Coal Washery Waste Water Treatment using Natural Coagulants and Chemical Precipitation

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Abstract: ***During the washing and beneficiation of coal or any minerals, particulates become suspended in waste water. Before reuse of these discharged waters, suspended particulates and various contaminants must be removed from this effluent. Coal washery consume huge amount of water and hence generates huge amount of waste water. If this water is directly discharged into streams, it will cause environmental pollution. Coal washery effluents contain high amount of suspended particles, has high turbidity, and color, besides it contains heavy metals. In this project work, chemical and natural coagulants have been used and comparative study has been made about the effectiveness of chemical and natural coagulants. The present study deals with the evaluation of treatment efficiency of natural coagulants okra seeds and bitter gourd seed, commonly available in market. Primarily the basic parameters-pH, suspended solids, turbidity, heavy metals and coagulant dosage are optimized. Coagulation of seed extract for okra and bitter gourd was assessed by the use of jar test experiment in coal washery effluent with various coagulant doses. About 50% of turbidity removal was achieved by okra seeds at neutral pH and 62% at pH between 7-8 and 99.96% removal efficiency of iron was obtained with bitter gourd seeds.***

Keywords: jar test method, low-cost waste water treatment, and natural coagulants.

1. Introduction

The process for having high quality coal requires wet cleaning process, the coal washery plants are used for washing the coals for improving its quality. In areas where there is demand for large volume of water for treating coal requires efficient recovery of water for the reuse and also for the area where is limited supply of water. When water supply is not the problem, disposal of slurry into the stream will create environmental pollution. Moreover, where there is high demand of drinking water due to ever increasing population, water recycling to plants is must. In a coal washing plant, discharge of the effluent is continuous and therefore, requires uninterrupted water supply in order to maintain the continuous production of washed coal. The continuous use of the same used water without clearing would lead to increasing impurities and will also decreases efficiency of coal washery operations.

After the process of coal cleaning the left effluent consist of chemical treated water, very fine particles, rock and clay etc which is also called as coal slurry. The rock, coal, and clays contain a wide range of heavy metals including arsenic, lead, cadmium, chromium, iron, manganese, aluminum and nickel all of which dissolve in the water and some hydrocarbons and other organic chemicals [3]. Chemicals used in the coal wash process may make serious concern to the workers in the plant. Natural coagulants are biodegradable and also cost effective as they can be locally grown. Natural coagulants have several other advantages when compared to chemical coagulants, as they produces less sludge and are also safe for human. Therefore, to control the problems from the effluent of coal washery, it can be treated using natural coagulants, which is also a cost reduction technique and by the chemical precipitation. Seeds of okra, bitter gourd as coagulants are used for the treatment, and the chemicals like lime & ferric chloride, are used for maintaining pH, reduction of turbidity and suspended solids. Therefore, there is a need of developing cheap and easily available coagulant from seeds to be used in water treatment, so that this will be useful for the area where there is the lack of water [4,5].

1.1 Okra Seeds (Abelmoschus Esculentus)-

An okra seed commonly known as lady’s finger, bhindi, is a flowering plant belonging to mallow family. Edible green seed pods increases its value. It is easily available in the market. The plant is cultivated in tropical, subtropical and in warm temperature regions around the world. It is an economically important plant. According to the literature okra is not only found to be edible but also used as a natural coagulant in waste water treatment in the past. It is found that okra seeds have property to decrease turbidity [6]. It is observed that whatever be the volume of okra seeds, turbidity decreases when pH increases. The flocculating property of okra seeds can be either because of chemical reaction or complex formation. As per the research papers, okra seeds are used for treatment of tannery effluent, textile effluent, surface water [7].

1.2 Bitter Gourd Seeds (Momordica Charantia)

Bitter gourd is one of the most popular vegetables in China, Taiwan, Thailand, and India. Bitter gourd is also called as Bitter melon, has an acquired taste. Bitter gourd belongs to cucubiataceae family. The plant is grown mainly for the immature fruits although the young leaves and tips are edible. Bitter melon needs warm/moist conditions during germination. It may fail or take long time to germinate if the soil temperature is too low. It is an excellent source of health benefits. It also contains a good amount of vitamin A. Together; these compounds help acts as protective scavengers against oxygen-derived free radicals and reactive oxygen species that play important role in cancers and various disease processes.

