

COMPARATIVE STUDY OF ALUM AND FOUR OTHER SELECTED COAGULANTS IN THE REMOVAL OF RAW WATER TURBIDITY

M. L. Yakubu and H.A. Daura

Civil Engineering Department, Kano University of Science & Technology, Wudil
Civil Engineering Department, Bayero University, Kano

ABSTRACT

Five different coagulants were used to assess the effectiveness of traditional alum in raw water turbidity removal in a typical water treatment plant, operated by Kano State Water Board, Northern Nigeria, with the aim of finding an alternative coagulant to replace alum due to its ever increasing cost and diminishing availability. The investigation involved raw water test between months April-May to represent dry season and August to represent wet seasons. The effectiveness of the chosen primary coagulants consisting of Alum, Sodium Silicate, Ferrous Sulphate, Moringa and Polyaluminium chloride (PAC) was evaluated and analysed for turbidity. Basically, turbidity is one of the most important indices for water quality, the less the turbidity, the better the water quality. Polyaluminium chloride (PAC) - a relatively new polymeric coagulant - is found more effective in turbidity removal than alum - the traditional coagulant. The three other selected coagulants were found less effective than the traditional alum. In order to gain further insight into the effectiveness of Alum and PAC on turbidity removal, and to establish seasonal variability as a result of flocculation conditions, a series of bench-scale coagulation jar tests were conducted using wet season raw water samples.

KEYWORDS: Coagulation, Turbidity, Alum, PAC

INTRODUCTION

There is growing concern towards the ever increasing cost and diminishing availability of alum which is traditionally used for water treatment. A recent socio-economic investigation carried out in Kano state, northern Nigeria reveals that the treated water from the state water treatment plant is milky, malodorous and foul testing (Parkman, 2000) this can be directly or indirectly linked with the higher dosage of alum required to treat a given litre of raw water.

Turbidity is defined as the amount of light scattered by particles in water solution (AWWA, 1990). It is one of the most commonly used parameters for evaluation of coagulation and flocculation processes, as well as an indicator of drinking water quality. As the number of particles increased, a higher intensity of light is scattered and a higher turbidity value is obtained. Turbidity is caused by suspended colloidal clay particles, such as silt, clay, microscopic organisms, soluble coloured organic compounds, finely divided organic or inorganic matter (Benefield et al., 1982). Higher turbidity water containing higher amount of particles generally requires higher dosages of coagulant and higher values of turbidity in drinking water represent undesirable presence of organic matter and inorganic contaminants (Zhu et al, 1996). Synthetic polyelectrolytes have been utilized in coagulation/flocculation process for water purification for more than four decades. Their principal uses in water or wastewater treatment are as primary coagulants as well as in the more traditional flocculation step of further binding the already formed small flocs into larger aggregates (Tzoupanos and Zouboulis, 2011). Historically, most coagulation processes are primarily designed for particle and turbidity removal (Tomaszewska et al, 2004) in water treatment, the purpose of coagulation is to remove suspended

matter from water in order to bring about clarification. Coagulation is a complex process that can combine colloidal particles and dissolved NOM into large aggregates. It is a key component of accepted water treatment practice in which coagulation/flocculation, sedimentation, filtration and disinfections processes are combined to clean the water by removal of colloidal particles, NOM, and some microbiological contaminants.

Inorganic aluminium coagulants, which include aluminium salts, are traditionally used in water and wastewater treatment often in conjunction with organic polymers. The main reason for the higher efficiency of organic polymers regarding flocculation is their higher molecular weight, which implies better aggregation properties (Tzoupanos and Zouboulis, 2011). The aggregation of colloidal particles and NOM can be achieved by four primary mechanisms as reported by Amirtharajah and Mills, (1982); Dempsey et al., (1985); Hundi and O'Melia, (1988); Randtke (1988); Edzwald and Van Benschoten, (1990) these include:

1. Adsorption and Charge neutralization/Destabilization (colloids only)
2. Enmeshment in precipitated floc particles (colloids only)
3. Adsorption onto precipitated floc particles (NOM only)
4. Complexation / Precipitation (NOM only)

The combination of these mechanisms might occur during coagulation and flocculation processes.

