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Effectiveness of Natural Coagulants in Comparison with Chemical Coagulant for Domestic Wastewater Treatment

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Abstract— Natural coagulants have been increasingly popular in the past few years due to its benefits and it can resolve most of the associated problems when using chemical coagulants. The utilization of natural coagulants are safe, eco-friendly, cheap, easier and locally available for wastewater treatment. They can be extracted from various plant components. The objectives of this study were to evaluate the comparative effectiveness and also to assess the possibility of using natural coagulants such as tamarind seed, moringa seed and bagasse ash as an alternative to the current commercial synthetic coagulant such as aluminium sulphate for the treatment of domestic wastewater. Various conditions such as coagulants dosages, stirring time and settling time were varied and their optimum values were obtained. The water parameters like pH, turbidity, electrical conductivity, TDS, TSS, BOD and COD were analyzed for wastewater and treated wastewater by different natural coagulants with varying dosages, stirring time and settling time and also compared removal efficiencies of these natural coagulants with alum. This study results show reduction in electrical conductivity, turbidity, TDS, TSS, BOD and COD by using natural coagulants and maximum removal efficiency was found in the combined use of moringa seed and tamarind seed powder. The final effluent can be readily used for irrigation purposes and sludge itself became a good fertilizer.

Keywords: Alum, Jar test, Natural coagulants, Removal efficiency, Settling time, Stirring time, Water parameters.

1 Introduction

The water is the most vital parameter among the natural resources. Water is vital to life and development in all parts of the world. The availability of a water supply adequate in terms of both quantity and quality is essential to hum an existence. Civilization developed around water bodies that could support agriculture and transportation as well as provide drinking water. Recognition of the importance of water quality developed more slowly [2].

The quality of water is superior for the stability of the ecosystem. The production of safe and healthy water from most raw water sources is an essential part to complete the water cycle. It is, however, important to subject water from every source to varying forms of treatment or purification before consumption or discharge back to the environment. The level of threat water poses determines the choice of treatment to be employed. However, major improvements in health conditions through the provision of sufficient safe water can only be achieved through domestic hygiene practice and proper methods of water purification. The provision of water supply nearby for consumers and sufficient for their daily needs will help greatly in decreasing the incidence of skin diseases, eye infections and also reduce diarrhea diseases as well as most worm infections, particularly if the water is of good quality bacteriologically [5].

Coagulation is one of the most widely used pre-treatment technology for water and wastewater treatment. Conventionally, metal-based coagulants (aluminium and iron) poses environmental challenges due to their complexity in biodegradation. However, these types of coagulants are associated with the formation of large volumes of sludge associated with complex metals. As a result, this poses great threat to agriculture, human health (memory loss, intestinal constipation, abdomen colic, spasms) and aquatic life if not treated before being disposed into the environment. Therefore, the improvement of the coagulation process by the use of cost-effective or biodegradable or natural coagulants is worth investigating, since there is limited information and studies on natural coagulants used for wastewater treatment [1].

The natural water resource is becoming scarce at many places and its unavailability is a major social and economic concern. Coagulation flocculation process is one of the efficient methods involved in the treatment of waste water. Coagulation depends on the effect of stirring time and settling time Coagulation using chemical coagulants is costly process and may also leads to various health problems. Aluminium sulphate (alum) is the most common chemical coagulant used for water purification. Hence coagulation using natural coagulants such as bagasse ash, tamarind and moringa seed powder can be used for treatment of waste water. Natural coagulants are eco-friendly, economical and locally available [5].

2 Methodology

2.1 Sample Collection

Here domestic waste water was collected from house, Chelannur for analysing the efficiency of natural coagulants. The water samples were collected in sterilized bottles and were preserved in the refrigerator during storage.

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2.2 Materials

2.2.1 Moringa Oleifera

Moring seeds were collected from the market and nearby locations. Moringa seeds were thoroughly washed with tap water to remove the sticks adhered on their surfaces and stored for preparation.

