operations i.e. soaking, liming, deliming & bating, chrome tanning was collected.

2.2 Sedimentation of suspended and insoluble materials

In this stage, samples were mixed in a beaker with a definite ratio 2:1:1:1 of different waste liquors i.e. soaking, liming, deliming-bating and chrome liquor. They were agitated properly to mix up well and kept for 6 hours for significant settling. A continuous study represents that approximately 700 mL supernatant liquid was collected from the 1000 mL beaker, where 300 mL was liquid & suspended mixture (Sludge). By considering the settled sample as raw, different environmental parameters of the raw sample were measured.

Table 1. Environmental parameters of the raw sample after sedimentation

Sl. No.	Parameters	After Sedimentation
01	Turbidity (NTU)	1150
02	TDS (mg/L)	15630.00
03	SS (mg/L)	9480.00
04	Conductivity (mS/m)	35.6
05	COD (mg/L)	28,800
06	Salinity (ppt.)	21.6
07	DO (mg/L)	2.79
08	pH	9.6

2.3 Collection of natural bio-adsorbent

Three types of natural adsorbent were used for batch experiments such as banana peel, sugarcane bagasse and orange peel. Banana peel was collected from the tea shop situated within the KUET campus. Bagasse was collected from a temporary local juice store at Fulbarigate in Khulna. Orange peel was collected from Dr. M. A. Rashid Hall dining at KUET.

2.4 Preparation of banana peel

The collected banana peel was cut into small pieces and washed with tap water. After that, sugarcane bagasse was imbued in 0.1 M HCl solution for 24 hours to remove external dirt and other coloring contaminants. The wetted banana peel was then kept into the air for removing the water from the surface and dried in the oven at 105°C for 24 hours. The dried banana peel was grounded into powder and kept in an air tighter container for further experimental uses.

2.5 Preparation of sugarcane bagasse

Collected Sugarcane Bagasse was cut into small pieces and washed with tap water. After that, sugarcane bagasse was soaked in 0.1 M HCl solution for 24 hours similar to the banana peel preparation in order to ensure the complete removal of dirt, lignin and coloring components. Then, the Bagasse was dried in the oven at 120~130°C for 24 hours and further triturated using a mortar until uniform size particle was obtained. Then, the material obtained was packed in a container and labeled.

2.6 Preparation of orange peel

Small pieces of orange peel were soaked in 0.1 M HCl solution for 24 hours to remove the contaminants. After that, the Bagasse was dried in the oven at 105°C for 24 hours. Then dried Orange peel was grounded into powder and kept in an air tied bottle for experimental uses.

2.7 Working procedure for different bio-adsorbents based on the amount

Batch experiments for pollutant removal were conducted based on the different amounts of selected adsorbents where different amount shows different percentage of absorbance. The supernatant from settling of the raw sample was treated by using the various amount of bio-adsorbents. For this purpose, 3 beakers of 50 mL were taken. Then the beakers were washed and conditioned properly in the oven. After that, these beakers were tagged as 1 for the banana peel, 2 for sugarcane bagasse and 3 for orange peel by using masking tape. The amount of sample in each beaker was taken 50 mL. Then 0.3 g of these three bio-adsorbents was taken in 1, 2 and 3 no tagged beaker. After that, bio-adsorbent was mixed with the sample at each beaker by stirrer for 30 min. After 4 hours turbidity was measured by collecting the supernatant through using turbidity meter. In this regard, 10 mL of supernatant was taken from each beaker and filtered through Whatman filter paper grade 1. Before filtration initial weight of filter papers and crucibles were taken. After filtration, filter papers and crucibles were dried in the oven and weighted again. Suspended solids (SS) and dissolved solids (DS) were calculated from the difference between two weights of filter papers and crucibles. Then, same procedure was followed for rest of the amounts i.e. 0.4 g, 0.5 g, 0.6 g and 0.7 g.

2.8 Working procedure for different bio-adsorbents based on contact time

After selecting the optimum amount of bio-adsorbent, the optimum time requirement for the treatment process is important to find out. For this purpose, 3 beakers of 50 mL were taken and prepared according to the previous process. After the preparation of beaker, the optimum amount of bio-adsorbent i.e. 0.3 g was selected and used for the study. Then bio-adsorbent was mixed with the sample of each beaker by stirring for 30 min and left the sample for several hours, for example 1 hour, 1.5 hours, 2 hours, 2.5 hours, 3 hours, 3.5 hours for treatment. Then turbidity, suspended solids (SS) and dissolved solids (DS) were measured by following the previous process.

