A Study on the Comparison of Coagulants Efficiency in River Water Treatment

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Abstract

In this research, the effectiveness of the use of coagulants such as poly aluminum chloride (PAC) and aluminum sulphate (alum) in river water treatment for potable purposes were studied. The river water samples were treated by less cost effective conventional method, coagulation. In this study water samples were collected from the Hlaing River near Ba Yint Naung bridge in Hlaing Township and from the Yangon river near Botahtaung jetty in Botahtaung Township and analysed for a number of water quality parameters such as temperature, pH, color, odor, electrical conductivity, turbidity, alkalinity, hardness, total solids, suspended solids, total dissolved solids, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total bacteria, E.coli, arsenic, cadmium, lead and absorbances at 254 nm, 465 nm and 665 nm wavelengths (called the E4/E6 ratio). Water samples were treated by coagulation with alum and PAC. The effectiveness of coagulation on the river water was studied by investigating the quality of river water and it was also assessed by comparing with WHO guideline. The optimal alum dosage of 20 mg/L significantly increased the removal efficiencies of turbidity, BOD, COD by 98.18, 60 and 45% for sample (1) and 98.15, 65 and 45% for sample (2) respectively. The optimal PAC dosage of 20 mg/L significantly increased the removal efficiencies of turbidity, BOD, COD by 98.78, 65 and 48% for sample (1) and 98.68, 75 and 50% for sample (2) respectively. According to the results, the removal percentage of the use of PAC was better than alum.

Keywords: PAC, alum, coagulation, turbidity

Introduction

Aluminium sulphate (alum) is, among the most widely applied coagulant agents, used mainly for the treatment of drinking water. The conventional treatment processes applied in most large-scale drinking water plants include typically the coagulation–flocculation step, followed by sedimentation and by gravity filtration through granular filter beds (usually consisted from sand). The coagulant agents, such as alum, are usually added during the initial stage of coagulation process, in order to enhance the removal of suspended solids, including colloidal particles, as well as of natural organic matter (NOM) (Huang, C. and Pan, J. ,2002). However, the efficiency of coagulants for the production of high quality water is often determined by the operational conditions. Thus, the selection of an appropriate coagulant, its dosage and various other operational parameters, such as the water temperature and the pH control, may significantly affect the coagulation-flocculation process and the subsequent treatment steps of sedimentation and filtration (Weber, W.J. (1972). More recently, the research related to coagulation processes was focused on the production of new and more effective coagulants. Coagulants are chemical substances, carrying a positive charge on their surface. Upon their addition in water and following their hydrolysis, the (usually) negatively charged colloidal impurities will be destabilized by the action of various mechanisms, such as charge neutralisation, due to mutual electrical attraction, or sweep flocculation (Duan, J. and Gregory, J.,2003). Polymeric aluminium compound has been proposed for drinking water treatment, as an alternative coagulant agent to alum, termed poly-aluminium chloride (PAC). PAC is a poly-nuclear form of $AlCl_3$ species, already contained highly positive charged species, such as "Al_{13}" in relatively high concentrations, even without the hydrolysis step.

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Consequently, PAC is considered as a more efficient coagulant than alum, mainly because of its higher overall positive charge. The aim of this study was to evaluate comparatively the efficiency of alum and PAC for the treatment of surface (river) water in a full-scale drinking water facility, the determination of optimum main operational conditions, i.e., coagulant dosage and pH, and the assessment of the overall performance of the river water treatment. Some physical, chemical and biological characteristics of raw water were determined and water samples were treated by coagulation with alum and PAC (Polyaluminum Chloride). Characteristics of raw and treated water samples were determined and compared with efficiency of coagulants.

Materials and Methods

Sample Collection and Investigation

Hlaing river and Yangon river were selected for the collection of the study of water sample during the rainy season. Water samples were collected near Ba Yint Naung bridge and near Botahtaung jetty. Sample collection point was presented on the sampling map of study area (Fig.1). River water samples were collected at a distance of about 30 ft from the river-bank and at a depth of 3 ft below the surface of the river. After that, raw samples were promptly transported in a cool-box to the laboratory of Department of Industrial Chemistry, Dagon University where most of the examinations were performed according to the standard methods for examination of water and wastewater. The samples were tested for initial values of pH using a pH meter HANNA Waterproof Tester, HI98127, turbidity using a portable HACH 2100Q turbidity meter, conductivity and total dissolved solids(TDS) using a Mi306 Automatic and logging on TDS/conductivity meter, color using a HACH test kit color model co-1 colorimeter, dissolved oxygen using a HANNA HI9146 dissolved oxygen meter, and temperature using a digital thermometer attached to the pH Meter. Turbidity for samples were collected ranged from 3.55 to 39.8 NTU.