Fig. 1 Moringa seed powder

The collected moringa seeds were dried in sun light until its moisture content was completely removed. The dried seeds were then grinded in to fine powder as in Fig.1 by using home grinder and sieved through 300 micron sieve size and kept it in an airtight container.

2.2.2 Tamarind seed

The collected tamarind seeds were dried in sunlight until its moisture content was completely removed.

Fig. 2 Tamarind seed powder

After grinding tamarind seed as in Fig.2, it is sieved through 300 micron sieve size and kept it in an airtight container.

2.2.3 Bagasse ash

The bagasse was collected from juice shop. It is a fibrous residue left after crushing the sugarcane into extracted juice. It is composed primarily of cellulose and hemicellulose along with lignin and small quantities of ash and waxes. Researchers are investigating the possibility of it being considered as a biofuel. They are agricultural by-product [4]. The collected bagasse were dried in sunlight until its moisture content was completely removed.

And burned bagasse into bagasse ash. After forming bagasse ash, grinded bagasse ash into fine powder as in Fig.3.

Fig. 3 Bagasse ash powder

After that it was sieved through 300 micron sieve size and kept it in an airtight container.

2.2.4 Alum

Alum was collected from shop and alum crystals were grinded into a fine crystalline powder before using.

2.3 Methods

2.3.1 Water analysis before treatment

The raw waste water samples were analyzed by various parameters such as pH, electrical conductivity, alkalinity, turbidity, DO, BOD, COD, chloride, TSS, TDS, nitrate, ammonia, faecal coliform, total coliform and oil and grease content.

2.3.2 Jar-test

The jar test apparatus was used to carry out coagulation and flocculation and studied the effect of coagulant dosage on coagulation and the effect of stirring time and settling time on coagulation. The wastewater samples were mixed thoroughly before being poured into beakers of 1 litres. Six different weights of the coagulant were placed in each beaker, the first having 0.2g, and the remaining five varying from 0.4-1.2 g at 0.2g interval in order to determine the optimum dosage. After an addition of desired dosage for each coagulant (0.2, 0.4, 0.6, 0.8, 1.0 and 1.2 g/l) in different steps to the suspension, the beakers were agitated at rapid mixing (100 rpm) for 1 min and slow mixing (30 rpm) for 15 min. Thereafter, 20 min of motionless settling was allowed and then the samples were collected with a syringe at 2 cm beneath the surface for analysis. The above procedure repeated for all remaining coagulants. The above procedure was used again. Effect of stirring time on coagulation was studied by varying stirring time from 10 min to 30 min at 5 min interval and by keeping optimum dosage and constant settling time of 20 min in all five beakers. The stirring time was varied at 10 mins, 15 mins, 20 mins, 25 mins and 30 mins for each beaker. Effect of settling time on coagulation was studied by varying settling time from 10 min to 50 min at 10 min interval and by keeping optimum dosage and optimum stirring time in five beakers.

2.3.3 Water analysis after treatment

The treated water samples were analyzed by various parameters such as pH, electrical conductivity, alkalinity, turbidity, DO, BOD, COD, chloride, TSS, TDS, nitrate, ammonia, faecal coliform, total coliform and oil and grease content. After sample analysis optimum dosage, optimum stirring time and optimum settling time of coagulants were found out.

3 Results and Discussions

Table 1 shows analysis of water sample before treatment.

TABLE 1
CHARACTERISTICS OF WASTE WATER BEFORE TREATMENT

Parameters	Unit	Before treatment		
		Sample 1	Sample 2	Sample 3
pH		7.82	7.69	7.5
EC	mS/cm	11	8	10
Turbidity	NTU	278	270	300
TSS	mg/l	582	590	547
TDS	mg/l	354	390	420
BOD	mg/l	420	450	610
COD	mg/l	965	970	997

The coagulation performance depends on dosage, stirring time and settling time. There is a need of determining the optimum dosage, optimum stirring time and optimum settling time for coagulation to improve the water quality and minimize the coagulant cost.

3.1 Effect of Dosage of Coagulants

Table 2 shows removal efficiency of alum for different water parameters with varying dosages.