2.9 Working procedure for different bio-adsorbents based on pH

This working process was also similar to the previous experiment for determining the optimum amount and contact time. At this stage the amount of bio-adsorbent and contact time were selected as 0.3 g and 2 hours respectively. For adjusting the pH, nitric acid and caustic soda were used. Then the process was continued at different pH 4, 5, 6, 7 and 8 respectively by following the similar procedure.

3. Results and discussion

3.1 Adsorption experiments for process optimization

3.1.1 Effect of the amount of bio-adsorbent for adsorption

The amount of bio-adsorbent has a great effect on wastewater treatment. The percentage of removal increases with the increase in amount until the saturation of the solution. Here, the number of adsorbent particles surrounding the metal ions or the ratio of adsorbent particles to metal ions increases simultaneously with the increase of adsorbents. Therefore, these particles attach more ions to their surfaces. Increase in adsorption with adsorbent dose can be attributed to increase adsorbent surface area and availability of more adsorption sites (Cay, *et al*, 2004).

3.1.2 Effect of the amount of bio-adsorbent on the removal of suspended solids

Here figure 1 shows the graphical representation of percentage removal of suspended solids.

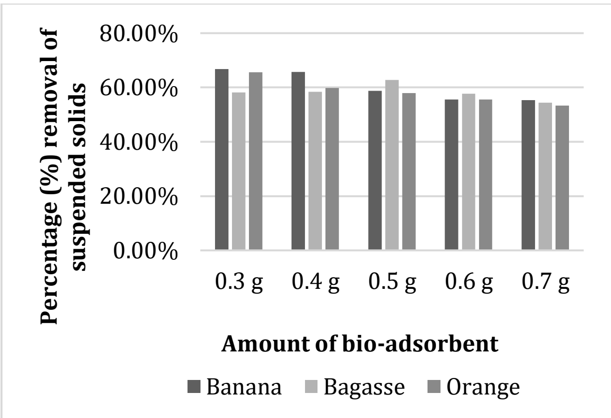

Fig.1 Amount of bio-adsorbent vs. percentage (%) removal of suspended solids

From the above graph, it is observed that maximum removal of suspended solids was achieved with 66.7% by banana peel and 65.60% by orange peel for the amount of 0.3 g whereas maximum removal of suspended solids was achieved with 62.70% by sugarcane bagasse for the amount of 0.5 g.

3.1.3 Effect of the amount of adsorbent for the removal of dissolved solids

Here figure 2 shows the graphical representation of percentage removal of dissolved solids.

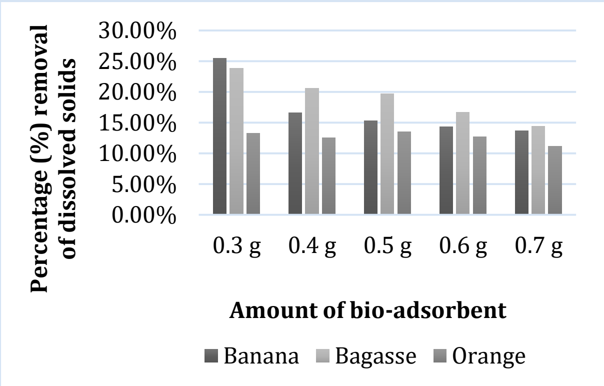

Fig. 2 Amount of adsorbent vs. percentage (%) removal of dissolved solids

From the above graph, it is observed that maximum removal of dissolved solids was achieved with 25.50% by banana peel and 23.86% by sugarcane bagasse for the amount of 0.3 g, on the other hand, maximum removal of dissolved solids was achieved with 13.53% by orange peel for the amount of 0.5 g.

3.1.4 Effect of amount of bio-adsorbent for the removal of turbidity

Here figure 3 shows the graphical representation of percentage removal of turbidity.

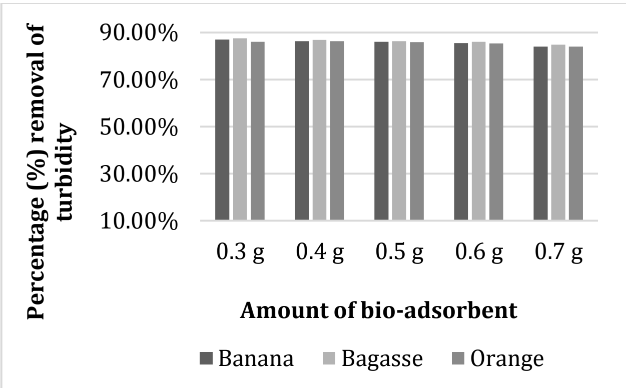

Fig. 3 Amount of adsorbent vs. percentage (%) removal of turbidity

From the above graph, it is observed that maximum removal of turbidity was achieved with 86.95%, 87.48% and 86.06% respectively by banana peel, bagasse and orange peel for the amount of 0.3 g.