Materials

Coagulants like Aluminium Sulfate (Alum), and Poly aluminium chloride (PAC), were purchased from 'Golden Lady' 28th street, Pabedan Township, Yangon Region.

Preparation of coagulant chemicals

Stock coagulant solutions should be made to a strength 1ml added to a litre of raw water will give a dose equalling 10 mg/L (Ghníomhaireacht *et al.*, 2002). In this study, stock solutions of aluminium sulphate and PAC were made at an equal 1% strength (weight/volume), since the raw water is mostly low turbidity.

Treatment of Water Samples by Coagulation using Alum

Water sample (1 liter) was placed in a beaker and left on the table for 24 hr by gravitational force to settle out. Then, the water sample was decanted carefully, making sure that the settled particles were not disturbed. Then, 5 mg/L of alum was added to the beaker. The contents of the beaker were stirred and held quiescently on a table for 24 hr. The supernatant solution was then decanted into another beaker. After coagulation, treated water sample was collected. The effectiveness of the treatment system using plain sedimentation followed by coagulation were studied by investigating the pH, turbidity, UV_{254}, E4/E6 ratio (calculated from the UV_{465}/UV_{665}) of the water samples and the results are shown in Tables (2 & 3). The same procedure was repeated for different amounts of alum such as 10 mg/L, 15 mg/L, 20 mg/L and 25 mg/L and their respective data are tabulated in Tables (2 & 3).

Treatment of Water Samples by Coagulation using PAC

The same procedure mentioned in using alum was carried out but coagulant (PAC) was used. The effectiveness of treatment system using plain sedimentation followed by coagulation with PAC with different doses of (5 mg/L, 10 mg/L, 15 mg/L, 20 mg/L, 25 mg/L) was studied by investigating the pH, turbidity, UV_{254}, E4/E6 ratio (calculated from the UV_{465}/UV_{665}) of the water samples and the results are shown in Tables (2 & 3).

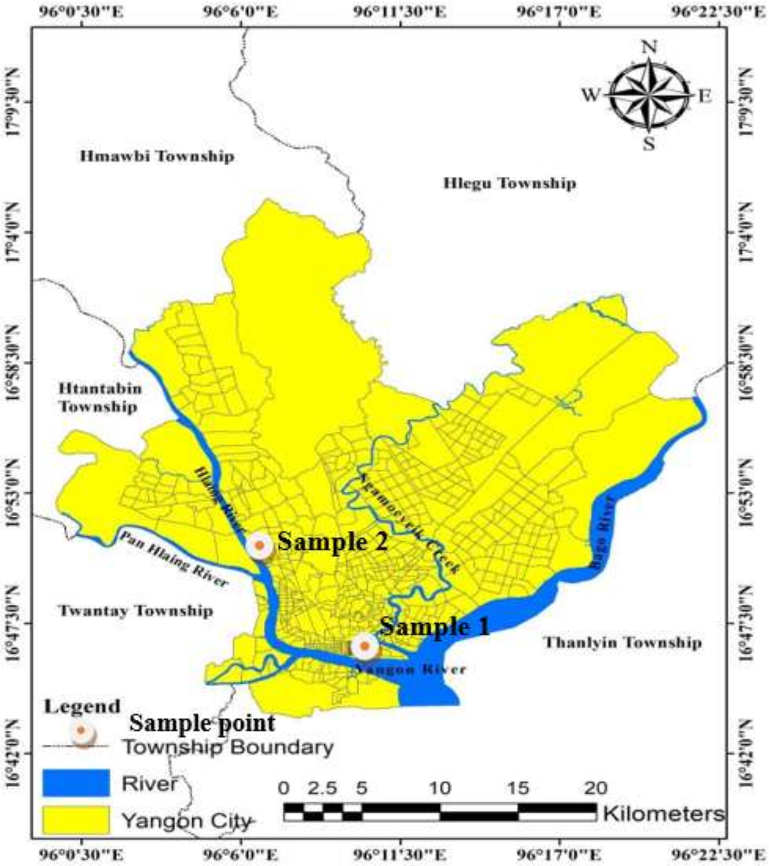

Figure 1. Sampling map of study area

Results and Discussion

The characteristics of river water sample from Yangon River (Sample-1) and Hlaing River (Sample-2) are determined. These results are expressed in Table (1) and compared with WHO drinking water standard. According to this table color, turbidity, BOD, COD, total bacteria and E. coil are higher than WHO drinking water standard. Some of the characteristics of river water samples are higher than WHO drinking water standard and unsuitable for potable purposes. The results indicate that water samples require appropriate treatment by physical, chemical and biological water treatment methods. So, the water samples are treated by coagulation using alum and PAC.

