Zimbabwe Journal of Science & Technology pp 101-108

Vol.10 [2015]
e-ISSN 2409-0360
Zimbabwej.sci.technol

Treatment of Low Turbidity Water Using Poly-Aluminium Chloride (PAC) and Recycled Sludge: Case study Chinhoyi

[a] Taurai Jowa and [b] Liberty L Mguni*

[ab] Department of Chemical Engineering, National University of Science and Technology, Zimbabwe

Email: liberty.mguni@nust.ac.zw

ABSTRACT

Coagulation of low turbidity water using PAC and recycled sludge was studied using a bench scale sedimentation jar test operated at ambient temperature and pressure. Tests were done on low turbidity raw water samples from the river Manyame in Chinhoyi. The coagulants tested were aluminium sulphate (control), PAC and recycled sludge. The effects of the coagulants on the final physical properties of treated water (pH, conductivity, floc quality and most importantly turbidity) were analysed. It was observed that for 60 mg/L dosages, final pH was in the 8.2-8.4 range with an average of 0.24 unit change for PAC and 0.12 for aluminium sulphate, changes in conductivity were less than 20 μScm^{-1}for both coagulants and PAC was more efficient in turbidity removal at all dosages. The higher efficiencies of PAC where due to the poly-ions formed during hydrolysis. An improvement to the coagulating system was attempted by using settled sludge from clarifiers. At a constant 30 mg/L PAC dosage, the maximum turbidity removal efficiency, 73%, was observed at 6 ml sludge dosage.

Keywords: Polyaluminium chloride, Aluminium sulphate, Sludge, Water Treatment, Low Turbidity

1.0 INTRODUCTION

Pure water is an odourless, tasteless and colourless liquid chemically composed of hydrogen and oxygen. Water does not exist in the purest form naturally because of contamination by various substances it comes in contact with. Water can dissolve every naturally or artificially occurring substance to some degree hence it being named the universal solvent. Water from various sources should therefore be treated before distribution to the public and industries. The main reasons for this is to remove disease causing organisms in the case of potable water and also to get rid of dissolved substances that may interfere with industrial processes.

The main stages of water treatment are clarification and disinfection. Clarification is a combination of processes designed to make the water clearer or less turbid (dirty/cloudy). This is an important stage of treatment as it accounts for 99% turbidity removal. The unit operations of clarification in a conventional treatment plant are chemical coagulation, flocculation, sedimentation and filtration. Coagulation is the most important step before sedimentation. Coagulation mechanisms include charge neutralisation, double layer suppression, enmeshment and bridging of colloidal particles via polymer addition (Amirtharajah & Melia, 1990). Factors such as the nature of the water, the coagulation pH and concentration of coagulant affect the range of species formed and hence the treatment performance.

The most commonly used coagulant for water treatment is aluminium sulphate (ALUM) and the polymerized forms, such as polyaluminium chloride (PAC) or poly-aluminium sulphate (PAS). The effectiveness of PAC and ALUM has been investigated by a number of authors (Pernitsky & Edzwald, 2006). PAC has generally been reported to perform better than ALUM in terms of turbidity reduction, dead organic content removal, colour removal and sludge quantities produced (Zouboulis & Traskas, 2005). Sludge recycling has been reported for both ALUM and PAC. These reports include research on; lead metal removal form wastewater (Wei, 1999), pre-treatment of livestock wastewater (Liang *et al.*, 2015), treatment of textile effluent (Chu, 2001), urban water (*Lu et al*., 2011) and wastewater treatment (Abhilash & Ahammed, 2013). The sludge used has generally been prepared by drying the sludge and reintroducing it. Recycled sludge plays a role of coagulant aid by increasing suspended solids in the wastewater resulting in higher adsorption of anionic surfactants and lower dosage of chemicals (Sriwiriyarat and Jangkorn, 2015).

In this study, the possible use of poly-aluminium chloride, PAC, as the coagulant chemical for treating the low turbidity surface water from the river Manyame in Chinhoyi was carried out. The effect of recycling settled sludge without drying it in treating water was also investigated. The yearly average turbidity for the water is below 4 Nephelometric turbidity units (NTU) with the highest turbidities above or near 200 during the first week of every rainy season.

2.0 Materials and Methods

2.1 Materials

Industrial grade aluminium sulphate (17%) and polyaluminium chloride (15%) were obtained from ALCOL Chemicals. All reagents were used as received. The sludge for recycling was collected from clarifier under flow at the water treatment plant with a density of 1400 kg/m^3 and was used without any treatment.