2. Methodology

In this study, coal washery water sample was collected from the coal washery plant. In the experiment, natural coagulants and chemical coagulants were used. The natural coagulants used are okra seeds and bitter-gourd seeds and chemical coagulants used are ferric chloride with lime. The comparative study is done between the natural and chemical coagulants. Turbidity was measured with a 'Digital Nephelo-meter turbidity meter'. The turbidity removal efficiency of the coagulants was calculated using the following equation

$$\text{Turbidity Removal (\%)} = \frac{No - N}{No} \times 100$$

2.1 Preparation of coagulants

The seed of the plant okra and bitter gourd was brought from a local super market. The seeds were initially washed thoroughly with water to remove any impurities, dried for 8h and then grinded and sieved to a mesh (500µm) particle size to remove large particles. For Okra seed powder, 10g of seed powder was mixed with 100ml of NaCl solution to form 100ml of suspension. The solution was thoroughly mixed with a magnetic stirrer for 5min to extract the active component. The solution was left untouched for 15min for suspension. The solution was then filtered to remove solid particles and the powder left at the surface was air-dried for 8h. Whereas, the bitter gourd seed powder was used directly used.

2.2 Experimental Work

a) For pH, Turbidity and suspended solids

Before treating the coal washery water sample, their physical parameters especially pH, turbidity, and suspended solids were measured with the aid of pH digital meter, turbidity meter. Suspended solids were also measured by using the standard method. Jar test method was carried out to determine the coagulation properties of the derived coagulants. All the 4 beakers were used for various dosing of the coagulants with the same quantity of sample. Jar test were conducted on 1000ml of coal washery water sample, which was highly turbidity. In the process, the amounts of coagulants added were 100, 200, 300, 400, 500, 600, 700 and 800 ppm respectively. The samples were subjected to slow mixing step at 50 rpm for 15min and rapid mixing at 150 rpm for 3min. The samples were allowed to settle for 30min. After sedimentation, the supernatant liquid was collected and analyzed. All the experiments were performed at room temperature. No pH control was applied, since the pH did not change during flocculation. The turbidity, pH, suspended solids of each of the samples was measured.

b) For heavy metal removal

In 1000ml of sample, 500, 1000 and 1500 ppm coagulant dosage were added and mixed using a magnetic stirrer at a speed 170 rpm (Rapid Mixing). The sample was allowed to settle for 30 minutes and the supernatant liquid was collected separately and measured.

3. Results and Discussion

3.1 Turbidity Removal

In this work, coagulants were used at different doses, and their performances in the turbidity removal of the coal washery sample are shown in the table 1. The initial turbidity of sample was 770 NTU.

Table 1: Properties of coal washery effluent

Parameters	*Coal washery effluent*
pH	5.5-8
Turbidity (NTU)	770
Suspended solids (mg/l)	76.9

a) Effect of bitter gourd seeds in coal washery effluent

From the experimental results it is seen that when dosage of bitter gourd seed powder was increased from 100 ppm - 800 ppm, the corresponding reduction in turbidity was observed to be 51.94 – 22.07%. It was noticed from the fig that the highest turbidity removal for the sample was achieved when the dose was 400 ppm which is shown in table 2 and has been represented graphically in fig-1.

Table 2: Effect of bitter gourd seeds on pH, turbidity and suspended solids

Coagulant dose(ppm)	*pH*	*Turbidity removal (%)*	*Suspended solids (mg/l)*
100	5.91	51.94	0.061
200	6.13	53.24	0.055
300	7.02	55.84	0.034
400	7.25	61.03	0.015
500	8.66	27.27	0.135
600	8.48	22.07	0.147
700	8.56	24.67	0.124
800	8.47	22.07	0.132

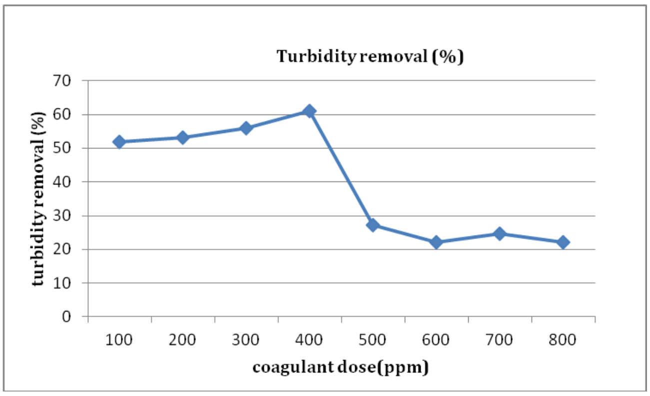


Figure 1: Effect of bitter gourd seeds on turbidity removal

b) Effect of okra seeds after extraction by NaCl

From the experimental results it is seen that when dosage of okra seeds after extraction by NaCl was increased from 100 - 800 ppm, the corresponding reduction in turbidity was observed to be 35.06 – 10.38%. It was noticed from the fig that the highest turbidity removal for the sample was achieved when the dose was 400 ppm which is shown in table 3 and has been represented graphically in fig-2.