During the process of coagulation, aluminium-based coagulants such as PAC hydrolyse to form a precipitate of aluminium hydroxide, which appears as spongy gelatinous masses that are frequently referred to as "floc" (AWWA, 1990). This floc has a very high surface area that can act to absorb or entrap bacteria, protozoa and other turbidity-causing particles.

METHODOLOGY

All chemical reagents used were analytically pure chemicals. Deionised water with conductivity lower than 0.5 mS/cm was used to prepare all the solutions, In the case of preparing the polymer solution, deionised water made of carbonate free by boiling, was used. A commercially available Alum with 17.5 %Al₂O₃, Sodium Silicate containing excess base (Na₂SiO₃), Polyaluminium chloride (PAC) solution with trademark name Bluwat model PAC-02 with chemical formula Al₁₃(OH)₂₀(SO₄)₂.Cl₁₅, Ferrous Sulphate (copperas) with molecular formula FeSO₄.7H₂O, *Moringa* found in Wudil village, Kano, northern Nigeria and C587 polymer were used in this research work.

The dosing system was observed and calibrated; subsequently samples were prepared to establish the workability of the system itself and have a base line for comparison. A series of turbidity tests using Stuart Scientific Flocculator combined with six 1-Litre square beakers were conducted in dry season using raw water entering the treatment plant to determine the effectiveness coagulants' turbidity removal under the condition of 60 seconds of 125rpm flash mixing followed by

9 minutes of flocculation at 60rpm and 5minutes of settling. Similar bench-scale jar tests were also conducted for optimum dosages of superfloc C-587 polymer for alum.

Alum and PAC Coagulation Jar Test

The raw water quality records from KSWB indicated that the quality of raw water changes with seasons. In order to gain further insight of the effectiveness of Alum and PAC on turbidity removal, and to establish seasonal variability as a result of flocculation conditions, a series of bench-scale coagulation jar tests were conducted using wet season raw water samples. The optimum dosage of Alum and PAC established using the raw water in dry season has to be adjusted. Based on the raw water quality and operational record of the plant Alum was tested at dosages of 30, 60, 75, 90, 110, and 120mg/l.

RESULTS AND DISCUSSION

Average Initial raw water turbidity = 479.9 NTU (dry season)

Average Initial raw water turbidity = 3236 NTU (wet season)

Table 1: Coagulants' Turbidity removal (Dry Season)

SAMPLE	COAGULANT DOSE (mg/l)					TURBIDITY (NTU)				
	ALUM	FeSO ₄ .7H ₂ O	Na ₂ SiO ₃	Moringa	PAC	ALUM	FeSO ₄ .7H ₂ O	Na ₂ SiO ₃	Moringa	PAC
15 Minutes										
A	22.4	90	175	160	12	363.5	360.5	395.0	298.0	237.0
B	32	150	350	320	24	334	82.0	345.0	232.5	40.5
C	64	210	525	640	48	19.0	40.0	230.0	113.0	11.0
D	96	300	700	960	72	13.5	27.0	160.5	37.0	12.5
E	128	360	875	1280	96	16.5	26.5	135.0	58.0	14.5
F	192	420	1050	1600	144	26.5	26.5	121.0	109.0	15.5
60 Minutes										
A	22.4	90	175	160	12	209.5	82.5	255.0	201.5	152.5
B	32	150	350	320	24	189.5	50.5	236.0	191.0	33.0
C	64	210	525	640	48	5.5	33.0	135.0	90.0	2.0
D	96	300	700	960	72	5.0	19.5	70.0	17.5	3.5
E	128	360	875	1280	96	6.0	19.5	78.0	24.0	4.0
F	192	420	1050	1600	144	9.5	19.5	58.0	27.0	4.0

When each coagulant was added to the raw water, many flocs were formed during the rapid and slow mixing, and then settled to the bottom during the settling time. This phenomenon indicated that all selected coagulants promoted the coagulation process and caused the aggregation of colloidal particles and dissolved NOM. However, the turbidity removal of each in the coagulation processes was not the same. The difference on the effect of each coagulant on turbidity removal can be seen from Table. From Table 1, low dosage of 48mg/l PAC initially after 15 minutes caused turbidity decrease to 11 NTU and later after 60 minutes to 2 NTU. While 96mg/l alum, initially after 15 minutes, caused turbidity decrease to 13.50 NTU, and later decrease to 5NTU after