From the observation of the above three graphs, it is found that maximum removal of suspended solids, turbidity and dissolved solids were achieved by banana peel, bagasse and orange peel for the amount of 0.3 g. So 0.3 g was considered as optimum amount for adsorption with bio-adsorbent.

3.2 Effect of contact time for adsorption

The number of sites on the surface are very large which allows adsorption to take place very easily. But with the passage of time, the active sites get saturated thereby reducing the rate at which adsorption occurs (Mall, *et al*, 2005).

3.2.1 Effect of the contact time for suspended solids removal

Here figure 4 shows the graphical representation of percentage removal of suspended solids.

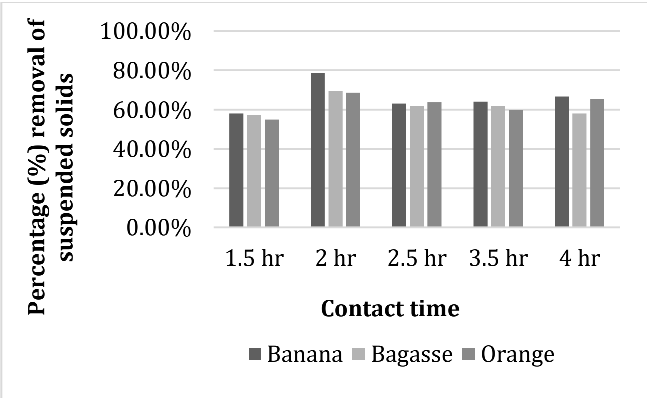

Fig. 4 Time vs. percentage (%) removal of suspended solids

From the above graph, it is observed that maximum removal of suspended solids was achieved at 78.58%, 69.40% and 68.67% respectively by banana peel, sugarcane bagasse and orange peel for 2 hours time period.

3.2.2 Effect of the contact time for dissolved solids removal

Here figure 5 shows the graphical representation of percentage removal of dissolved solids.

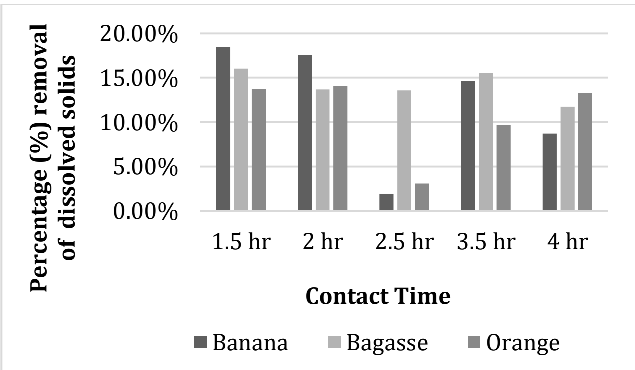

Fig. 5 Time vs. percentage (%) removal of dissolved solids

From the above graph, it is observed that maximum removal of dissolved solids was achieved with 18.43% and 16.02% by banana peel and sugarcane bagasse respectively for 1.5 hours time period but maximum removal of dissolved solids was achieved with 14.08% by orange peel for 2 hours time period.

3.2.3 Effect of the contact time for turbidity removal

Here figure 6 shows the graphical representation of percentage removal of turbidity.

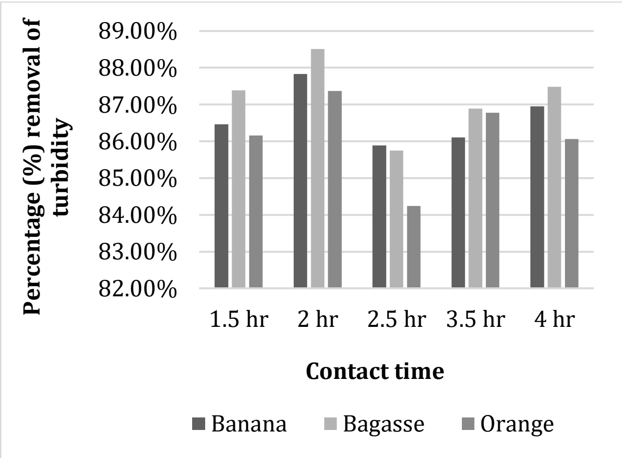

Fig. 6 Time vs. percentage (%) removal of turbidity

From the above graph, it is observed that maximum removal of turbidity was achieved at 87.83%, 88.51% and 87.37% respectively by banana peel, sugarcane bagasse and orange peel for the time of 2 hours.

