PERFORMANCE EVALUATION OF NATURAL COAGULANTS (CICER ARIETINUM AND ABELMOSCHUS ESCULENTUS) COMPARING WITH ALUM IN COAGULATION PROCESS

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ABSTRACT

Cicer Arietinum (CA), Abelmoschus esculentus (AE) seeds were investigated as an alternative natural material for treating surface water based on the problems arises with chemical coagulants like Alum. A threat for human health named Alzheimer's disease is associated with the high aluminium residual in treated water. Therefore alternative natural material has been emphasised as a solution. The study of lab results illustrates that natural coagulant helps reducing turbidity of different turbid water (50, 150, 250 NTU) sample are well. On the other hand result depicts that the problem related to reduction of pH due to chemical improves while using natural coagulant. Moreover the other observed variation associated with alum improves. Adding more, 30 mg/l of extract from CA found to be the best removal of turbidity to 39.43 NTU and AE has not been observed better than CA. Furthermore an certain amount of alum (10, 15, 20%) added with CA and AE for experiment and observed the per performance of CA and AE improves significantly. AC10% (Alum+Cicer Arietinum) of 20 mg/l has been performed efficiently reducing turbidity to 0-5 NTU for different turbid water sample. Meanwhile AC15% of 30 mg/l has been establish as capable of 100% efficient in reduction turbidity of all three different turbid water investigate on the study. Therefore, the study represents different quantity of extract from CA can reduce the turbidity as well as its performance increases while adding a small quantity of alum.

Keywords: *Alum; natural coagulant; turbid water; Cicer Arietinum; pH*

1. INTRODUCTION

Water is a prominent element for the earth survival and pure water is an emergent gem. Human can easily access only a small quantity of water which can be use for living. The most common and easily accessible water resource is known as surface water. But it becomes a discouraged one, due to its turbidity problem. The problem increases and decreases with the change of seasons. The maximum turbidity has been observed in the monsoon and reduces continuously as the water flow reduces in winter. It carries enormous amount of suspended and colloidal particle load caused by land erosion in monsoon. These suspended colloidal particles carry various types of impurities. Thus the surface water is not aesthetic for drinking as well as for use. Besides that, surface water is free from contamination problems found in ground water like arsenic. However, more than six million peoples die because of diarrhoea which is caused by drinking polluted water (Asrafuzzaman et al., 2011). Meanwhile, World Health Organization (WHO) has set the guideline value for the residual turbidity in drinking water at 5 Nephelometric Turbidity Units (NTU) (Eman et al., 2010; McConnachie et al., 1999). According to Bangladesh environmental quality standard (EQS, 1997) the maximum turbidity of drinking water is 10 NTU. Therefore, the treatment of water is necessary to reduce the turbidity. In treatment process, coagulation is one of the key parts. Coagulation and flocculation are very crucial for the removal of smaller or colloidal suspended dissolved particles from the surface water which is responsible for turbid water. Ghebremichael (2004), states that developing countries like Bangladesh spends a high cost importing chemicals for water treatment. Recent studies have indicated a number of serious drawbacks linked to the use of chemical coagulant like aluminium salts such as Alzheimer's disease associated with high aluminium residuals in treated water, excessive sludge production during water treatment and considerable changes in water chemistry due to reactions with the OH- and alkalinity of water (Muhammad et al., 2015; Crapper et al., 1973; Miller et al., 1984). Considering this serious problem, the concept of natural coagulant has been developed. There are several researches have been done on natural alternative materials for the coagulation process of water treatment. A recent research about utilization of natural coagulants for surface water treatment by Rahman and Tapadar (2014), depicts that natural coagulant like *Cicer Arietinum* (CA) is capable of reducing turbidity of water more than 86% to 87%. Furthermore, the better turbidity removal efficiency has been found while using mixed proportion AC20%

(Alum20% + CA80%), which is 95% to 99%. Encouraged from the researches, *Abelmoschus Esculentus* (AE) has been chosen to demonstrate the performance in reducing turbidity. Therefore, the research has prime focus to provide safe and clean water using locally available natural coagulants substituting the chemical coagulants.