Table (2 & 3) show that treatment of river water by coagulation using varying doses (5, 10, 15, 20 and 25mg/L) of alum and PAC. The organic substance content of sample is determined by the use of UV absorbance at wavelengths of 254 nm (Szerzyna1.S et al., (2017). The ratio of absorbances of dilute aqueous solutions of humic materials at 465 and 665 nm (called the E4/E6 ratio) are commonly used to characterize humic materials. E4/E6 ratios for humic acids are determined to be in the 5.44 - 5.7 range and for fulvic acids in the 8.88 -

9.9 range (Chen et.al, 1977). The E4/E6 ratio of water samples are found between 1.0 and 1.3. These values are much lower than references. According to the results, the water samples do not contain significant amount of humic and fulvic acids.

Absorbance decreases with increasing amount of alum and PAC. If alum and PAC dosages are more than 20 mg/L, both absorbance and pH decrease. However, if alum and PAC dosages are less than 20 mg/L, the water samples are turbid. At 20 mg/L of alum and PAC dosage, percent removal of turbidity is the highest. It is noted that the optimum dose of alum and PAC are 20 mg/L. Generally, turbidity removal increased with dosage for both coagulants. For turbidity of PAC is more efficient than alum as shown in Figure (2 & 3).

Table (4) shows that comparisons of removal efficiency of coagulants of river water before and after treatment. According to these results, % removal of color, turbidity, TS, SS, TDS, BOD, COD, total bacteria and E. coli by using PAC are higher than alum as shown in Fig (4 & 5). But the results of removal of BOD, COD, total bacteria and E. coli by coagulation are found to be unsatisfactory. And then pH, color, turbidity, TS, SS, TDS fall in the range of WHO Standard whereas BOD, COD, total bacteria and E. coli do not fall in the range of WHO Standard. So, another effective water treatment method should be used for potable purposes.

Table 1. Characteristics of River Water Samples

No.	Parameter	Sample (1)	Sample (2)	WHO Drinking Water Standards	
				Desirable	Permissible
1	pH*	7.2	7.4	7-8.5	6.5-9.2
2	Color ** (TCU)	180	200	5	25
3	Odor*	Nil	Nil	Unobject	Unobject
4	Turbidity **(NTU)	330	380	5	25
5	Temperature* (°C)	28.6	28.9	-	<25
6	Electrical Conductivity* (µs/cm)	73.3	114.5	100	750
7	Total Solids* (TS) (mg/L)	100	150	500	1500
8	Suspended Solids*(SS) (mg/L)	63.3	113.4	30	500
9	Total Dissolved Solids* (TDS) (mg/L)	36.7	36.6	450	1000
10	Dissolved Oxygen* (DO)(mg/L)	6.88	6.78	-	>5
11	Alkalinity**** (mg/L)	81	86	-	120
12	Hardness**** (mg/L)	20	32	-	250
13	BOD** (mg/L)	20	22	-	<5
14	COD** (mg/L)	64	64	-	10
15	Arsenic**** (mg/L)	0	0	0.01	0.01
16	Cadmium**** (mg/L)	ND	ND	0.003	0.003
17	Lead**** (mg/L)	ND	ND	0.01	0.01
18	Total Bacteria***(CFU/ml)	46×10^2	12×10^2	0	0
19	E.coli*** (CFU/ml)	10×10^6	20×10^6	ND	ND

ND=Not Detected

* The samples were analysed at the laboratory of Department of Industrial Chemistry, Dagon University.