From the observation of the above three graphs, it is found that maximum removal of suspended solids, turbidity and dissolved solids were achieved by banana peel, bagasse and orange peel for the time of 2 hours. So, 2 hours time for adsorption with bio-adsorbent was considered.

3.3 Effect of pH for adsorption

pH is one of the most important parameters which controls the surface properties of adsorbents, functional groups and ionic state of metal's species. The adsorption capacities of solid waste from water into bio-adsorbent were strongly affected by the pH (Hossain, *et al*, 2012).

3.3.1 Effect of pH for suspended solids removal

Here figure 7 shows the graphical representation of percentage removal of suspended solids.

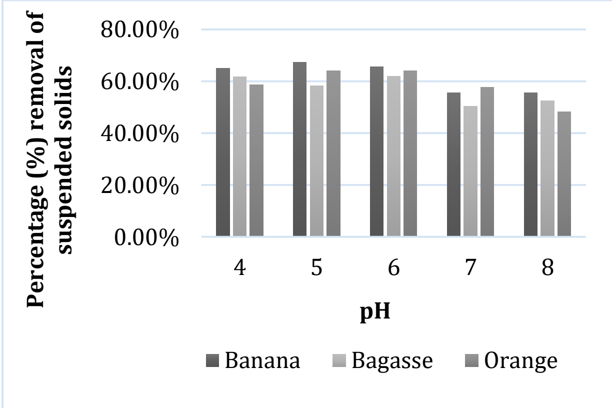

Fig. 7 pH vs. percentage (%) removal of suspended solids

From the above graph, it is observed that maximum removal of suspended solids was achieved with 67.29% by banana peel for pH 5. Maximum removal of suspended solids was achieved 62.02% and 64.03%% by bagasse and orange peel for pH 6.

3.3.2 Effect of pH for dissolved solids removal

Here figure 8 shows the graphical representation of dissolved solid removal percentage.

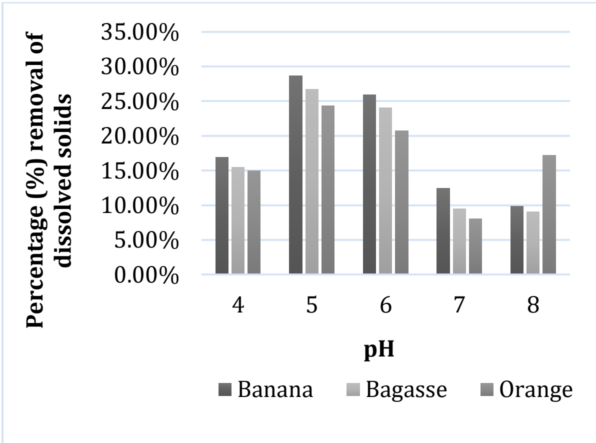

Fig. 8 pH vs. percentage (%) removal of dissolved solids

From the above graph, it is observed that maximum removal of turbidity was achieved at 28.68%, 26.71% and 24.30% by banana peel, bagasse and orange peel for pH 5. But the removal of turbidity for pH 6 was achieved at 25.91%, 24.05%, and 20.73% by banana peel, bagasse and orange peel which are nearby the percentage of pH 5.

3.3.3 Effect of pH for turbidity removal

Here figure 9 shows the graphical representation of turbidity removal percentage.

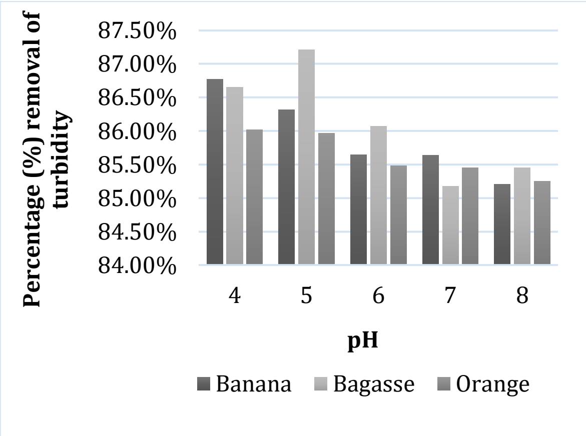

Fig. 9 pH vs. percentage (%) removal of turbidity

From the above graph, it is observed that maximum removal of turbidity was achieved at 86.32%, 87.21% and 85.97% by banana peel, bagasse and orange peel for pH 5. But the removal of turbidity for pH 6 was achieved at 85.65%, 86.07%, and 85.48% by banana peel, bagasse and orange peel which is nearby the percentage of pH 5.