60minutes. 360mg/l use of Ferrous Sulphate initially after 15 minutes caused turbidity decrease to 26.5NTU and further decrease to 19.5NTU after 60minutes. Sodium Silicate is the least in performance following *Moringa* where as high as 1050mg/l dose of Sodium Silicate caused 121NTU decrease in turbidity after 15minutes, and then to 58NTU decrease in turbidity after 60 minutes. While *Moringa* dose of 960mg/l caused a decrease in turbidity after 15 minutes to 37NTU, which further decrease to 17.5NTU after 60 minutes. Matawal et al (2005) found that 1,200mg/l to 3,000mg/l dosage of *Moringa* was the effective range for water treatment; the findings of this research work supported the Matawal's findings.

The combined effect of alum and *Moringa* has been investigated by Habeeb and Naziru, (2007) within same period and same source of raw water. The results of their findings shows that, keeping Alum constant at 200mg/l and varying the dose of *Moringa* between 300-1800mg/l, the lowest turbidity obtained was 20NTU at 800mg/l of *Moringa* (i.e. 200mg/l alum+800mg/l *Moringa*). While keeping *Moringa* constant at 1,000mg/l and varying Alum between 20-320mg/l, the least

turbidity obtained was 28NTU at 220mg/l of alum (1,000mg/*Moringa* +220mg/l alum). The turbidity was obtained after the coagulated water was allowed to settle for 15 minutes with initial raw water turbidity of 573NTU. The above results gives a fair ground for comparison with the results obtained in this research work, low dose of 48mg/l of PAC lowers the raw water initial turbidity of 548NTU to just 11NTU after 15 minutes.

Table 2: Alum, PAC and C587 at 15min (Dry Season)

ALUM				PAC			
SAMPLE	DOSE(mg/l)	C587	TURBIDITY(NTU)	SAMPLE	DOSE(mg/l)	C587	TURBIDITY(NTU)
A	64	5	13.5	A	24	5	9.5
B	64	10	6.5	B	24	10	21.5
C	64	20	28.5	C	24	20	39.0
D	64	30	36.0	D	24	30	31.0
E	64	40	27.5	E	24	40	45.0
F	64	50	20.0	F	24	50	42.0

Table 3: 48mg/ PAC and C587 at 15min (Dry Season)

PAC			
SAMPLE	DOSE(mg/l)	C587	TURBIDITY(NTU)
A	48	5	10.0
B	48	10	16.0
C	48	20	17.5
D	48	30	16.0
E	48	40	20.5
F	48	50	16.5

The combined effects of alum and PAC with polymer on turbidity removal were different. This can be seen from Table 2 and 3 when 64mg/l of alum was used with 10mg/l of C587 the optimum turbidity was 6.5NTU while 24mg/l of PAC with 10mg/l of C587 gives an optimum turbidity of 21.5NTU. When 48mg/l of PAC was used with 10mg/l of C587 did not give any better result. This indicated that alum work well with polymer than PAC.