Table 3: Effect of okra seeds on pH, turbidity and suspended solids

Coagulant dose(ppm)	*pH*	*Turbidity removal (%)*	*Suspended solids*
100	7.45	51.94	0.049
200	8.07	53.24	0.059
300	7.86	55.84	0.052
400	7.65	61.03	0.052
500	8.84	27.27	0.092
600	8.80	22.07	0.120
700	8.90	12.90	0.082
800	8.91	10.38	0.129

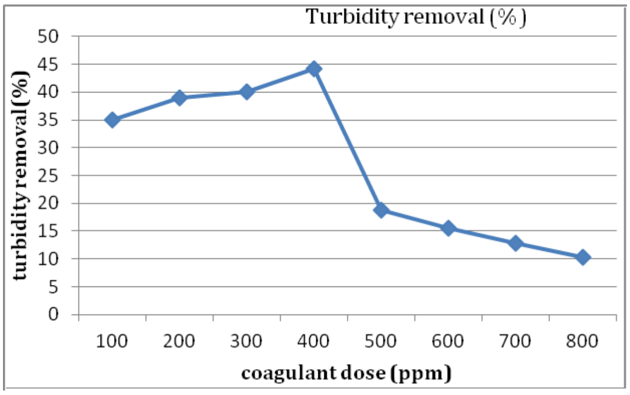


Figure 2: Effect of okra seeds after extraction by NaCl on turbidity removal

c) Effect of ferric chloride

From the experimental results it is seen that when dosage of ferric chloride was increased from 100 - 800 ppm, the corresponding reduction in turbidity was observed to be 48.05 –63.63%. It was noticed from the fig that the highest turbidity removal for the sample was achieved when the dose was 400 ppm which is shown in table 4 and has been represented graphically in fig 3.

Table 4: Effect of ferric chloride on pH, turbidity and suspended solids

Coagulant dose (ppm)	*pH*	*Turbidity removal (%)*	*Suspended solids*
100	3.11	48.05	0.094
200	4.14	76.62	0.082
300	2.99	79.22	0.072
400	2.72	81.81	0.081
500	5.08	79.02	0.086
600	5.45	68.83	0.089
700	3.45	56.63	0.076
800	4.56	50.74	0.098

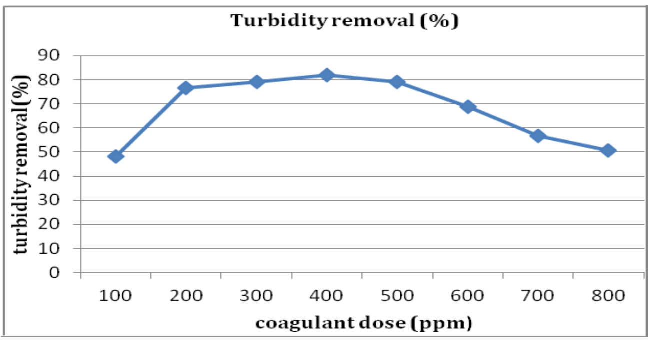


Figure 3: Effect of ferric chloride on turbidity removal

d) Effect of ferric chloride with lime

From the experimental results it is seen that when dosage of ferric chloride was increased from 100 - 400 ppm, the corresponding reduction in turbidity was observed to be 96.49 – 99.87%. It was noticed from the fig that the highest turbidity removal for the sample was achieved when the dose was 400 ppm which is shown in table 5 and has been represented graphically in fig 4.

Table 5: Effect of ferric chloride with lime on pH, turbidity and suspended solids

Coagulant dose (ppm)	*pH*	*Turbidity removal (%)*	*Suspended solids(mg/l)*
100	6.32	96.49	0.011
200	6.32	99.61	0.006
300	6.56	99.74	0.003
400	6.58	99.87	0.004
500	7.25	90.85	0.016
600	7.90	84.34	0.011
700	8.07	80.90	0.132
800	8.25	76.98	0.110