From the observation of the above three graphs, it is found that maximum removal of suspended solids, turbidity and dissolved solids were achieved by banana peel, bagasse and orange peel for pH 5. So, pH 5 for adsorption with bio-adsorbent was optimized. But the percentage of removal of suspended solids, turbidity and dissolved solids were achieved by banana peel, bagasse and orange peel for pH 6 is nearby the percentage of pH 5. High amount of acid will be needed to reduce the pH from 8-9 to 5 of the solvent, in this regard, costing will be high. On the other hand, acid requirement for pH 6 is less. So, pH 6 was considered.

3.4 Comparison of removal performance between three bio-adsorbent based on optimum parameters

From the above study, it is found that the optimum amount, time and pH are 0.3 g, 2 hours and pH 6 respectively. Based on this parameter the data are given below:

Table 2. SS, DS and turbidity removal percentage by using adsorbents

Name of bio-adsorbent	Suspended Solids (SS)	Dissolved Solids (DS)	Turbidity
Banana peel	65.71%	25.91%	85.65%
Bagasse	62.02%	24.05%	86.07%
Orange peel	64.03%	20.73%	85.48%

From the table stated above, it is observed that the optimized conditions for all three bio-adsorbents are adsorbent mass 0.3 g 50 mL^{-1}, contact time 2 hours and pH 6. The Banana peel found to be comparatively more efficient with the highest percentage removal of suspended solids and dissolved solid and that are 65.71% and 25.91% respectively compared to the Bagasse and Orange peels where the percentage removal of suspended solids and dissolved solid are found to be 62.02%, 24.05% and 64.03%, 20.73%. This is due to the presence of hydroxyl groups and carboxyl functions present on pectin substances of banana peel (Thirumavalavan, *et al*, 2010). It is observed that among three adsorbent banana peel is most effective to use as bio-adsorbent. Percentage reduction of turbidity was also good and that was 85.65%, 86.07% and 85.48% respectively for Banana peel, Bagasse and Orange peel.

3.5 Comparison of environmental parameters of wastewater before treatment and after treatment

Here the table 3 representing a comparison among different environmental parameters of raw water, after sedimentation and after treatment.

Table 3. Comparison of environmental parameters

Parameters	Raw Sample	After Sedimentation	After Treatment		
			Banana	Bagasse	Orange
Turbidity (NTU)	4780	1150	150	144	175
TDS (mg/L)	41200	15630	24300	23600	16010
SS (mg/L)	15180	9480	3150	3970	2502
Conductivity (mS/m)	58.8	35.6	34.36	35.05	35.01
COD (mg/L)	3200	28800	19,200	25,600	22,400
Salinity (ppt.)	44.1	21.6	25.90	24.20	21
DO (mg/L)	0.22	2.79	5.89	5.89	5.40
pH	11.2	9.6	7.12	7.30	7.58

Conclusions

In this research work, the percentage removal of suspended solids, dissolved solids and turbidity from tanning industry wastewater was carried out by the application of low-cost natural bio-adsorbents like banana peel, sugarcane bagasse and orange peel. The performance and effectiveness of natural bio-adsorbent was investigated based on the effect of pH, time and amount. This investigation confers a new approach in the process of water treatment through minimal energy input, less labor, low investment and this approach is also biodegradable compared to synthetic adsorbent and chemicals. The following points are concluded from this work:

1) The optimized conditions for all three bio-adsorbents are 0.3 g of mass, 2 hours of contact time and pH 6 for per 50 mL.
2) The Banana peel was found to be comparatively more efficient in terms of the percentage removal of suspended solids, dissolved solids and turbidity and that are 65.71%, 25.91% and 85.65%, respectively compared to the Bagasse and Orange peels where the percentage removal of suspended solids, dissolved solids and turbidity are found to

be 62.02%, 24.05 %, 86.07% and 64.03%, 20.73%, 85.48%.

3) Therefore, it can be concluded that the effectiveness of all these three bio-adsorbent is almost similar. As a result, a great expectation comes that the natural bio-adsorbent can play an important role and provide an ecofriendly solution for the reduction of pollution load from tanning industry wastewater without exposing potential health hazard and very low cost due to its availability in nature.
4) Further reduction of different pollutants can be done by adding this process with biological treatment. That means, this process can be used as the pretreatment.
5) Specious investigation and continuous research are required for the reproduction and reusability of bio-adsorbent.

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