2.2 Raw water collection and characterisation

Twenty litres raw water samples were collected on different days from a tank receiving water from Manyame River in Chinhoyi and characterised. Larger samples were not taken because turbidity changes with time hence samples had to be as fresh as possible. The samples were tested for initial values of pH using a pH meter, turbidity using a portable HACH 21009 turbidity meter, conductivity using a Acqua Lytic AL20C on conductivity meter and temperature using a digital thermometer attached to the pH Meter. Turbidity for samples collected ranged from 3.55 to 39.8 NTU.

2.3 Preparation of coagulant chemicals

Stock coagulant solutions should be made to a strength such that 1ml added to a litre of raw water will give a dose equalling 5 or 10mg/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 throughout the year. Most plants use 10% strength solutions however, for this work more dilute solutions (1%) were employed. The reasons for use of dilute solutions were for ease of handling and to ensure good mixing in the jar (Greville, 1997).

2.4 Jar Test

Three most widely used tests are the jar tests, cylinder tests and zeta potential tests (Armenate, 2000). Jar tests are used when clarification is for raw water with less than 5000 mg/L suspended solids. In this study, the tests were designed such that the Chinhoyi Spreckley Kopje water treatment plant conditions for coagulation, rapid mixing, slow mixing and sedimentation were simulated. A Velp Scientifica JLT16 was used for the settling tests. 1000 ml of the raw water was added to each of the six beakers. Coagulant to be tested was added in increasing amounts to the beakers using pipettes. For sludge recycling each sample was treated using PAC and the solids. The samples were stirred at 200 rpm for 3 min this allowed for rapid mixing of coagulant with raw water. The stirring speed was then reduced to 25 rpm for 30 min to allow for flocculation. The beakers were thereafter left standing for 30 min to allow for floc settling.

3.0 RESULTS AND DISCUSSIONS

3.1 Turbidity Reduction

Turbidity of the raw water varies every single day depending on upstream activities and conditions. The samples collected for this test work had turbidity ranging between 3.44 and 39.8 NTU. Generally, turbidity removal increased with dosage for both coagulants. For turbidity of 3.55 PAC was more efficient than ALUM as shown in Figure 1. The optimum dosage for PAC at this turbidity indicated by the minimum point on the graph was 20 mg/L while for ALUM was 40 mg/L. Efficiency improved when the initial turbidity was a bit high, 22-39.8 NTU for both coagulants. For the medium case, 22 NTU, the optimum dosage was 60 mg/L and 100 mg/L for PAC and ALUM respectively.