2. METHODOLOGY

Emphasising on the different seasonal changes in turbidity of surface water in river, three different turbid water sample has been prepared namely high turbid (250 ntu), medium turbid (150 ntu) and low turbid (50 ntu). The selection of seeds as natural coagulating agent has been done from the previous researches. Rahman and tapadar (2014) states that the crude protein of seed works as coagulating agent. In this study, *Cicer Arietinum* (CA) and *Abelmoschus Esculentus* (locally known as Dherosh) were selected to investigate the performance. Therefore, CA and AE were collected from the local market. However, the Then the most important step coagulation and flocculation is accomplished by jar test apparatus. Afterwards, different laboratory tests like, turbidity, pH, TS, DS were performed and analyzed.

2.1 Preparation of artificial water sample

Artificial water sample has been prepared by mixing distilled water with the raw surface water. The raw surface water has been collected from local surface water source river Surma maintaining standard procedure followed by Blix (2011).

2.2 Collection of active agents from the seeds

Figure 2.1: CA and its powder

Figure 2.2: AA and its powder

Naturally dried good seeds of *Cicer Arietinum* (CA) and *Abelmoschus Esculentus* (AE) were collected from the plant and removed from the pod for sun dry. After that kernel of the seed has been crushed and mashed in powder (figure 2.1, 2.2). The procedure continues with sieving the powder in 600 µm (Rahman and Tapadar, 2014; Asrafuzzaman et al., 2011). The fine powder has been added to distilled water to make 1% w/V solution (figure 2.3) and shaken vigorously for 20 minutes at a room temperature to extract active components (Blix, 2011). Subsequently the solution was filtered through the filter paper (Whatman no. 42, 125mm dia.) once (figure 2.4). The seed solutions were then kept and stored in refrigerator at a temperature of 4º C.
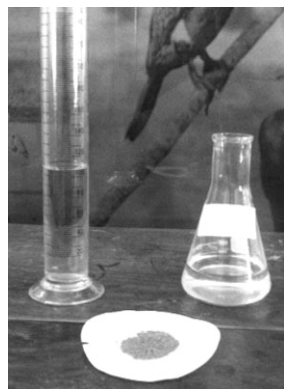

Figure 2.3: Samples before extraction

Figure 2.4: Filtration part of extracting active agents

2.3 Jar testing procedure and lab tests

Jar test is the most widely used experimental method for coagulation and flocculation. It was performed, accommodating a series of four 1000 ml beakers together with four spindle steel paddles. Prior to the operation

of jar test the sample was mixed properly and poured into the beakers (figure 2.5). Subsequently, the desired amount of coagulants doses 10-40mg/l have been added to the suspension, the water has been agitated at various mixing time and speed, which consist of rapid mixing (180-200 rpm) for 4 minutes and slow mixing (30-40 rpm) for 20 minutes (Rahman and Tapadar, 2014). After the agitation being stopped, the suspensions were allowed to settle for 60 minutes so that the flocs sink to the bottom of the beakers as a residue. After settling period turbidity, pH, total solid and dissolved solid were tested. All tests were performed at an ambient temperature in range of 25-29°C for different turbidity level of water.

Figure 2.5: Jar test operation

2.4 Methods of data collection

Focusing on the key part of turbidity reduction, the experiment was done with Microprocessor Turbidity Meter (HI 93703 by HANNA Instruments). pH was tested with pH meter (HI 8014 by HANNA Instruments) also the Total and dissolved solid tests were done following standard of AWWA.

