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Research paper

Removal of turbidity from washing machine discharge using *Strychnos potatorum* seeds: Parameter optimization and mechanism prediction

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Abstract

In this research an attempt has been made to utilize the *Strychnos potatorum* seed powder as an environmentally friendly coagulant for the removal of turbidity from washing machine discharge. The performance of this system was also compared with synthetic water. Experimental studies were conducted for the maximum removal of turbidity from washing machine discharge and synthetic turbid water which were varied from 50 to 145 NTU. The effect of operating parameters such as initial turbidity, *S. potatorum* dosage and pH of the solution was optimized for the maximum removal of turbidity. It was seen that the percentage removal of turbidity lay was between 68–89% and 65–84% for synthetic turbid water and washing machine discharge sample respectively, at an ideal pH of 6–7. The experimental values were compared with the Langmuir and Freundlich isotherm models to understand the extent of influence of the sorption of the particles onto the *S. potatorum* seed powder. Better results with respect to concordance of experimental data were observed with Langmuir isotherm model, indicating a monolayer sorption of particles onto the *S. potatorum* seed powder. It was observed from the isotherm study that the sorption may also be influenced in the removal of turbidity to some extent from the washing machine discharge and synthetic water. The prepared material can be effectively utilized for the removal of turbidity from the water.

Keywords: Coagulation; Sorption; *Strychnos potatorum* seeds; Turbidity

1. Introduction

The contaminants in the water/wastewater are available in the form of colloidal particles which are not ready to settle immediately [1]. The colloidal particles in the water provide the turbidity and color to the water samples which cannot be removed by the ordinary sedimentation process. It is an important problem in many developing countries to get clean drinking water at low cost. The turbidity in water can be generally solved by adding the chemical agents like aluminum sulfate (alum) but this is costly and also the sludge disposal will be another problem [1–3]. The coagulation/flocculation treatment technique was adopted for the treatment of water/wastewater for the removal of turbidity, natural organic matter and color [4]. Some of the coagulants such as alum, ferric chloride, calcium carbonate, polyaluminium chloride and polyethyleneimine were used as common inorganic coagulants in the water treatment units [5,6]. The residual of the alum and polyaluminium chloride may produce the Alzheimer's disease [7,8] and some of the synthetic organic polymers provide the neurotoxic and carcinogenic effects [9]. The important solution to the current problems may be given by implementing the natural coagulants which are preferably an alternative and excellent material for the removal of turbidity from the water. These natural coagulants should be biodegradable and should not produce any toxic effects to the human beings and also other living organisms.

In current years, many studies were carried out on utilizing the different plant materials as natural coagulants for the removal of turbidity from the drinking water. Some of them include *Moringa oleifera* [9–13], *Phaseolus vulgaris* [14–16], *Strychnos potatorum* [17,18] etc. The extract of *S. potatorum* seeds consists of anionic polyelectrolyte. Currently, the natural organic *S. potatorum* has been increasingly used in the coagulation of suspended matters in water/wastewater treatment. *S. potatorum* Linn (also called Nirmali seed) is an important source of the preparation of natural coagulant and which was

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utilized as a source for the removal of turbidity from the water system. The application of *S. potatorum* seed for the removal of turbidity from water was mentioned in the *Sushruta Samhita*. Sanskrit writings from India reported that the seeds of the Nirmali tree were used to clarify the turbid surface water over 4000 years ago. *S. potatorum* seeds have shown a high coagulation activity for the high turbidity water. The settling ability of the particulate matter in the turbid water depends on the density of the material and the size of particles.

The aim of the present research is to establish the usefulness of *S. potatorum* seed powder towards the removal of turbidity from the washing machine discharge. The influencing parameters such as solution pH, initial turbidities and *S. potatorum* dosage have been studied for the maximum removal of turbidity from the water system. The performance of the prepared material was compared with the synthetic turbid water system. The experimental data of the present system were adapted from the Langmuir and Freundlich models. The results from the isotherm studies assisted/enabled the prediction of the influence of the sorption process along with the coagulation process.