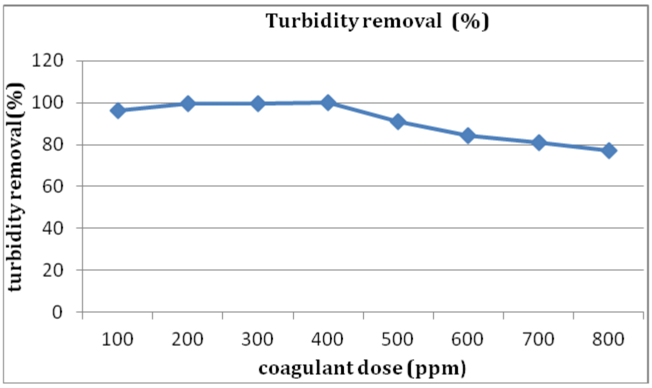


Figure 4: Effect of ferric chloride with lime on turbidity removal

The ferric chloride was very effective on removal of turbidity but it changes the pH value and therefore lime was used to maintain pH value. Ferric chloride and lime was added in the same proportion.

e) Effect of ferrous sulphate

From the experimental results it is seen that when dosage of ferrous sulphate was increased from 100 - 800 ppm, the corresponding reduction in turbidity was observed to be 35.06– 28.57%. It was noticed from the fig that the highest turbidity removal for the sample was achieved when the dose was 500 ppm which is shown in table 6 and has been represented graphically in fig 5.

Table 6: Effect of ferrous sulphate on pH, turbidity and suspended solids

Coagulant dose (ppm)	*pH*	*Turbidity removal (%)*	*Suspended solids*
100	5.80	35.06	0.005
200	5.52	51.95	0.002
300	5.42	53.24	0.003
400	5.48	54.54	0.006
500	5.90	56.67	0.007
600	4.98	32.46	0.012
700	4.54	28.51	0.034
800	3.54	29.87	0.011

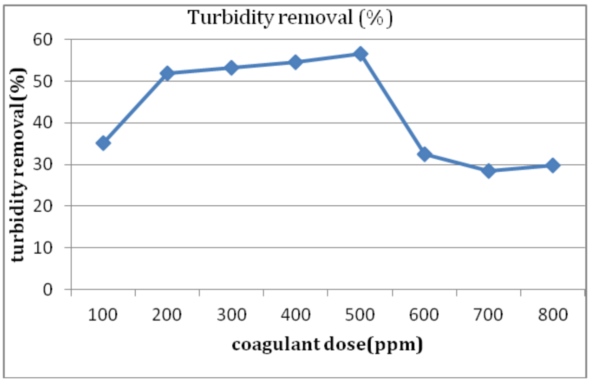


Figure 5: Effect of ferrous sulphate on turbidity removal

f) Effect of ferrous sulphate with lime

From the experimental results it is seen that when dosage of ferrous sulphate was increased from 100 - 800 ppm, the corresponding reduction in turbidity was observed to be 67.53- 64.93%. It was noticed from the fig that the highest turbidity removal for the sample was achieved when the dose was 400 ppm which is shown in table 7 and has been represented graphically in fig 6.

Table 7: Effect of ferrous sulphate with lime on pH, turbidity and suspended solids

Coagulant dose (ppm)	*pH*	*Turbidity removal (%)*	*Suspended solids (mg/l)*
100	8.05	67.53	0.010
200	8.05	74.02	0.009
300	8.30	80.52	0.008
400	8.50	81.81	0.007
500	9.00	72.72	0.020
600	9.50	70.76	0.012
700	9.75	67.11	0.015
800	10.20	64.93	0.008

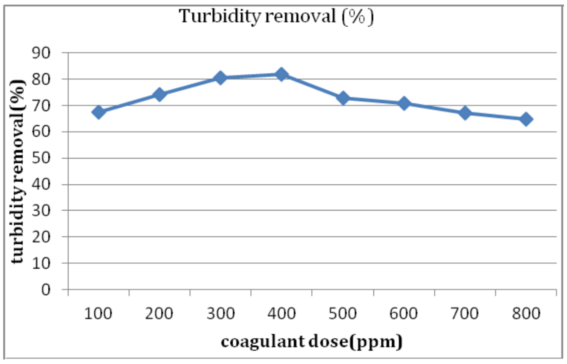


Figure 6: Effect of ferrous sulphate with lime on turbidity removal

3.2 Heavy metal removal

In this work, coagulants were used at different doses, and their performances in the removal of heavy metals. Initial concentration of Lead (Pb) and Iron (Fe) of the coal washery sample are shown in table 8.