** The samples were analysed at the laboratory of ISO TECH, Insein Township, Yangon.

*** The samples were analysed at the laboratory of Pharmaceutical Research Department, Insein, Gyo Gone.

**** The samples were analysed at the laboratory of Ecological Laboratory, ALARM, Kan Street, Hlaing Township, Yangon.

Table 2. Treatment of River Water by Coagulation using Varying Doses of Alum and PAC (Sample 1)

Sr. No.	Dose (mg/L)	pH		UV_{254}		E4/E6		Turbidity	
		Alum	PAC	Alum	PAC	Alum	PAC	Alum	PAC
1	0	7.2		0.705		1.133		330	
2	5	7.2	7.1	0.0161	0.103	1.282	1.102	22	19
3	10	7.2	7.1	0.119	0.098	1.100	1.102	13	12
4	15	7.2	6.9	0.108	0.096	1.157	1.026	9.5	7.5
5	*20	7.1	6.8	0.102	0.090	1.135	1.027	6	4
6	25	6.4	6.5	0.101	0.087	1.055	1.027	5.5	3.8

*Optimum dose

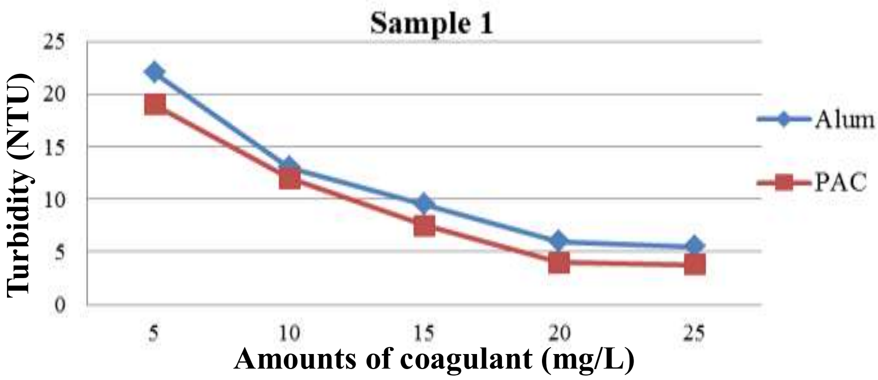

Figure 2. Effect of varying amounts of coagulant on turbidity of water (Sample 1)

Table 3. Treatment of River Water by Coagulation using Varying Doses of Alum and PAC (Sample 2)

Sr. No.	Dose (mg/L)	pH		UV_{254}		E4/E6		Turbidity	
		Alum	PAC	Alum	PAC	Alum	PAC	Alum	PAC
1	0	7.4		1.020		1.297		380	
2	5	7.3	7.4	0.116	0.098	0.892	1.157	32	29
3	10	7.3	7.2	0.106	0.096	0.937	1.131	26	21.4
4	15	7.2	7.0	0.101	0.096	1.047	1.111	12.5	10.9
5	*20	7.1	7.0	0.096	0.092	1.111	1.114	7	5
6	25	6.5	6.5	0.096	0.089	1.083	1.114	6.8	4.6

*Optimum dose

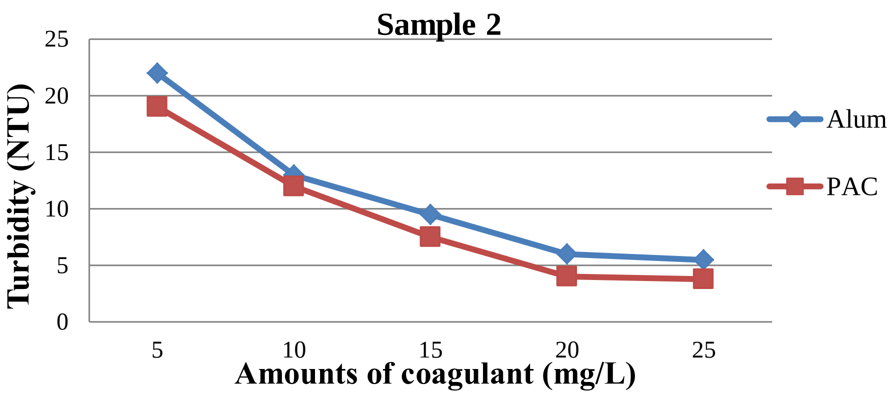

Figure 3. Effect of varying amounts of coagulant on turbidity of water (Sample 2)

Table 4. Comparisons of Removal Efficiency of Coagulants of River Water Samples Before and After Treatment