2. Experiment

2.1. Preparation of S. potatorum seed powder

S. potatorum (SP) seeds were obtained from Pudukkottai District, Tamilnadu, India. The seeds were washed with double distilled water to remove the surface impurities and dirt present in it. The excess water content in the seeds was completely removed by using simple filtration units. This material was further dried in sunlight to remove the moisture content. The dried materials were made into powder by using mixer grinder. The powder thus obtained was utilized as a natural coagulant for the removal of turbidity from the turbid water.

2.2. Washing machine discharge collection

The discharge from the washing machine was collected from the residential places regularly and the average residual turbidity of the collected sample was found to be 145 NTU. The coagulation tests were done on the water discharged from the washing machine. Washing machine discharge is cloudy and turbid in nature and hence the efficiency of *SP* seed powder in removing turbidity from the sample was tested.

2.3. Preparation of synthetic turbid water

The synthetic turbid water samples were prepared based on the residual turbidity of the washing machine discharge. 10 g of kaolin was added to 1 L of tap water. The suspension was stirred uniformly for one hour in a magnetic stirrer for uniform dispersion of kaolin particle. The suspension was allowed to stand for 24 h at room temperature (30 ± 2 °C) to allow complete hydration of the kaolin. This kaolin suspension was used as a stock solution for the experiments. Small amounts of the stock solution were diluted to 1 L using tap water to prepare synthetic turbid water of various turbidity levels. The initial pH of the kaolin suspension prepared just before the coagulation tests was found to be 7.5. The initial turbidities of the made up solutions were measured using an electronic digital nephelometer (SANSEL Instruments India Pvt. Ltd., India).

2.4. Coagulation study

2.4.1. Effect of initial turbidity

1 L synthetic water samples (50, 80, 110, 125, and 145 NTU) were taken in five beakers. These beakers were placed in the slots of the jar test apparatus. The measured quantity of SP was added in each of the five beakers. The mixtures were subjected to the rapid mixing (150 rpm) for 2 min followed by slow mixing (30 rpm) for about 30 min. The mixtures were kept for sedimentation for about 1 h without any disturbance. After the set period of sedimentation, the supernatant was analyzed for its residual turbidity using nephelometer. For the present study, the SP dosage and solution pH were maintained as 0.6 g and 6–7, respectively. The same coagulation experimental studies were conducted in washing machine discharge. The average turbidity level of the washing machine discharge was measured as 145 NTU. The same experimental conditions were maintained for the washing machine discharge and the percentage removal of turbidity was estimated using the following formula:

$$\%\ \text{Turbidity Removal} = \left(\frac{C_o - C_f}{C_o}\right) \times 100 \quad (1)$$

where Co is the initial turbidity of the waster sample (NTU) and Co is the final turbidity of the waster sample (NTU). The experimental studies were repeated thrice to check its repeatability and the average values only were discussed in the report.

2.4.2. Effect of S. potatorum dosage

The ideal SP dosage for the maximum removal of turbidity from water sample was carried out by conducting the experimental studies. The effect of SP dosage on the removal of turbidity was studied for initial turbidities ranging from 50 to 145 NTU by varying the SP dosage from 0.2 to 1.0 g. The same experimental procedures were followed as mentioned above.

2.4.3. Effect of pH on the removal of turbidity

The required pH or an optimum pH for the present system was measured by varying the pH of the system from 5.0 to 9.0. The pH of the water samples was measured by using the pH meter (pH meter, Elico Model, India). The pH of the test solution was adjusted at the desired level by using the buffer solutions. Once the pH of the test solution was fixed then the optimum amount of SP powder was added in each test solution in the beakers. The similar experimental and analytical procedures were carried out as mentioned previously.

2.4.4. Sorption studies

The different sorption isotherm models such as Langmuir (1918) [19] and Freundlich (1906) [20] were applied to the data observed from the effect of initial turbidity studies. It is important to predict the influence of the sorption process in the removal of turbidity from the water samples using SP seed

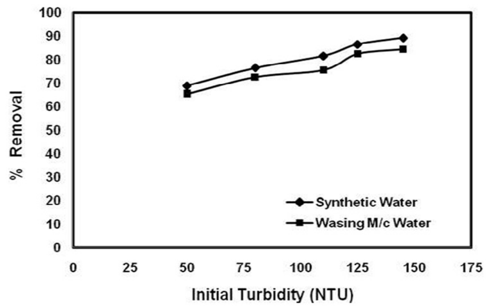

Fig. 1. Effect of initial turbidity on the removal of turbidity from water samples.

