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Evaluation Of Cationic And Anionic Polyelectrolytes As A Coagulant Aids In Turbidity Removal From Surface Water

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Coagulation-flocculation is an important technique used for removal of turbidity from water. The study aims to investigate effect of alum as coagulant in conjunction with polyelectrolytes as coagulant aids for removal of turbidity from surface water (pond and river water). Water was collected in March, June, September and December 2018 from both pond and river. Turbidity for pond water was 174 NTU, 192 NTU, 101.5 NTU and 147 NTU and for river water, it was 92 NTU, 251 NTU, 121 NTU and 161 NTU for March, June, September and December 2018, respectively. Conventional jar test was done for removal of turbidity by determining the pH, electrical conductivity, temperature, optimum mixing intensity and proper dosage. The two polyelectrolytes used were organopol 5470C and chemfloc 430A. Research aims to evaluate effect of organopol 5470C and chemfloc 430A used as coagulation and flocculation aids in different surface water and to examine their effectiveness for treatment of water. For pH range of 7.0-8.0, organopol 5470C shows better flocculation strength than chemfloc 430A in pond and river water, while, chemfloc 430A has better results at pH more than 8.0. The objective of work is to assess performance of two synthetic polyelectrolytes on turbidity of surface water.

KEYWORDS

Coagulant, Coagulation, Electrical conductivity, Flocculation, Polyelectrolytes, Turbidity

1. INTRODUCTION

The water quality in surface water depends upon geological factors, morphological factors, vegetation, industrial and agricultural land in its proximity. Turbidity is one of the most unaesthetic measures of water quality in surface water [1,2]. The turbidity in water is due to suspended and colloidal matter including clay, silt and finely divided organic matters [3]. Turbidity in water affects aesthetics adversely [4]. It also brings unpleasant taste and foul odour. Turbidity also affects water treatment process including disinfection as well as increasing the cost of treatment. In addition, turbidity is harmful as turbid water inhibits respiratory processes and reduces visibility, so it is very essential to minimize the turbid level of surface water. The variation in temperature in different seasons also affects the chemical characteristics of water. High temperature also decreases gas solubility and respiratory rates. Of late river pollution in India has become critically alarming due to speedy growth of industrialization and unplanned urbanization [5]. The entire living world is affected by pollution of river water. The problem of deterioration of water quality is mainly due to human activities, such as discharge of industrial waste, sewage waste and agriculture runoff [6]. The present study was designed to assess the water quality of pond water and river water and to minimize their value of turbidity by coagulation-flocculation method. An attempt has been made here to study the quality of the Yamuna river and pond of village Thanthari, district Palwal, Haryana. The Yamuna is a major tributary to the Ganga river. The river enters Delhi 1.5 km north of Palla and leaves Delhi at Jaitpur downstream of Okhla barrage after traversing around 22 km. Major drains are falling into the river between Wazirabad and Okhla, which includes Najafgarh drain. The river is getting a large quantity of treated and untreated waste [7,8].

This stable system can be destabilized by the application of coagulation-flocculation [9,10]. But inorganic coagulant alone is not sufficient enough to get the best results. Because most essential drawback involved by this technique is low efficiency, large amount of sludge and high level of water mineralization. So, polyelectrolytes have been applied in the water treatment because