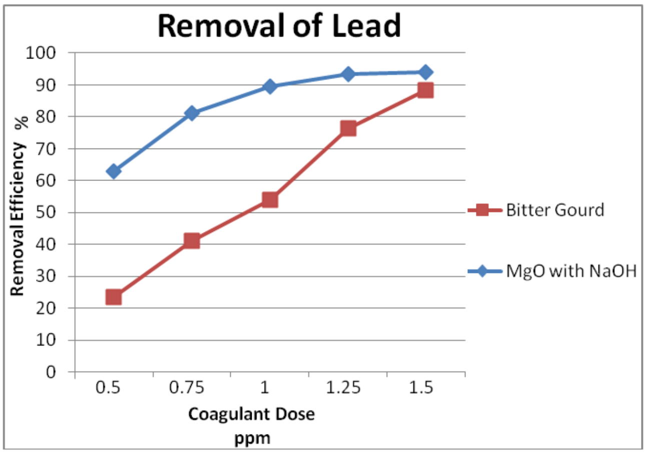
Table 8: Initial concentration of Lead(Pb) and Iron(Fe)

Heavy metals	*Initial Concentration (mg/l)*	*Permissible limit*
Iron (Fe)	30.0	3 max
Lead (Pb)	0.17	0.1

a) Effect of bitter gourd and MgO with NaOH on removal of Lead (Pb)

From the experimental results it is seen that when the dosage of Bitter gourd and MgO with NaOH was increased from 500-1500 ppm, the corresponding reduction in Lead removal was observed to be 23.53-88.23% and 63- 94.11% respectively

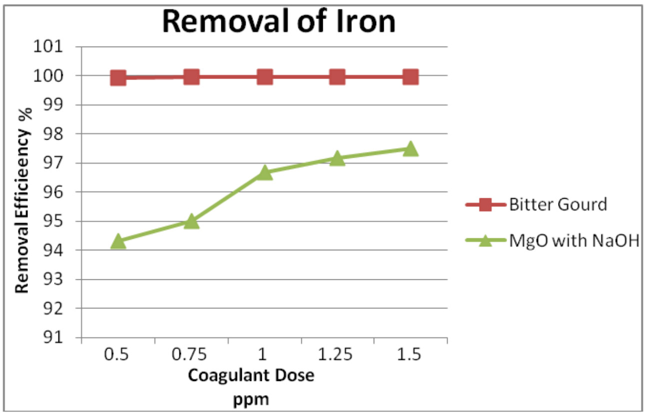
Sr.No	*Coagulant Dose ppm*	*Final Concentration mg/l*		*Efficiency %*	
		Bitter Gourd	*MgO with NaOH*	*Bitter Gourd*	*MgO with NaOH*
1	0.5	0.13	0.063	23.53	63
2	0.75	0.10	0.032	41.17	81.2
3	1	0.08	0.018	54	89.4
4	1.25	0.04	0.013	76.5	93.35
5	1.5	0.02	0.01	88.23	94.11



b) Effect of bitter gourd and MgO with NaOH on removal of Iron (Fe)

From the experimental results it is seen that when the dosage of Bitter gourd and MgO with NaOH was increased from 500-1500 ppm, the corresponding reduction in Iron removal was observed to be 99.93-99.96% and 94.3-97.4% respectively

Sr.No	*Coagulant Dose ppm*	*Final Concentration mg/l*		*Efficiency %*	
		Bitter	*MgO with*	*Bitter*	*MgO with*
1	0.5	0.02	1.72	99.93	94.3
2	0.75	0.10	1.5	99.96	95
3	1	0.01	1.0	99.96	96.66
4	1.25	0.01	0.85	99.96	97.16
5	1.5	0.01	0.74	99.96	97.5



4. Conclusion

In the developing countries treatment plants are expensive, the ability to pay for services is minimal and skills as well as technology are scarce. In order to alleviate the prevailing difficulties, approaches should focus on sustainable water treatment systems that are low cost, robust and require minimal maintenance and operator skills. Therefore, locally available materials can be exploited towards achieving sustainable safe water supply. The study was conducted to obtain okra seeds and bitter gourd seeds as new source of bioremediation for the treatment of coal washery effluent. The effect of seeds on pH, suspended solids, turbidity, is to be compared accordingly. The chemical coagulants ferrous sulphate with lime, ferric chloride with lime was used for comparing the values with natural coagulants. The results obtained from this research revealed that bitter gourd seeds without extraction are more effective than okra seeds with extraction by NaCl in removal of turbidity of coal washery effluent. The efficiency of bitter gourd seeds, okra seeds, ferrous sulphate with lime and ferric chloride with lime was 61.03%, 44.15%, 81.81% and 99.87% respectively for an optimum dosage of 400 ppm. The chemical coagulants were found to be more effective in removing turbidity as well as suspended solids. Also bitter gourd seeds were used for removal of heavy metals like lead and iron and the results were compared with the removal efficiency of the same heavy metals using chemical coagulant magnesium oxide with NaOH. It was found that removal efficiency of lead was greater in chemical coagulant than in natural coagulant and removal efficiency of iron was greater in natural coagulant than in chemical coagulant.

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