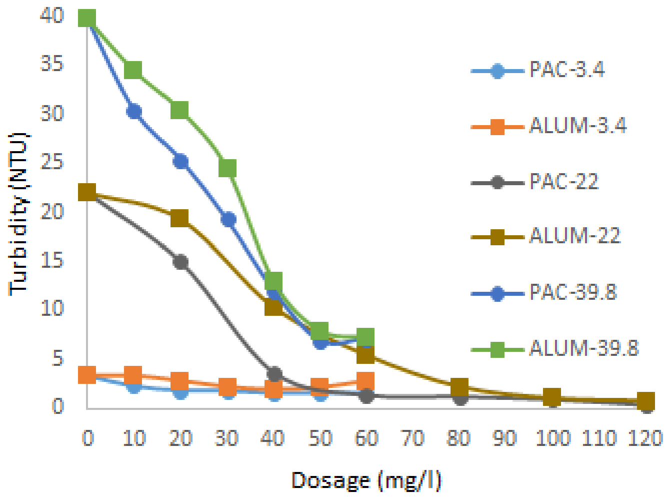

Figure 1: Final Turbidity versus Dosage

Higher concentrations of chemical result in improved turbidity reduction. Figure 2 below indicates the efficiencies of the coagulants at different dosages for 3 samples of different turbidity. The experiment results were recorded up to the maximum efficiency for given initial turbidity. It was observed that PAC was more efficient than ALUM for different turbidity and dosages. PAC was more efficient than ALUM, for 0-120 mg/L dosages, for all raw water turbiditys. For 3.4 NTU samples, the range for PAC is 31.2-54% efficiency compared to 5-42% for ALUM. Efficiencies of 23-83% were observed for PAC compared to 13.3-82% for ALUM when raw water had 39.8 NTU. Increase in chemical dosage resulted in greater efficiency for both PAC and alum at low dosage below 40 mg/l. This was as expected since increase in chemical concentration results in more coagulation reactions taking place hence more turbid particles are removed. Lowest efficiencies were recorded for 3.4 NTU turbidity water. The main reason is because of less suspended matter hence collisions between coagulant and turbid particles are minimal. This result in less flocs being formed leading to poor settling. PAC was more efficient in reducing turbidity because of how it reacts as discussed by (Feralco, 2014). It is poly-cationic hence releases more hydrolysed Al^{3+} per milligram added to raw water.

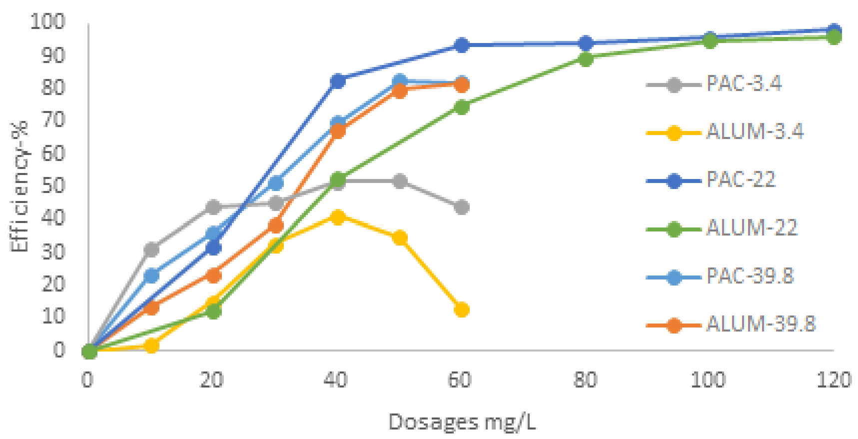

Figure 2: Coagulant Efficiencies 0-120mg/L

3.2 Effect on pH

For the 0-120 mg/L dosages, pH changes were more pronounced when ALUM was used. The final pH at the highest dosage was 7.64 for PAC and 7.01 for ALUM. PAC recorded a change of 0.76 units and ALUM 1.36 (Figure 3).

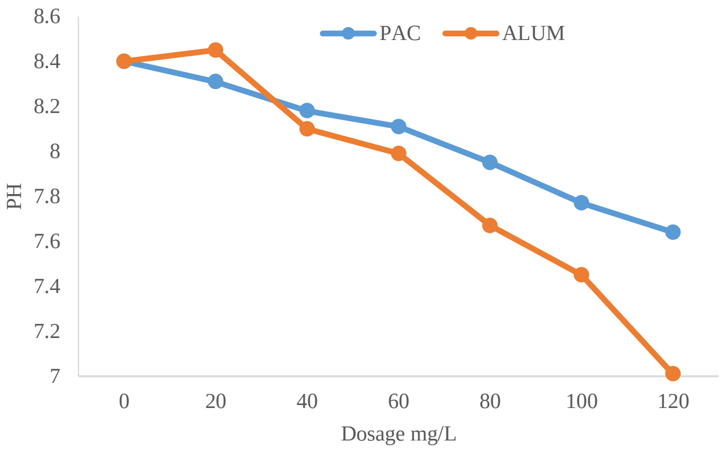

Figure 3: Changes in pH with Dosage 0-120 mg/L

The fall in pH with dosage is because the coagulants consume alkalinity during hydrolysis. ALUM consumes more alkalinity hence the trends shown in Figures 3. These results are consistent with the fact that ALUM is more acidic than PAC hence it consumes more alkalinity (Sahu & Chaudhari, 2013). The lowest pH changes were observed for the low dosages. This is because less alkalinity is consumed at low coagulant concentration. All dosages resulted in pH within the acceptable range of 6.5-9 for potable water.

3.3 Conductivity

Generally conductivity increased with dosage. The trend was similar for both coagulants. The highest change was 28 μScm^{-1} from an initial of 292 μScm^{-1} for both coagulants at a dosage of 120 mg/L. Figure 4 shows the trend observed.