3. RESULTS AND DISCUSSIONS

The performance evaluation of natural coagulants as a coagulating agent has been emphasised on this research. Various laboratory tests have been done for the evaluation and results obtained from tests provided the
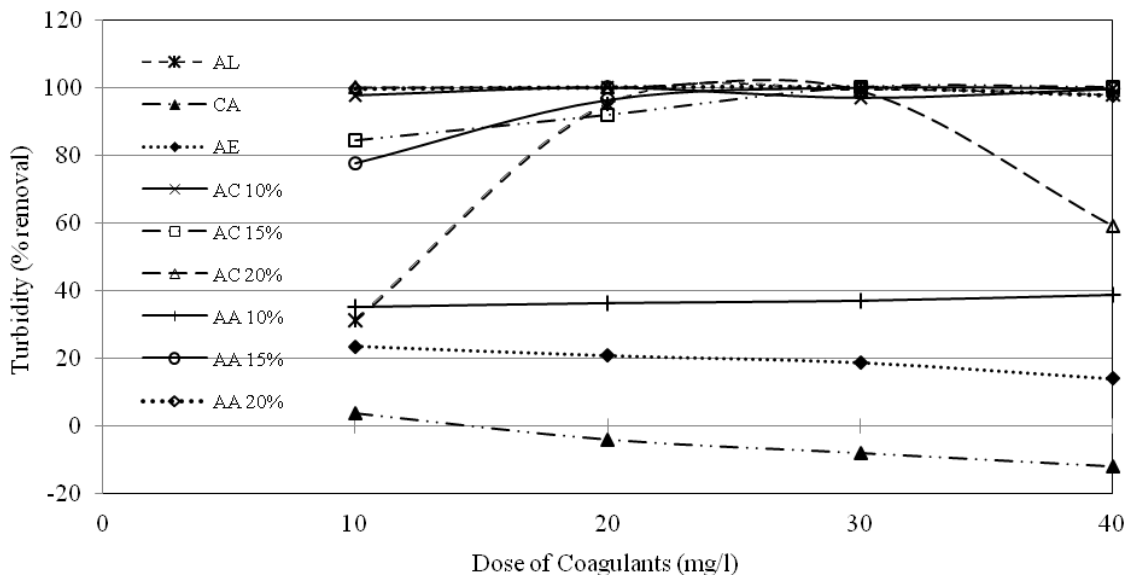

Figure 3.2: % removal of turbidity with variable dosage (iTur = 50 NTU)

significant information about the performance of natural coagulant *Cicer Arietinum* (CA) and *Abelmoschus Esculentus* (AE) comparing with chemical coagulant Alum (AL). The experiments have been done for high (250

ntu), medium (150 ntu), and low turbid (50 ntu) water with variable doses (10, 20, 30, 40 mg/l) of coagulants where the performance of individual coagulant has been observed. The result shows 30 mg/l dose of CA removes more than 80% turbidity for 250 ntu sample (Table 3) where the removal efficiency was not satisfactory for medium and low turbid water sample. The performance of AE ranges only 13-34% for three turbid water samples and CA has shown removal efficiency up to 78% (figure 3.3) for highly turbid water
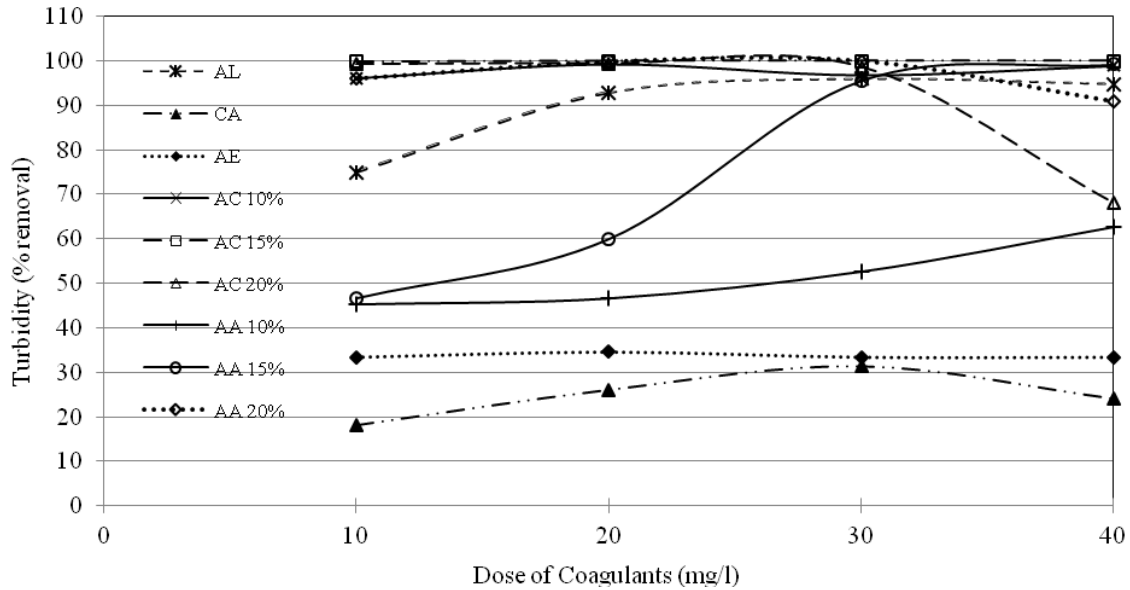