TABLE 2
REMOVAL EFFICIENCY WITH VARYING DOSAGES- ALUM

Parameter	Removal efficiency with varying dosages Alum (%)					
	0.2g/l	0.4g/l	0.6g/l	0.8g/l	1g/l	1.2g/l
EC	61.82	74.55	72.73	70.9	66.36	63.64
Turbidity	89.93	97.48	95.32	93.2	91.73	91.01
TSS	76.8	84.02	81.1	79.4	78.52	78.01
TDS	28.81	37.85	35.88	33.9	32.2	31.07
BOD	68.1	80.48	77.62	75.7	73.57	71.67
COD	64.25	76.48	70.78	63.5	59.07	56.48

From table 2, removal efficiencies of all water parameters were found to be increased up to optimum dosage. Maximum removal efficiencies of alum for EC, turbidity, TSS, TDS, BOD, COD were 74.55%, 97.48% 84.02%, 37.85%, 80.48% and 76.48% respectively at optimum dosage of 0.4g/l. After optimum dosage of 0.4g/l, removal efficiencies of all water parameters were decreased due to the formation of floc after coagulation. Inadequate and overdose of coagulants might result in poor performance [3].

Table 3 shows removal efficiency of bagasse ash for different water parameters with varying dosages. From table 3, removal efficiencies all water parameters were found to be increased up to optimum dosage.

TABLE 3
REMOVAL EFFICIENCY WITH VARYING DOSAGES- BAGASSE ASH

Parameter	Removal efficiency with varying dosages Bagasse Ash(%)					
	0.2g/l	0.4g/l	0.6g/l	0.8g/l	1g/l	1.2g/l
EC	45.45	48.18	51.82	54.6	56.36	53.64
Turbidity	69.42	72.66	74.82	75.2	76.98	75.54
TSS	41.24	47.59	55.33	61.3	68.21	65.64
TDS	15.25	17.8	19.21	21.2	27.12	25.71
BOD	36.19	44.05	50.95	54.8	56.9	55.24
COD	29.22	34.3	39.07	45.8	52.95	49.53

Maximum removal efficiencies of bagasse ash for EC, turbidity, TSS, TDS, BOD, COD were 56.36%, 76.98% 68.21%, 27.12%, 56.9% and 52.95% respectively at optimum dosage of 1.0g/l. After optimum dosage of 1.0g/l, removal efficiencies of all water parameters were decreased. Inadequate and overdose of coagulants might result in poor performance [3].

Table 4 shows removal efficiency of tamarind seed for different water parameters with varying dosages. From table 4, removal efficiencies all water parameters were found to be increased up to optimum dosage. Maximum removal efficiencies of tamarind seed for EC, turbidity, TSS, TDS, BOD, COD were 68.8%, 92.6% 78%, 32.8%, 77.8% and 71.7% respectively at optimum dosage of 0.8g/l.

TABLE 4
REMOVAL EFFICIENCY WITH VARYING DOSAGES- TAMARIND SEED

Parameter	Removal efficiency with varying dosages Tamarind seed(%)					
	0.2g/l	0.4g/l	0.6g/l	0.8g/l	1g/l	1.2g/l
EC	51.25	56.25	62.5	68.8	60	55
Turbidity	80.37	84.81	89.63	92.6	83.7	78.52
TSS	66.27	73.22	75.42	78	76.95	74.92
TDS	26.15	28.21	29.74	32.8	31.79	30.51
BOD	50.67	61.11	71.56	77.8	79.11	72.44
COD	46.39	58.25	66.7	71.7	72.68	69.59

After optimum dosage of 0.8g/l, removal efficiencies of all water parameters were decreased. Inadequate and overdose of coagulants might result in poor performance [3].