powder. The Langmuir sorption isotherm model is given as follows:

$$\frac{1}{q_e} = \frac{1}{q_m K_L C_e} + \frac{1}{q_m} \tag{2}$$

where q_e is the sorption capacity at equilibrium (mg/g), q_m is the Langmuir maximum monolayer sorption capacity (mg/g), K_L is the Langmuir constant (L/g), C_e is the final or equilibrium concentration of suspended solids in solution (mg/L). The sorption was determined by using a dimensionless constant, separation factor, R_L, and is given as follows:

$$R_L = \frac{1}{1 + K_L C_o} \tag{3}$$

where C_o is the initial concentration of suspended solids (mg/L). The importance of R_L value is as follows: $0 < R_L < 1$, favorable sorption; $R_L > 1$, unfavorable sorption; $R_L = 0$, irreversible sorption.

Freundlich (1906) sorption isotherm model is given as follows:

$$\log q_e = \frac{1}{n} \log C_e + \log K_F \tag{4}$$

where K_F is the Freundlich constant *((mg/g)(L/mg)*$^{(1/n)}$*)* related to the bonding energy and n is a measure of the deviation from linearity of sorption process. The importance of 'n' is as follows: $n < 1$, sorption is chemical process; $n = 1$, sorption is linear; $n > 1$, sorption is favorable physical process. The value of 'n' observed the degree of non-linearity between solution concentration and sorption. The extent of the sorption process and its influence in the coagulation process was identified with the isotherm models.

3. Results and discussion

3.1. Effect of initial turbidity

The effect of initial turbidity on the removal of turbidity from the water samples (synthetic water/washing machine discharge) by varying the initial turbidities ranging from 50 to 145 NTU at an optimum solution pH of 7.0 and at an optimum dose of 0.6 g was carried out in the jar test apparatus. The results of the experimental studies were presented in Fig. 1.

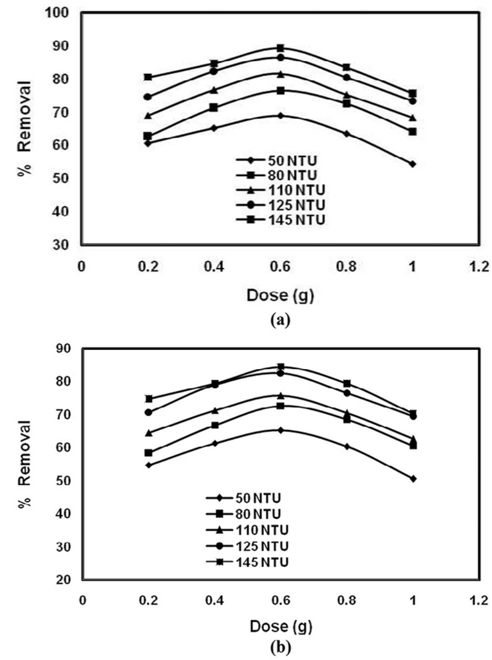

Fig. 2. (a) Effect of SP dosage on the removal of turbidity from synthetic water. (b) Effect of SP dosage on the removal of turbidity from washing M/c water.

From Fig. 1 it can be seen that the removal of turbidity was increased [for synthetic water: 68.92% (50 NTU) to 89.21% (145 NTU) and for washing M/c water: 65.21% (50 NTU) to 84.45% (145 NTU)] with the increase in initial turbidity from 50 NTU to 145 NTU. This may be due to the fact that: (i) at higher turbidity level, the more amount of colloidal particles was available and there is a possibility of more collision between the particles which leads to the maximum removal of turbidity at higher turbidity level; (ii) at lower turbidity level, the minimum amount of colloidal particles was available and only the less interactions between the particles were possible which leads to the lesser removal of turbidity at lower turbidity level [21]. The same operating conditions were maintained for both synthetic water samples and washing M/c water samples.

3.2. Effect of S. potatorum *dosage*

The effect of *SP* dosage on the removal of turbidity from the water samples (synthetic water/washing machine discharge) by varying the SP dosage from 0.2 to 1.0 g for the different initial turbidities ranging from 50 to 145 NTU was carried out and the results were presented in Fig. 2(a) for synthetic water and Fig. 2(b) for washing M/c water. The experimental studies were conducted at optimum conditions.