Figure 3.2: % removal of turbidity with variable dosage (iTur = 150 NTU)

sample. Meanwhile CA increases turbidity for 50 ntu sample (figure 3.1) where the decrease of removal percentage shows the increase of turbidity. This increase of turbidity may cause due to active CA particles present in the solution even after full completion of processes. Perceiving the output of individual natural coagulant, the further study has been done by mixing small percentage (10-20%) of chemical coagulant (AL)
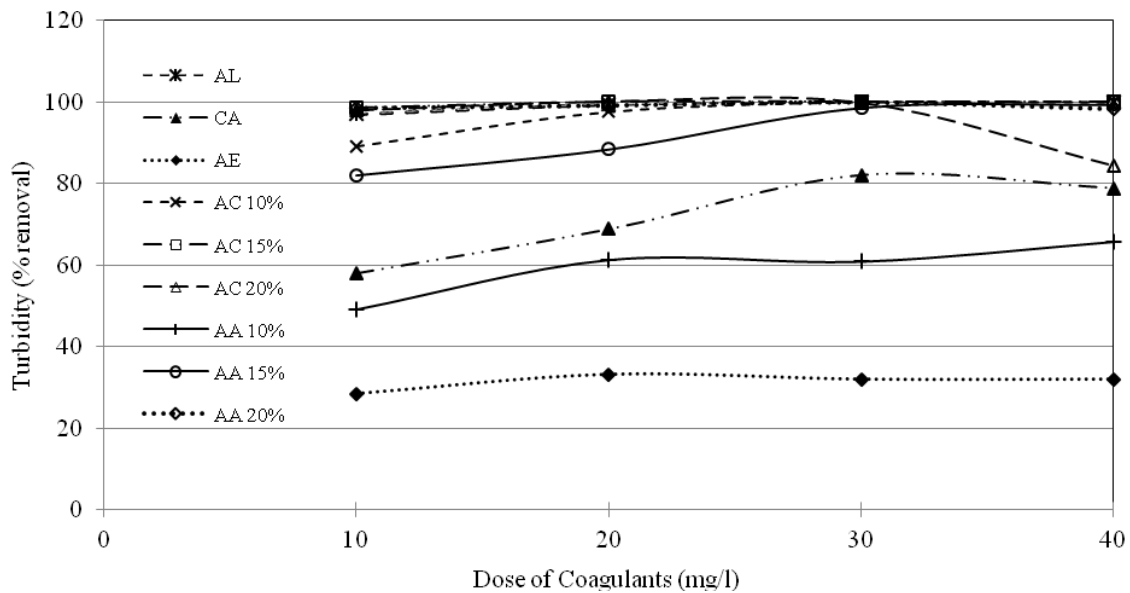

Figure 3.3: % removal of turbidity with variable dosage (iTur = 250 NTU)

with natural coagulant. However the performance of natural coagulant increases dramatically. Evaluating all results AC10% (Al 10% + CA 90%) and AA20% (Al 20% + AE 80%) exhibits the best removal efficiency (96-

100%) for low turbid water with various doses. Adding more, for medium turbid water AC10%, AC15% and AA20% has been capable of reducing turbidity more than 96%. Meanwhile in terms of high turbid water,AC10%, AC15% and AA20% shows a satisfactory result, removing up to 100% of turbidity which is closer to the result found by Rahman and Tapadar (2014) investigating the performance of mixture of AC (Al + CA). Even the problem associated with reducing pH for chemical coagulant improves using natural coagulant