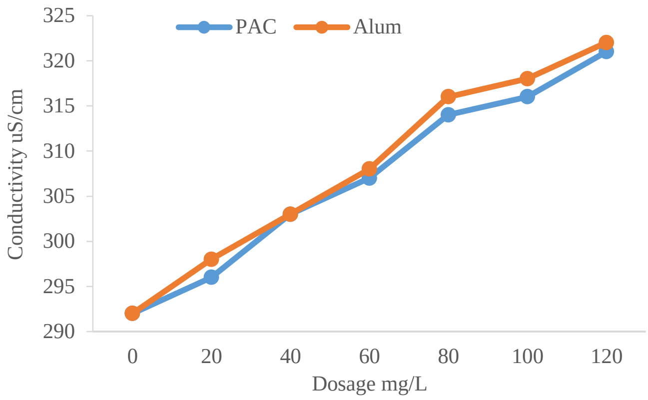

Figure 4: Changes in Conductivity with Dosage, 0-120 mg/L

The increase in conductivity was as expected. It was a result of ions being formed in the water during coagulation. These obviously carry a charge that contributes to the overall conductivity. More coagulant in solution will therefore lead to the observed increase in conductivity. Final conductivity for all treated samples was within the acceptable range of 0-3000 μScm-1 (World Health Organisation, 2011).

3.4 Floc Quality

The observed floc quality for PAC and aluminium sulphate varied depending on dosage. The floc were observed to change from pin to fluffy for PAC while small to pin and then fluffy for Alum as more coagulant was added. Fluffy floc was observed at 60 mg/L and above for PAC for the dosage range investigated.

Table 1: Floc Quality for 0-120 mg/L Dosages

Dosage-mg/L	PAC Floc Quality	ALUM Floc Quality
10	Small	-
20	Pin	-
30	Pin	Small
40	Pin	Small
50	Pin	Pin
60	Fluffy	Pin
80	Fluffy	Pin
100	Fluffy	Fluffy
120	Fluffy	Fluffy

As shown in table 1, all flocs obtained above 80mg/L coagulant dosage were fluffy. Floc quality is a function of dosage. The smaller the dosage the poor the floc formation as observed when small or no floc was obtained at 10mg/L. However, PAC floc showed pin characteristics even at low dosage (30-40 mg/l) which is contrary to the case for aluminium sulphate. Floc particles that are discrete (pin) and fairly dense in appearance are usually better than floc particles that have a light, fluffy appearance. Large floc (fluffy) is impressive but it is neither necessary nor always desirable. Large, light floc does not settle as well as smaller, denser floc and it is more subject to breaking up by water turbulence.

3.5 Sludge Recycling-Constant PAC

PAC was found to be more effective than Alum and therefore selected for further tests. For these set of tests, constant PAC was employed with varying amounts of sludge. The initial turbidity was low therefore 30mg/L PAC was employed. A greater value would lead to increase in turbidity as previously noted (Figure 5). Two runs were done for each value of sludge added. Final Turbidity decreased with increasing amount of sludge added for 2-6 ml of sludge added, the final turbidity and efficiency ranged from 1.2-0.55 NTU and 50-73% respectively. Efficiency decreased with further increase in sludge dosage above 6ml. This is because after reaching the optimum sludge dosage, additional amounts will add turbidity to the water thus the poor results. After 6ml turbidity started increasing and efficiency dropped. These results are for an initial turbidity of 2.25 NTU