From Fig. 2(a) and (b), it can be seen that the removal of turbidity was increased with the increase in SP dose. The maximum removals of turbidity for the different initial turbidities were observed at an optimum dosage of 0.6 g. This is because the surface area was increased with the increase in the SP dosage which provides the more contact between the colloidal particles and the SP seed powder. After the dose of 0.6 g, the removal of turbidity was decreased with the increase in SP

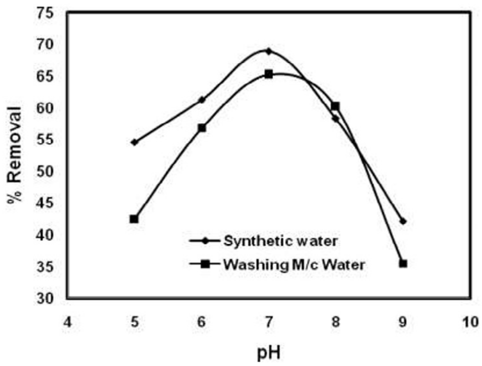

Fig. 3. Effect of pH on the removal of turbidity.

dose. This might be due to the SP seed powder being able to provide the turbidity to the already available turbidity solution. The excess dose of SP in the treatment causes the saturation of the polymer bridge sites [21–23]. This causes the re-stabilization of the destabilized particles due to the less number of particles to acquire the more inter-particle bridges. The optimum SP dose for the present system was found to be 0.6 g.

3.3. Effect of pH

The pH of the water system is always an important parameter which influences the removal of turbidity from the water samples. The effect of pH on the removal of turbidity from water samples (synthetic water/washing machine discharge) at optimum conditions (SP dosage = 0.6 g; Initial turbidity = 50 NTU) was studied and the results were presented in Fig. 3.

From Fig. 3, it was observed that the removal of turbidity was increased with the increase in solution pH. After the pH of 7.0, the removal of turbidity was decreased with the increase in solution pH. At low pH, the less removal was observed because of the competition between the hydronium ions and the ions in the water samples towards the surface of the SP. When the pH was increased from the lower value then the competition between the hydronium ions and the ions in the solution was found to be less which makes more ions in the solution move towards the surface of the SP due to the electrostatic attraction. At higher pH, the electrostatic repulsion between the ions in the solution and the functional groups on the surface of the SP was observed [21]. The maximum removal of turbidity was measured at the solution pH of 7.0.

3.4. Sorption studies

The experimental data from the effect of initial turbidity were applied to the Langmuir and Freundlich isotherm models [24–30]. The fitted isotherm models for the synthetic water and washing M/c water samples were presented in Figs 4 (a and b) and 5 (a and b), respectively.

The Langmuir and Freundlich isotherm parameters such as q_m, K_L, K_F, n and correlation coefficient (R^2) values were estimated from Figs 4 and 5 and the details were given in Table 1. The best provided isotherm model was predicted based on the

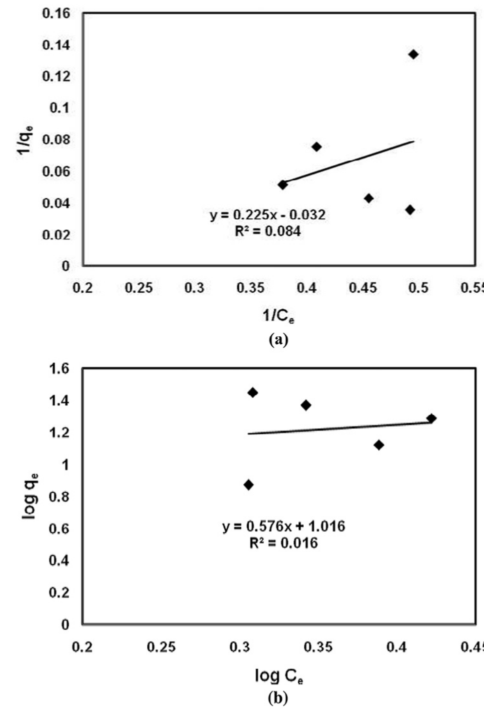

Fig. 4. (a) Langmuir isotherm model for the synthetic water samples. (b) Freundlich isotherm model for the synthetic water samples.