Table 1: Percent change of different parameters with variable dosages (for 50 NTU)

Coagulant	Dosage (mg/l)	Turbidity (% removal)	pH (% change)	Total Solid (% change)	Dissolve Solid (% change)
Alum	10	31.2	4.76	6.45	22.19
	20	95.24	10.44	22.58	94.61
	30	99.48	17.66	32.25	99.41
	40	97.94	23.34	9.67	97.67
CA	10	3.84	0	3.22	-8.75
	20	-4	-0.46	6.45	-17.61
	30	-8	-1.22	12.90	-22.14
	40	-12	-2.76	19.35	-26.66
AE	10	23.52	0.15	19.35	13.50
	20	20.76	0.46	16.12	10.38
	30	18.7	1.22	9.67	8.05
	40	13.96	1.68	22.58	2.69
AC10%	10	97.72	4.30	16.12	97.42
	20	100	4.76	32.25	100
	30	96.98	5.06	12.90	96.58
	40	99.6	5.52	25.80	99.54
AC15%	10	84.3	5.68	25.80	100
	20	91.82	5.06	22.58	100
	30	100	4.91	16.12	100
	40	100	6.29	9.67	100
AC20%	10	100	5.22	0	100
	20	100	5.68	32.25	100
	30	99.06	5.99	19.35	98.93
	40	59.06	6.91	9.67	53.69
AA10%	10	35.32	-0.30	22.58	26.85
	20	36.4	0	19.35	28.07
	30	37.04	1.68	6.45	28.79
	40	38.62	2.45	25.80	30.58
AA15%	10	77.58	1.53	22.58	74.64
	20	96.4	1.84	22.58	95.92
	30	100	2.61	16.12	100
	40	99.74	3.22	19.35	99.70
AA20%	10	99.6	2.30	19.35	99.54
	20	100	3.22	9.67	100
	30	100	3.53	22.58	100
	40	97.6	4.76	29.03	97.28

and its mixture. The total solid (TS) and dissolved solid (DS) tests have been also done to see the particle behaviour. It has been observed that the amount of DS   decreases with the decrease of turbidity for this study. Meanwhile low turbid (50 ntu) water sample, it has been observed that the turbidity increases with the increase of doses using CA and AE separately (figure 1).Moreover the performance of AL improves while mixing with CA and AE. Although other mixing proportion performs good, 20 mg/l of AC10% displays the best removal efficiency (100%) considering least quantity of AL has been used for mixture (figure 3.1; table 1). However for medium turbid water it has also been observed that AC10% can remove more than 99% while AC15% removes 100%. Considering the lowest dose 10 mg/l dose of AC15% depicts 99.81% of turbidity removal (figure 3.2). Moreover the performance of AC10%, AC20% and AA20% shows good removal efficiency. Figure 3.2, also shows that the removal efficiency reduces with the increase of the dose in the sample and AL in the mixture.

Furthermore, AE shows better performance than CA while using individually. AE has been removed more than 34% of turbidity using 20 mg/l (figure 3.2) even though it is not closer to the removal efficiency of AL where more than 90% has been removed. From previous researches, it has been known that the removal efficiency of coagulant increases with the increase of turbidity. Therefore testing high turbid water it has been found that the removal efficiency of CA increases up to 82% using 20 mg/l. Moreover the pH of the sample increases about 0.45% which is far better than the AL where removal efficiency ranges 97-100% while the pH decreases 17-36% (table 3). The performance of AE was not satisfactory as there was no increase in removal percentage of turbidity.