Table 5 shows removal efficiency of moringa seed for different water parameters with varying dosages. From table 5, removal efficiencies all water parameters except BOD and COD were found to be increased up to optimum dosage. In the case of BOD and COD, removal efficiency was increased up to dosage of 1.6g/l. By comparing all other water parameters the optimum dosage was found as 0.6g/l. Maximum removal efficiencies of moringa seed for EC, turbidity, TSS, TDS, BOD, COD were 73.75%, 96.3%, 79.66%, 36.41%, 78.22% and

75.77% respectively at optimum dosage of 0.6g/l.

TABLE 5
REMOVAL EFFICIENCY WITH VARYING DOSAGES- MORINGA SEED

Parameter	Removal efficiency with varying dosages Moringa seed(%)								
	0.2 g/l	0.4 g/l	0.6 g/l	0.8 g/l	1 g/l	1.2 g/l	1.4 g/l	1.6 g/l	1.8 g/l
EC	58.75	67.5	73.75	70	65	61.25	--	--	--
Turbidity	83.33	88.52	96.3	90.7	85.93	84.44	--	--	--
TSS	68.14	75.59	79.66	78.5	77.8	76.61	--	--	--
TDS	27.18	33.33	36.41	35.4	33.08	32.05	--	--	--
BOD	53.33	67.78	78.22	78.9	79.33	80	80.67	81.11	78.89
COD	57.53	64.43	75.77	76.5	77.01	77.32	77.63	77.63	76.29

After optimum dosage of 1.0g/l, removal efficiencies of all water parameters were decreased due to the formation of floc after coagulation. Inadequate and overdose of coagulants might result in poor performance [3].

Table 6 shows removal efficiency of combination of moringa seed and tamarind seed for different water parameters with varying dosages.

TABLE 6
REMOVAL EFFICIENCY WITH VARYING DOSAGES- MORINGA+TAMARIND SEED

Parameter	Removal efficiency with varying dosages Moringa+Tamarind seed(%)						
	0.2 g/l	0.4 g/l	0.6 g/l	0.8 g/l	1.0 g/l	1.2 g/l	1.4 g/l
EC	62.5	67.5	68.75	71.3	75	70	--
Turbidity	88.15	90.74	93.33	96.3	97.78	95.56	--
TSS	76.1	78.81	81.19	82.5	85.25	84.24	--
TDS	28.21	31.54	34.62	36.4	38.72	37.18	--
BOD	57.11	62.22	68.44	75.6	79.33	80	78.22
COD	52.99	55.15	61.34	73.8	76.8	77.73	75.67

From table 6, removal efficiencies all water parameters were found to be increased up to optimum dosage. Maximum removal efficiencies of combination of moringa seed and tamarind seed for EC, turbidity, TSS, TDS, BOD, COD were 75%, 97.78%, 85.25%, 38.72%, 79.33% and 76.8% respectively at optimum dosage of 1.0g/l.

Removal efficiency of all coagulants for turbidity is graphically represented in Fig.4.

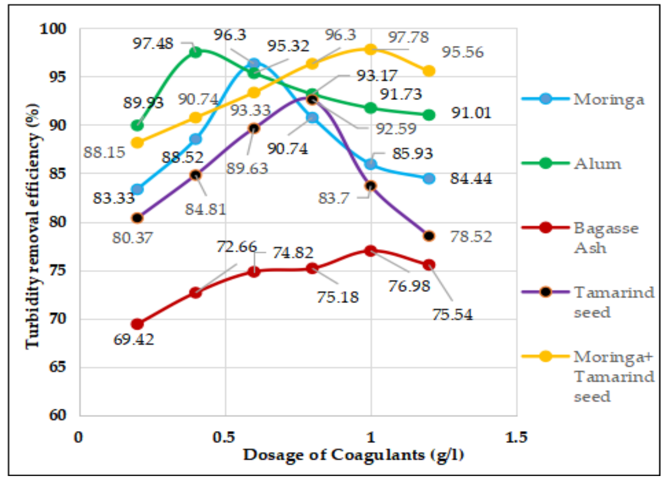

Fig. 4 Removal efficiency with varying dosages- Turbidity

Combination of moringa and tamarind seed had greater removal efficiency for turbidity among these coagulants. Bagasse ash powder was found to be least removal efficiency. At optimum dosage, removal efficiencies of all natural coagulants except bagasse ash had nearer values as compared to alum.