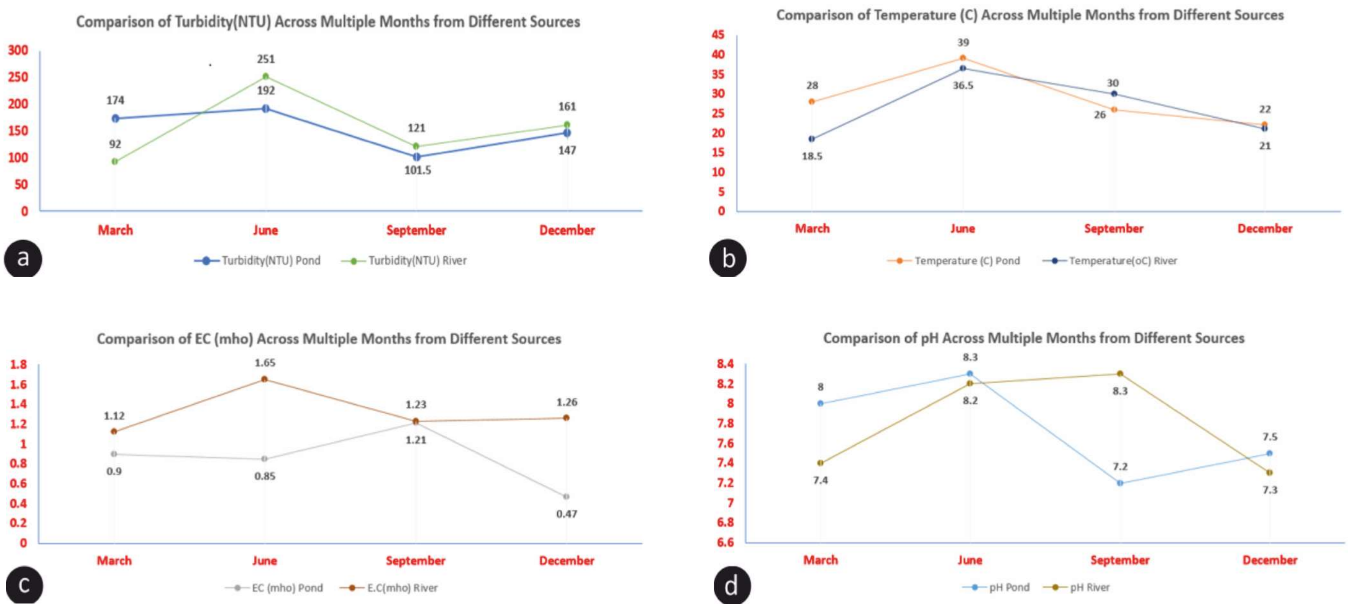

Figure 1. *Measures of (a) turbidity, (b) temperature, (c) electrical conductivity and (d) pH on pond and river water across months*

it is an efficient technique used for removal of turbidity [11,12]. Polyelectrolytes are inexpensive organic polymeric flocculants that can be used for water purification in combination with inorganic coagulants [10,13]. The advantages of using polyelectrolytes are reduction in sludge volume, no adverse effect on water pH and decrease in total dissolved solids in finished water [14,15]. The present study was designed to ascertain the role of two different commercially available polyelectrolytes used as coagulation-flocculation aids in four different seasons water samples of pond and river having different turbidities. Both organopol 5470C and chemfloc 430A are high charge density and high molecular weight polyacrylamide based polyelectrolytes. Organopol 5470C is cationic while the chemfloc 430A is anionic polyelectrolytes. Polyacrylamide can remove dense, large and stronger floc with good settling characteristics as compared to inorganic coagulants [16]. It also reduces sludge volume to a larger extent. The flocculation performance depends on ionic nature, type of flocculants and its molecular weight and type of wastewater [16,17,18]. As of now, very little literature is available for the use of organopol 5470C and chemfloc 430A in water treatment [19]. Perhaps they have been used for the first time in surface water treatment.

2. MATERIAL AND METHOD

2.1 Sample collection and analysis

The water samples were collected in four different seasons, namely March (spring), June (summer), September (autumn) and December (winter) of 2018. The water sample was collected four times in each season. A total of sixteen water samples were collected from every sampling point. Mean experimental values of various physico-chemical parameters in different seasons are shown in graphical presentation. The study has provided information on the quality of surface water and impact of anthropogenic activities. The water was analyzed as per standard methods for the examination of water and wastewater [20]. The pH of water was recorded with the help of pH meter (Hanna HI 8314, USA). The electrical conductivity (EC) of water was measured with Philips conductivity bridge and dip type cell at 27 ± 3^0C. The turbidity of all water samples has been measured with the help of turbidity meter (Hanna HI93703, USA).