Table 2: Percent change of different parameters with variable dosages (for 150 NTU)

Coagulant	Dosage (mg/l)	Turbidity (% removal)	pH (% change)	Total Solid (% change)	Dissolve Solid (% change)
Alum	10	74.97	3.41	-2.04	71.69
	20	92.86	9.47	12.24	91.93
	30	96	15.83	6.12	95.47
	40	94.83	19.25	2.04	94.16
CA	10	18	0.31	-6.12	16.67
	20	26	0.93	0	29.58
	30	31.33	1.24	4.08	40.42
	40	24	1.55	-2.04	24.58
AE	10	33.33	0.46	-4.08	24.60
	20	34.66	0.62	6.12	26.11
	30	33.33	2.17	16.32	24.60
	40	33.33	3.26	6.12	24.60
AC10%	10	96.16	0.62	0	95.66
	20	99.34	1.24	6.12	99.25
	30	96.86	2.95	8.16	96.45
	40	98.97	4.96	12.24	98.84
AC15%	10	99.81	1.39	14.28	99.79
	20	100	2.32	4.08	100
	30	100	3.41	8.16	100
	40	100	3.88	16.32	100
AC20%	10	99.22	2.01	2.04	99.13
	20	99.41	2.95	14.28	99.34
	30	98.60	4.19	16.32	98.42
	40	68.12	6.05	4.08	63.95
AA10%	10	45.33	0.46	-2.04	38.17
	20	46.66	1.39	6.12	39.68
	30	52.66	1.70	14.28	46.47
	40	62.66	3.10	8.16	57.78
AA15%	10	46.66	1.70	4.08	39.68
	20	60	3.88	12.24	54.76
	30	95.62	5.27	0	95.05
	40	99.26	5.59	16.32	99.16
AA20%	10	96.00	1.39	8.16	95.48
	20	99.81	4.50	16.32	99.78
	30	100	5.90	6.12	100
	40	90.90	6.98	14.28	89.71

For the mixing proportion, performance increases as usual. AC (10%,15%,20%) shows really good results for all the doses where AC15% shows the better removal percentage ranging 98%-100% (figure 3.3). Meanwhile for AA the result shows better performance than previous low and medium turbid water. AA20% has been illustrating the good result removing up to 100% with 20 mg/l. But the pH decreases with the increase of doses. However in this study the artificial water sample has been prepared mixing distilled water with raw surface water sample and the investigation regarding the change of pH has not been more than 0.5-1%.

Table 3: Percent change of different parameters with variable dosages (for 250 NTU)

Coagulant	Dosage (mg/l)	Turbidity (% removal)	pH (% change)	Total Solid (% change)	Dissolve Solid (% change)
Alum	10	97.06	17.94	9.83	96.76
	20	99.33	27.14	3.27	99.26
	30	100	33.78	13.11	100
	40	100	36.80	8.19	100
CA	10	58	0.45	14.75	53.65
	20	68.8	0.15	6.55	65.57
	30	82	-0.15	4.91	80.13
	40	78.8	-0.45	1.63	76.60
AE	10	28.4	-1.05	16.39	20.99
	20	33.2	-1.35	9.83	26.29
	30	32	-1.50	14.75	24.97
	40	32	-2.11	3.27	24.97
AC10%	10	89.2	1.65	-1.63	88.08
	20	97.59	3.46	4.91	97.34
	30	100	4.37	11.47	100
	40	100	4.22	3.27	100
AC15%	10	98.68	2.86	1.63	98.54
	20	100	3.46	0	100
	30	100	5.27	6.55	100
	40	100	6.63	4.91	100
AC20%	10	97.86	5.42	4.91	97.64
	20	100	6.18	11.47	100
	30	99.68	7.84	3.27	99.65
	40	84.36	10.55	8.19	82.74
AA10%	10	49.2	0.15	9.83	43.94
	20	61.2	0.75	14.75	57.18
	30	60.8	1.80	11.47	56.74
	40	65.6	3.01	0	62.04
AA15%	10	82.04	4.22	-1.63	80.18
	20	88.38	4.82	3.27	87.18
	30	98.54	5.73	4.91	98.38
	40	99.33	7.08	1.63	99.26
AA20%	10	98.58	4.97	8.19	98.43
	20	99.21	5.58	4.91	99.13
	30	100	6.48	13.11	100
	40	98.34	8.89	9.83	98.16