No.	Parameter	Sample (1)			Sample (2)		
		Before Treatment	After Treatment		Before Treatment	After Treatment	
			Alum	PAC		Alum	PAC
1	pH*	7.2	7.1	6.8	7.4	7.1	7.0
2	Color ** (TCU)	180	Nil	Nil	200	Nil	Nil
3	Odor*	Nil	Nil	Nil	Nil	Nil	Nil
4	Turbidity **(NTU)	330	6	4	380	7	5
5	Temperature* (°C)	28.6	28.1	28.1	28.9	28.3	28.3
6	EC*(μs/cm)	73.3	65.7	64.5	114.5	69.2	66.3
7	Total Solids* (mg/L)	100	50	40	150	60	50
8	Suspended Solids* (mg/L)	63.3	16.7	7.3	113.4	27	23.1
9	TDS*(mg/L)	36.7	33.3	32.7	36.6	33.0	30.9
10	DO* (mg/L)	6.88	5.65	5.63	6.78	5.98	5.95
11	Alkalinity**** (mg/L)	81	78	72	86	77	74
12	Total Hardness**** (mg/L)	20	18	15	32	30	30
13	BOD** (mg/L)	20	8	7	22	7.5	5.5
14	COD** (mg/L)	64	35	33	64	35	32
15	Arsenic**** (mg/L)	0	0	0	0	0	0
16	Cadmium**** (mg/L)	ND	ND	ND	ND	ND	ND
17	Lead**** (mg/L)	ND	ND	ND	ND	ND	ND
18	Total Bacteria***(CFU/ml)	46×10^2	2×10^2	1×10^2	12×10^2	2×10^2	2×10^2
19	E.coli*** (CFU/ml)	10×10^6	6×10^6	9×10^6	20×10^6	15×10^6	16×10^6

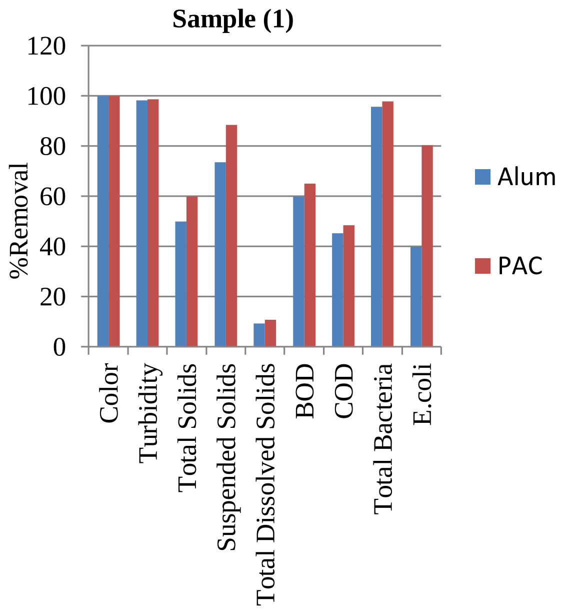

Figure 4. Comparisons of efficiency of percent removal of coagulants (Sample-1)

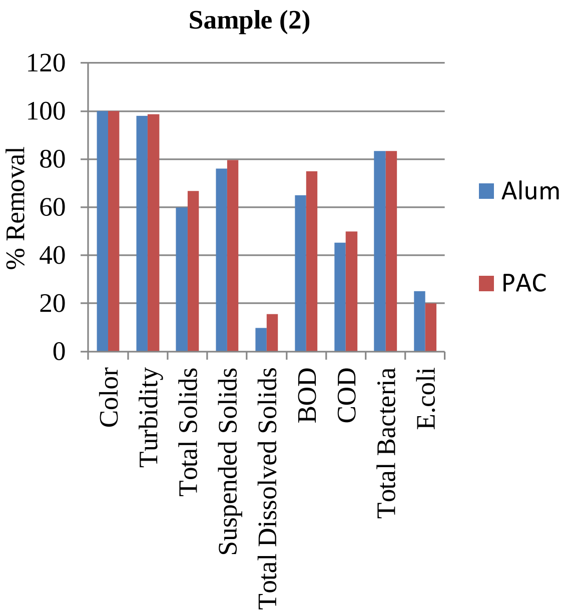

Figure 5. Comparisons of efficiency of percent removal of coagulants (Sample-2)

Conclusion

In this research, the contaminated river water from Hlaing river and Yangon river was not suitable for drinking due to the presence of more range of color, turbidity, BOD, COD, total bacteria and E. coli do not fall in the range of WHO Standard. So, water samples were treated by coagulation with different doses of alum and PAC respectively. According to the results, it can be concluded that alum and PAC reduced color, turbidity, BOD, COD, total bacteria and E. coli, treatment by coagulation using PAC was more effective than alum. Coagulation operation, pH, color, odor, turbidity, EC, TS, SS, TDS of water samples were found to be acceptable for potable purposes according to WHO Drinking Water Standard. But BOD, COD, total bacteria and E. coli do not fall in the range of WHO Drinking Water Standard. So for potable purpose, effective method for removal of BOD, COD, total bacteria and E. coli should be attempted.

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