The value of turbidity of pond water was found to be maximum in June and minimum in September as shown in figure 1a. In river water, turbidity is found to be highest in June and minimum in March 2018. The high turbidity in summer season may be due to high water temperature because suspended particles absorb heat from sun making the temperature of water high. The average temperature of pond water and river water is shown in figure 1b. The average temperature is maximum in June (39^{o}C) and minimum in December (22^{o}C) in pond water. However, same trend has been found in river water. The EC of pond water varies during investigation with a maximum in June and minimum in March

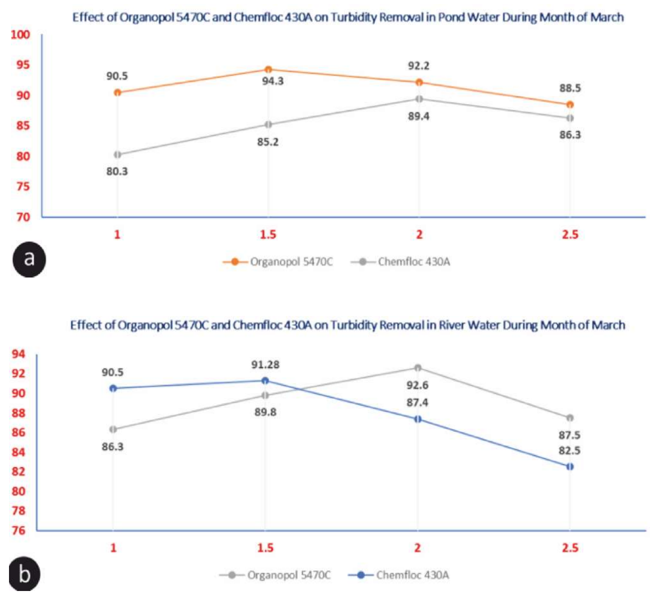

Figure 2. *Turbidity removal with different dosages of polyelectrolytes for sample taken from (a) pond and (b) river for month of March 2018*

Table 1. *Optimum alum dosages in different surface water samples for March*

Season (2018)	Water	Turbidity (NTU)	Dosage of alum (mg/L)
March	Pond	174	7.5
	River	92	12.5
June	Pond	192	7.5
	River	251	5.0
September	Pond	101.5	12.5
	River	121	10
December	Pond	147	10
	River	161	7.5

as shown in figure 1c. However, in river water, the maximum value is found in September and minimum value has been recorded in December 2018. The pH of pond water is shown in figure 1d. The pH of pond water also varies in different seasons. The pH of pond water is 8.00, 8.30, 7.20 and 7.50 in March, June, September and December 2018, respectively. However, it was found to be 7.4, 8.2, 8.3 and 7.3 in March, June, September and December 2018 in river water, respectively. It is a very important factor for further treatment of turbidity.

2.2 Reagent used

Organopol 5470C and chemfloc 430A polyelectrolytes were used as coagulant aid. Organopol 5470C was purchased by Ciba Speciality Chemicals and anionic polyelectrolyte chemfloc 430A was purchased by Chemkimia. Alum was obtained from CDH (India) and their solutions were prepared in distilled water having a concentration of 10 mg/L.

2.3 Experimental setup

The raw water was first put through filtration by stainless sieve followed by filter paper of 7-8 μm size. After the filtration treatment, a jar test procedure was used in this experiment. The jar test is a common lab method that has been used in coagulation and flocculation process on a bench scale. The aim is to use it to determine the optimum operating conditions, such as pH, dosages of alum and polyelectrolytes for water treatment. A conventional jar test apparatus, the Phipps and Bird six–paddle stirrer with illuminated base was used for jar test with 2 L square Plexiglass. In this study, two different types of polyelectrolytes, that is cationic polyacrylamide organopol 5470C and anionic polyacrylamide chemfloc 430A were used in conjunction with alum for removal of turbidity in pond and river water. In this research work, jar test procedure consists of four consecutive steps : (1) filling of beaker with 1 L turbid water, (2) addition of alum in each beaker at various doses and agitated for 1 min at 100 rpm, (3) the desired dosages of polyelectrolyte as a coagulant aid was added after mixing alum and (4) the mixing speed was reduced to 50 rpm for 7.5 min followed by 20 rpm for 7.5 min. After sedimentation for 30 min, an aliquot of 10 mL was taken out from mid-depth of the beaker and residual turbidity was determined. The process was repeated in turn with all four types of polyelectrolytes.