4. CONCLUSIONS AND RECOMMENDATIONS

Drinking water free from impurities is a prime need for humans to live. Availability of surface water encourages the research to focus on it. But the existing turbidity in surface water impeded the proper utilization of this resource. Therefore the study focuses on reduction of turbidity using locally available natural coagulants as there is several drawbacks of chemical coagulant threatening human health. The results of the study depicts that the performance of natural coagulant *Cicer Arietinum* (CA) is better than *Abelmoschus Esculentus* (AE). But the maximum removal efficiency of more than 80% has been found for high turbid water sample with 30 mg/l dose. The removal efficiency of AE was not satisfactory comparing with CA. Meanwhile AL showed the optimum performance, but the problem regarding the decrease of pH was noticeable. However, when a small percentage of alum was mixed with the natural coagulant, the turbidity removal efficiency increased substantially like alum and significant pH improvement was observed as well. The research outcome depicts that the combination of alum and natural coagulant is effective reducing turbidity. All the mix proportion of (Alum+*Cicer Arietinum*) AC (10,15,20%) and (Alum+*Ambelmoschus Esculentsus*) AE (10,15,20%) works effectively but AC10% (AL 10% + CA 90%), AC15% (AL 15% + CA 85%) and AA20% (AL 20% + AE 80%) shows the optimum removal efficiency for low turbid water (50 ntu). Study shows, AC10%, AC15% and

AA20% can remove the turbidity more than 97%. However for medium turbid water (150 ntu), CA and AE has shown the removal efficiency below the 35%. On the other hand AC10%, AC15% and AA20% have the better turbidity removal efficiency than others and AC15% has pointed as removed more than 99%. From various researches it is known that the coagulant works better in high turbid water. The research has also found the similarity with this statement. Meanwhile for high turbid water (250 ntu), CA has removal efficiency of 82% with 30 mg/l dose. AC10%, AC15% and AA20% have depicted overall better removal efficiency more or less 90-100%. It has also been noticed that after a certain point the more increase of AL percentage in the mixtures increases the turbidity. On the other hand, the pH and dissolved solid (DS) demonstrates a reasonable result for AC15% with 100% removal efficiency for three turbid water sample tested in this research using 30mg/l doses. Finally the experimental result illustrates AC has overall better removal efficiency than AA. Even it needs fewer doses than AA. In short, the research outcome illustrates 30mg/l of AC15% (Alum+*Cicer Arietinum*) as the optimum. Meanwhile there are several scopes for this research where other water testing parameters should be investigated. The research outcome may demonstrate on small scale of water treatment plant for observing accuracy.

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REFERENCES

Asrafuzzaman, M., Fakhruddin, A.N.M., Hossain, M.A., (2011). Reduction *of turbidity of water using locally available natural coagulants*. International Scholarly Research Network, ISRN Microbiology. Article ID 632189:6,doi:10.5402/2011/632189.

Blix, A., (2011). *Enhancing the capacity of seeds as turbidity removal agents in water treatment*. TRITA-LWR Degree Project. KTH Land and Water Resources Engineering.

Crapper, D.R., Krishnan, S.S., Dalton, A.J., (1973). *Brain aluminum distribution in Alzheimer's disease and experimental neurofibrillary degeneration*. *Science*, 180 (4085): 511 – 513.

Eman, N.A., Suleyman, A.M, Hamzah, M.S., Alam, M.Z., Salleh, M.R.M., (2010). *Production of natural coagulant from Moringa Oleifera seed for application in treatment of low turbidity water*. Journal of Water Resource and Protection. 2(3):259-266.doi:10.4236/jwarp.2010.23030.

Ghebremichael, K.A., (2004). *Moringa seed and pumice as natural alternative materials for drinking water treatment*. Ph.D.thesis, KTH Land and Water Resources Engineering.

McConnachie, G.L., Folkard, G.K., Mtawali, M.A., Sutherland, J.P., (1999). *Field trials of appropriate hydraulic flocculation processes.* Water Research. 33(6):1425–1434.

Miller, R.G., Kopfler, F.C., Kelty, K.C., Stober, J.A. Ulmer, N.S., (1984). *The occurrence of aluminum in drinking waters*. J. AWWA, 76: 84-91.

Rahman, M.M., & Tapadar, M.H.A., (2014). *Utilization of natural coagulants for surface water treatment* (Unpublished bachelor thesis). Leading University.