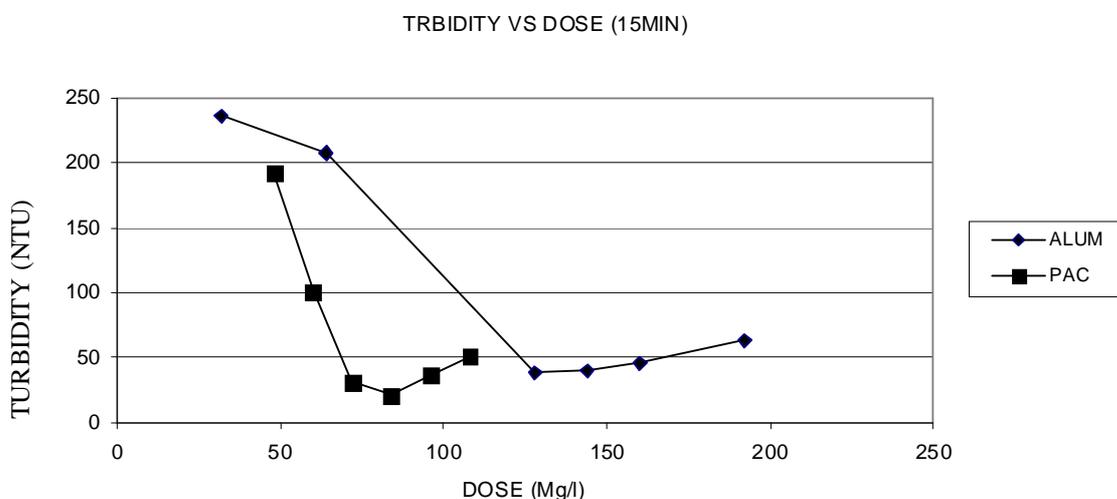


Figure 1: effects of Alum and PAC on Turbidity removal at 15 minutes (Wet season)

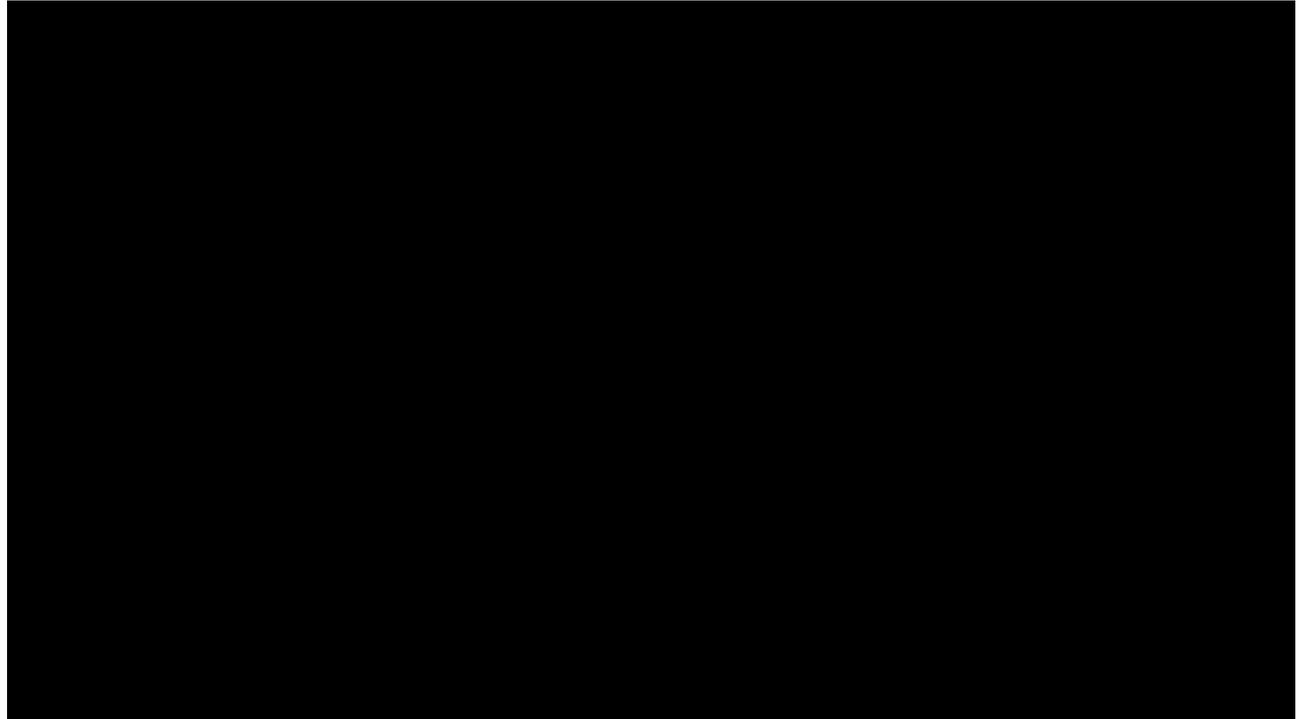


Figure 2: effects of Alum and PAC on Turbidity removal at 60 minutes (Wet season)

Due to the efficiency of PAC and alum in the removal of turbidity during dry season, they were further subjected to test using the raw water in wet season. The turbidity of the raw water in wet season increased by about 85% in August; as a result, the optimum dosage of Alum and PAC established using the raw water in dry season, were adjusted. The wet season result with worst raw water turbidity can be seen from Fig. 1 above. The results indicated that PAC was more effective than alum in turbidity removal from the raw water. The optimum dosage of PAC was 48mg/l and 84mg/l for dry and wet season respectively. While that of alum was 96mg/l and 192mg/l for dry and wet season respectively.