3. RESULT AND DISCUSSION

Results on optimization of alum dosage for different samples are shown in table 1. It was observed from the result that as the turbidity of water sample increases, optimum dosage of alum decreases. To reduce the residual concentration of aluminium in treated water and a further decrease in turbidity value, different polyelectrolytes have been used as a coagulant aid in conjunction with alum. Better performance was obtained when coagulant aid was added in water sample after the mixing of alum as compared to the case when polyelectrolyte and alum were added simultaneously. After adding optimum dosage of alum, polyelectrolytes were added as coagulant aids. Two different polyelectrolytes, namely cationic polyacrylamide organopol 5470C and anionic polyacrylamide chemfloc 430A have been used in different types of surface water.

Jar test was first conducted in March on pond water

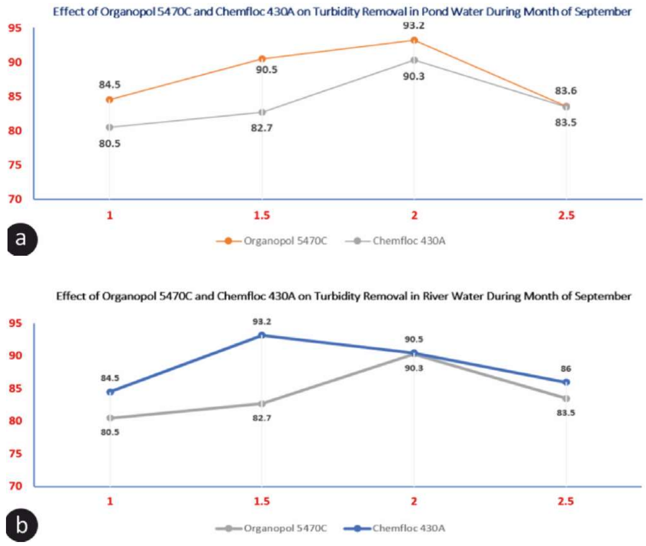

Figure 3. *Turbidity removal with different dosages of polyelectrolytes for the sample taken from (a) pond and (b) river for month of June 2018*

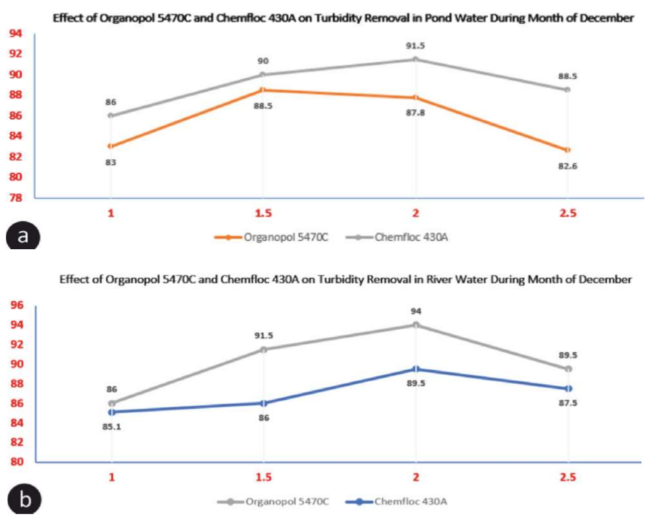

Figure 4. *Turbidity removal with different dosages of polyelectrolytes for sample taken from (a) pond and (b) river for month of September 2018*

and river water having turbidity 174 NTU and 92 NTU, respectively. The performance of both types of polyelectrolytes in pond water samples has been shown in figure 2. It has been observed from the result that organopol 5470C has advantages over chemfloc 430A polyelectrolytes in pond water sample of March 2018. Organopol 5470C is high molecular weight and high charge density cationic polyelectrolyte, whereas chemfloc 430A is also high molecular weight and high charge density but anionic polyelectrolyte. High charge density and high molecular weight cationic polymers are found to be more effective in turbidity removal in pond water. Organopol 5470C could remove 94.3% turbidity at 1.5 mg/L dosage. However, chemfloc 430A could remove 89.4% turbidity at 2 mg/L dosage in pond water at pH 8.0. Whereas the results in river water also showed same trend as shown in figure 2b. Organopol 5470C could remove 92.6% turbidity from pond water at 2 mg/L dosage. However, chemfloc 430A could remove 91.28% turbidity at dosage of 1.5 mg/L at pH 7.4.