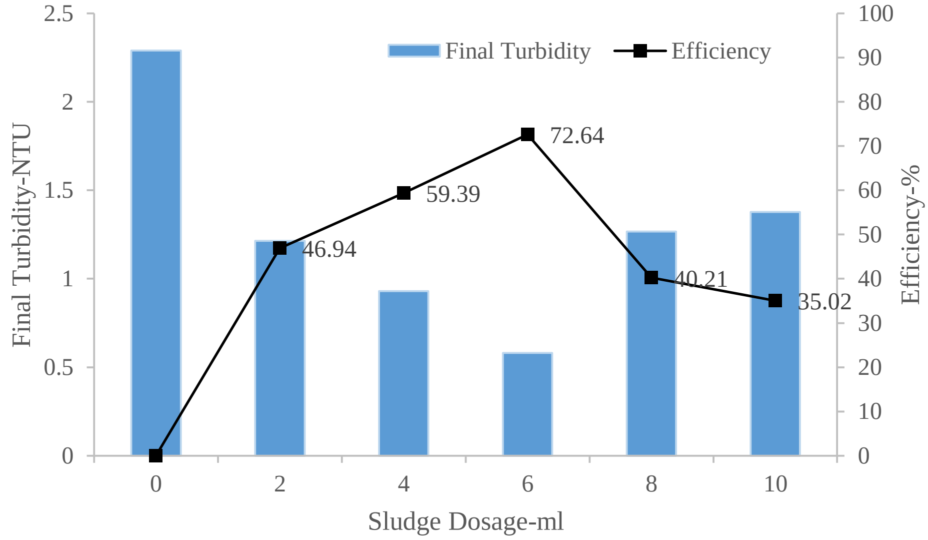

Figure 5: PAC 30 mg/L plus Sludge

4.0 CONCLUSION

It has been shown that using PAC to treat low turbidity water is more efficient than ALUM in terms of turbidity reduction. The range of efficiency was 31.2-83% for PAC compared to 15-82% for ALUM. PAC was more efficient at lower dosages hence it is a better choice. Both coagulants lowered pH gradually with increase in concentration. All of the final pH values were in the required range for potable water. The largest change in conductivity was 28 μScm^{-1} observed at the highest dosage. However, this change in conductivity results in conductivity within the required range for drinking water.

Above 80 mg/l dosage fluffy flocs were formed. This undesirable fluffy floc is difficult to settle therefore resulting in their carry over to filters. Recycling of sludge can be advantageous as indicated by the results.

Acknowledgements

I greatly appreciate the roles played by the following individuals in the completion of this project:Mr S Muzemba and Mr Tapfumaneyi, the two supervisors at the Municipality of Chinhoyi water treatment plants. Special thanks to Justin Maluwa, Rumbidzai Munemo, Walter Mwanza and Jonathan Sibanda.

5.0 REFERENCES

Abhilash, N., & Ahammed, M. M. (2013).The Reuse Of Water Treatment Sludge As A Coagulant For Post-Treatment Of UASB Reactor Treating Urban Wastewater. *Journal Of Cleaner Production* 96 (1) ; 272-281.

Amirtharajah, A. O., & Melia, C. R. (1990). Coagulation Processes: Destabilization, Mixing, And Flocculation. McGraw-Hill, INC., (USA); 1194

Armenate, M. P. (2000). *Coagulation and Flocculation.* New York: NJIT.

Chu, W. (2001). Dye Removal From Textile Dye Wastewater Using Recycled Alum Sludge. *Water Research* 35 (13); 3147-3152.

Feralco. (2014). Polyaluminium Chloride. Feralco (UK) LTD.

Ghníomhaireacht , Chaomhnú , & Comhshaoil. (2002). *Water Treatment Manuals: Coagulation, Flocculation and Clarification.* Wexford: Environmental Protection Agency.

Greville, A. S. (1997). How To Select A Chemical Coagulant and Flocculant.

Liang, J., Wang, C., & Pei, Y. (2015). Use of Drinking Water Treatment Sludge For

Pre-treatment Of Livestock WasteWater. *Chinese Journal of Environmental Engineering* 9 (6); 2569-2576

Lu, Q., Rong, C., Hong-chen, W., Xiang, Z., Guang-ming, Z., & Gui-bai, L. (2011). Recycle of Alum Sludge with PAC (RSAP) For Drinking Water Treatment. *Desalination and Water Treatment, 25* (1-3); 170-175.

Pernitsky, D. J., & Edzwald, J. K. (2006). Selection of Alum and Polyaluminium Coagulants: Principles and Applications. *Journal Of Water Supply, Research and Technology*, 55; 121-141.

Sahu, O. P., & Chaudhari. (2013). Review of chemical treatment of industrial waste water. *Journal of Applied Science Environmental Management*. 17; 241-257.

Sriwiriyarat, T. & Jangkorn S. (2009) Evaluation of waste activated sludge as a coagulant aid for the treatment of industrial wastewater containing mixed surfactants.

Journal of Environmental Science and Health, Part A, 44; 507-514.

Wei, C. (1999). Lead Metal Recovery Using Recycled Sludge. *Journal of Water Research*, 33 (13); 3019-3025.

WHO (World Health Organization), 2011. Guidelines for Drinking- water Quality. World Health Organization

Zouboulis A., & Traskas G., (2005). Comparable evaluation of various of commercial availiable alumina-based coagulants for the post-treatment of urban wastewater. *Journal of Chemical Technology and Biotechnology* 80;1136-1147