CONCLUSION

This research work found PAC more effective in raw water turbidity removal than other chosen coagulants, it also supported Matawal et al (2005)

REFERENCES

- American Water Works Association (AWWA) (1990); "Water Quality and Treatment" 4 ed., McGraw-hill co., new work.
- Amirtharajah, A. and Mills, K. M. (1982); "Rapid-mix Design for Mechanisms of Alum Coagulation" Journal of the American Water Worker Association 74(4); 210-216.
- Benefield, L.D., Judkins, J.F. and Weand, B.L. (1982); "Process Chemistry for Water and Wastewater Treatment" Prentice Hall Inc., Englewood Cliffs, N.J.

findings on the effective range of Moringa dosage. Considering the effectiveness, reliability of supply, labour & equipment for storage, feeding, and handling; it is recommended to consider the use PAC instead of traditional Alum or any of the considered coagulants in this research for a typical water treatment plant for removal of turbidity. As observed in this study, the settling properties of PAC were superior to those of Alum and other selected coagulants. From engineering point of view, use of PAC would reduce the size of flocculation tanks, lessen filter maintenance, lessen transportation cost and simplify coagulation processes. Thus, the coagulation operation would be controlled more easily using PAC alone than using Alum and polymer as is often the practice. This simple coagulation process is important for treatment plants operated by Kano State Water Board.

- Dempsey, B.A., Sheu, H. Tanzeer-Ahmed, T.M and Mentink, J, (1985); "Polyaluminium chloride and alum coagulation of clay-fulvic Acid suspensions" Journal of American water works association 77(3): 74-80.
- Edward, J.K. and Van Benschoten, J.E., (1990), "Aluminium Coagulation of Natural Organic Matter: Chemical Water and Wastewater Treatment" Hahn and Klute. New York, springer-verlag: 341-359.

- Geoff, F., John, S. and Rod, S., (2004); "Water Clarification Using M. Oleifera Seed Coagulant" Water and environmental health at London and Loughborough (WELL). <http://www.iboro.ac.uk/well/>
- Habeeb, S.M. and Naziru, F.A., (2007); "Comparative Study between Alum and Moringa as Coagulants in Water Treatment" A B.Eng thesis submitted to Civil Engineering Department, BUK.
- Hundi, T.R and O'Melia, C.R., (1988); "*Aluminium-Fulvic Acid Interactions: Mechanism and Applications*" Journal of the American Water Works Association 79(12): 26.
- Matawal, D.S., Jerome, A.E., and Mathew, I.A. (2005); "*A new water treatment system using Moringa seed*" International journal of environmental issues 3(1): 1-6
- Parkman (Nigeria) Limited, (2000); Parkman consulting Engineers, Kaduna, Nigeria, report on "National Water Rehabilitation Project" Greater Kano water supply feasibility study, final reports Vol.1.
- Randtke, S.J (1998); "*Organic Contaminant Removal by Coagulation and Related Process Combination*" Journal of the American Water Works Association 80(5): 40-56
- Tomaszewska Maria, Sylwia Mozia, and Antoni W. Morawski (2004) "*Removal of organic matter by coagulation enhanced with adsorption on PAC*" journal of Desalination (161): 79-87
- Tzoupanos N.D. and Zouboulis A.I. (2011) "*Preparation, characterisation and application of novel composite coagulants for surface water treatment*" journal of water research (45): 3614-3626
- Zhu Honghui, Daniel W. Smith, Hongde Zhou, and Steven J. Stanley (1996); "*Improving removal of turbidity causing materials by using polymers as filter aid*" Journal of water resources (30): 103-114