3.2 Effect of Stirring Time

Table 7 shows the details of water parameters after the treatment of domestic waste water by effect of stirring time on coagulation of moringa seed and tamarind seed powder.

TABLE 7
REMOVAL EFFICIENCY WITH VARYING STIRRING TIME- MORINAGA AND TAMARIND SEED

Parameter	Coagulant	Removal efficiency with varying stirring time (%)				
		10 min	15 min	20 min	25 min	30 min
EC	Moringa seed	68.00	73.80	78.00	77.50	76.10
Turbidity		90.33	96.33	98.33	95.67	94.33
TSS		74.41	79.71	88.30	87.2	85.56
TDS		30.24	36.43	38.10	37.14	35.71
BOD		54.43	78.2	81.64	83.77	80.82
COD		53.96	75.43	76.23	78.34	76.03
EC	Tamarind seed	58.00	68.80	73.00	71.00	69.50
Turbidity		86.67	92.67	94.33	92.33	91.00
TSS		72.58	77.88	83.55	81.35	79.89
TDS		28.57	32.62	34.05	32.14	31.19
BOD		51.64	77.70	78.69	79.02	76.56
COD		45.64	71.61	73.02	74.32	72.72

From table 7, maximum removal efficiencies of moringa seed for EC, turbidity, TSS, TDS, BOD, COD were 78%, 98.33%, 88.3%, 38.1%, 81.64 and 76.23% respectively at optimum dosage of 0.6g/l and constant settling time of 20min. And maximum removal efficiencies of tamarind seed for EC, turbidity, TSS, TDS, BOD, COD were 73%, 94.33%, 83.55%, 34.05%, 78.69 and 73.02% respectively at optimum dosage of 0.8g/l and constant settling time of 20min.

Removal efficiency of moringa seed powder and tamarind seed powder in different stirring time for turbidity is graphically represented in Fig.5.

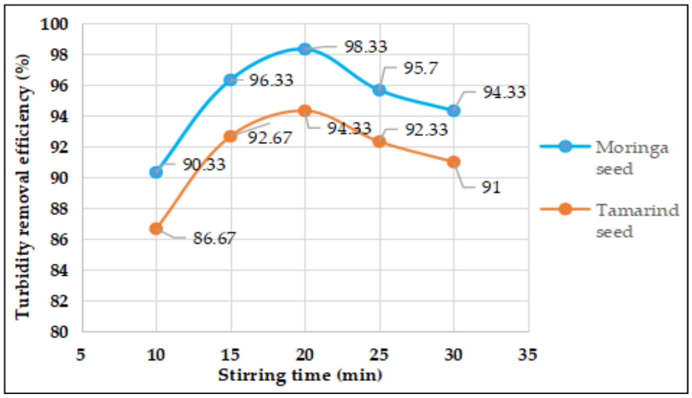

Fig. 5 Removal efficiency with varying stirring time- Turbidity

The maximum removal efficiencies for different water parameters were found to be at optimum stirring time of 20min for moringa seed and 20min for tamarind seed powder.

3.2 Effect of Settling Time

Table 4.8 shows the details of water parameters after the treatment of domestic waste water by effect of settling time on coagulation of moringa seed and tamarind seed powder.

TABLE 8
REMOVAL EFFICIENCY WITH VARYING SETTLING TIME- MORINGA AND TAMARIND SEED

Parameter	Coagulant	Removal efficiency with varying settling time (%)				
		10 min	20 min	30 min	40 min	50 min
EC	Moringa seed	66	78	80	78	77
Turbidity		94.67	98.33	98.67	97	95.33
TSS		83	88.3	89.95	87.57	86.84
TDS		33.33	38.1	38.57	36.67	36.67
BOD		75.9	81.64	82.13	81.64	80.33
COD		67.9	76.23	76.43	76.03	75.53
EC	Tamarind seed	64	73	74	76	71
Turbidity		90.67	94.33	95	96	92.33
TSS		77.15	83.55	84.46	85.01	82.08
TDS		32.14	34.05	34.52	34.76	33.57
BOD		71.15	78.69	79.02	79.51	77.54
COD		60.98	73.02	73.22	73.42	71.92