higher R^2 values. Based on the R^2 values, it can be seen that the removal of turbidity by SP seed powder was followed by the Langmuir model than the Freundlich model. But the better results were observed for washing M/c water samples as

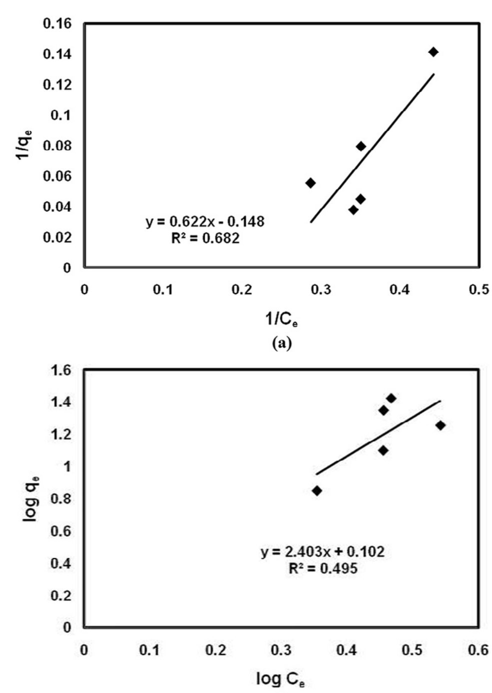

Fig. 5. (a) Langmuir isotherm model for the washing M/c water samples. (b) Freundlich isotherm model for the washing M/c water samples.

Table 1
Isotherm model parameters for the removal of turbidity using *Strychnos potatorum* seed powder.

Isotherm model	Parameters	Synthetic water samples	Washing M/c water samples
Langmuir	q_m (mg/g)	−31.25	−6.757
	K_L (L/g)	−0.0072	−0.092
	R^2	0.084	0.682
	Fitted equation	$\frac{1}{q_e}=\frac{0.225}{C_e}-0.032$	$\frac{1}{q_e}=\frac{0.622}{C_e}-0.148$
Freundlich	K_F ((mg/g)(L/mg)$^{(1/n)}$)	10.375	1.265
	n	1.736	0.416
	R^2	0.016	0.495
	Fitted equation	$\log q_e = 0.576 \log C_e + 1.016$	$\log q_e = 2.403 \log C_e + 0.102$

compared with the synthetic water samples. This indicates that the sorption plays a significant role in the removal of turbidity from washing M/c water samples as compared with the synthetic water samples. The negative values of R_L for the Langmuir model were obtained for the different initial turbidity values. The values of 'n' for the synthetic water samples and washing M/c water samples were calculated as 1.736 and 0.416, respectively. From Table 1, it was observed that the 'q_m' value was found to be negative for both water samples which indicates that the sorption is not completely influenced in the removal of turbidity by using SP seed powder. The results indicate that the removal of turbidity from both water samples was mainly due to the coagulation process but with the little influence of the sorption process.

4. Conclusion

The present research was successfully carried out for the removal of turbidity from the washing machine discharge using the *S. potatorum* (SP) seed powder. The coagulation influencing parameters such as pH, initial turbidity and SP dosage were optimized for the maximum removal of turbidity from the washing machine discharge. The performance of the present system was also compared with the synthetic water system. Some of the important findings that were observed from the present research are as follows:

- The ideal SP dosage for the maximum turbidity removal was calculated as 0.6 g.
- The required solution pH of the present system was measured as 6.0.
- The maximum removal of turbidity was measured at optimum conditions as follows: For washing machine discharge – from 65.21% (50 NTU) to 84.45% (145 NTU) and for synthetic water sample – from 68.92% (50 NTU) to 89.21% (145 NTU).
- The influence of sorption in the removal of turbidity was checked by fitting the experimental data with the Langmuir and Freundlich sorption isotherm models. The data were described by the Langmuir model as compared with the Freundlich model.
- The isotherm results were best adopted for the washing machine discharge rather than the synthetic water samples. For this system, the Langmuir model was best obeyed with the experimental data.
- The sorption results indicate that the turbidity removal was somewhat influenced by the sorption process.

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