From table 8, maximum removal efficiencies of moringa seed for EC, turbidity, TSS, TDS, BOD, COD were 80%, 98.67%, 89.95%, 38.57%, 82.13 and 76.43% respectively at optimum dosage of 0.6g/l and optimum stirring time of 20min. And maximum removal efficiencies of tamarind seed for EC, turbidity, TSS, TDS, BOD, COD were 76%, 96%, 85.01%, 34.76%, 79.51% and 73.42% respectively at optimum dosage of 0.8g/l and optimum stirring time of 20min.

Removal efficiency of moringa seed powder and tamarind seed powder in different settling time for turbidity is graphically represented in Fig.6.

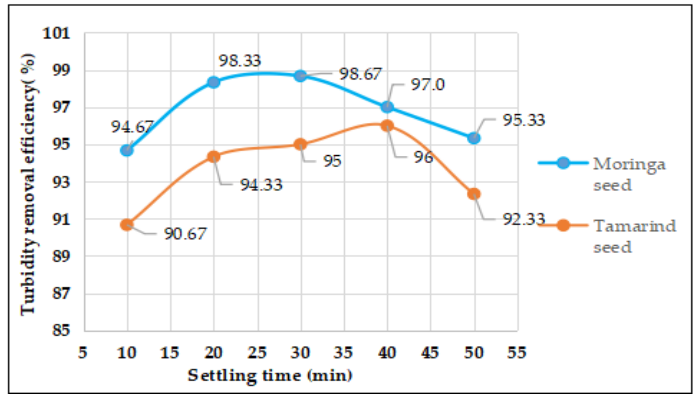

Fig. 6 Removal efficiency with varying settling time- Turbidity

The maximum removal efficiencies for different water parameters were found to be at optimum settling time of 30min for moringa seed and 40min for tamarind seed powder.

4 CONCLUSION

In this present study, an attempt has been made to evaluate the comparative effectiveness of chemical coagulant, Alum with natural coagulants such as Moringa Oleifera, Bagasse ash and Tamarind seed in domestic waste water treatment. The pH, electrical conductivity, turbidity, BOD, COD, TSS and TDS were determined in treated sample of coagulants and maximum reduction efficiency were found out. The maximum removal efficiencies for different water parameters of alum, moringa oleifera, bagasse ash, tamarind seed and combination of moringa and tamarind seed were found with optimum dosage of 0.4g/l, 0.6g/l, 1.0g/l, 0.8g/l and 1.0g/l respectively. According to results obtained, coagulation using combination of moringa seed and tamarind seed powder is a promising technique for kitchen waste water treatment. Moringa seed powder coagulant is more effective than the tamarind seed powder when used for the coagulation-flocculation process. And also single use of moringa at optimum stirring time of 20min and optimum settling time of 30min and tamarind seed at optimum stirring time of 20min and optimum settling time of 40min show good coagulation property at their optimum dosages as compared to alum. Inadequate and overdose of coagulants might result in poor performance. From the present study, it can be concluded that combination of moringa seed and tamarind seed powder as a natural coagulant found to be more effective and can be used as an alternative to chemical coagulant, alum. But in case of bagasse ash powder, it is not effective (as a natural coagulant) in reduction of various parameters of kitchen waste water. The utilization of locally available moringa seed powder and tamarind seed powder as coagulant is found to be suitable, easier, cost effective and environment friendly for waste water treatment.

Treated wastewater is also a resource that can be applied for productive uses since wastewater contains nutrients that have the potential for use in agriculture. Here the reuse of treated waste water which is less expensive can deliver positive benefits to the farming community. It can be concluded that domestic waste water and its nutrient content can be used extensively for irrigation after the treatment with moringa seed powder and tamarind seed powder as natural coagulant.

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