Jar test was conducted on pond water and river water having turbidities of 192 NTU and 251 NTU, respectively for June 2018. The turbidity reduction with chemfloc 430A is more as compared to organopol 5470C in pond and river water of June 2018 as shown in figure 3. The removal of turbidity was in order of 80.3%, 95.6%, 90.8% and 87.5% at dosage of 1 mg/L, 1.5 mg/L, 2.0 mg/L and 2.5 mg/L, respectively with chemfloc 430A. However, removal percent with organopol 5470C is found to be 84.5%, 88.6%, 92.7% and 87.5% at dosages of 1 mg/L, 1.5 mg/L, 2.0 mg/L and 2.5 mg/L, respectively. The results showed that chemfloc 430A was found to give better results in pond water sample of June 2018. It was found to be 84.3%, 97.2%, 94.4% and 89.3% with chemfloc 430A in river water of June 2018. The removal of turbidity with organopol 5470C was in order of 80.5%, 84.3%, 92.4% and 82.5% at dosage of 1 mg/L, 1.5 mg/L, 2.0 mg/L and 2.5 mg/L, respectively. In water samples of river and pond water, chemfloc 430A showed better results as compared to organopol 5470C at pH 8.3 and 8.2, respectively.

Jar test was conducted on pond water and river water having turbidities of 101.5 NTU and 121 NTU, respectively for September 2018 at pH 7.2 and 8.3, respectively. The percent removal of turbidity at various dosages was also studied. Figure 4 shows that in pond water, turbidity removal was found to be 84.5%, 90.5%, 93.2% and 83.6% at dosage of 1 mg/L, 1.5 mg/L, 2.0 mg/L and 2.5 mg/L respectively, with organopol 5470C at pH 7.2. However, chemfloc 430A could remove 80.5%, 82.7%, 90.3% and 83.5% at dosage of 1 mg/L, 1.5 mg/L, 2.0 mg/L and 2.5 mg/L, respectively. Figure 4 predicts the efficiency of organopol 5470C and chemfloc 430A in turbidity removal in river water. Maximum removal with organopol 5470C was 90.3% at 2.0 mg/L dosage. However, chemfloc 430A showed better results as compared to organopol 5470C in river water. It could remove 93.2% turbidity at 1.5 mg/L dosage at pH 8.3. Figure 5 show the significant effect of organopol 5470C and chemfloc 430A on turbidity removal in pond and river water sample of December 2018. Organopol 5470C could remove 94% turbidity at 2 mg/L dosage whereas chemfloc 430A could remove 89.5% turbidity at same dosage at pH 7.3. However, in case of river water,

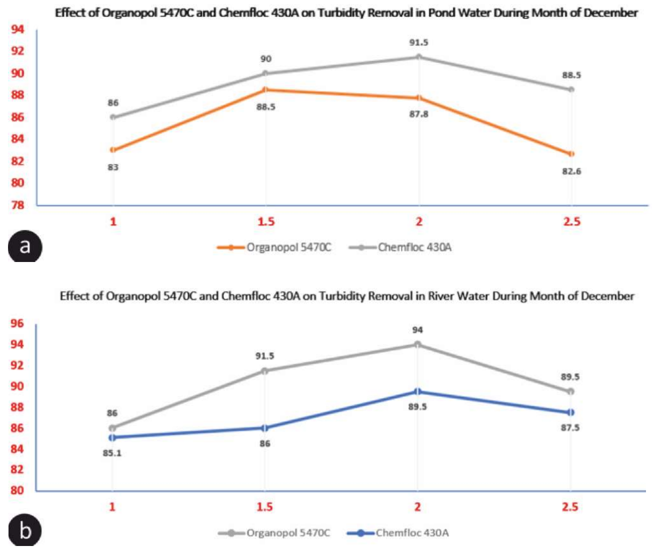

Figure 5. *Turbidity removal with different dosages of polyelectrolytes for sample taken from (a) pond and (b) river for month of December 2018*

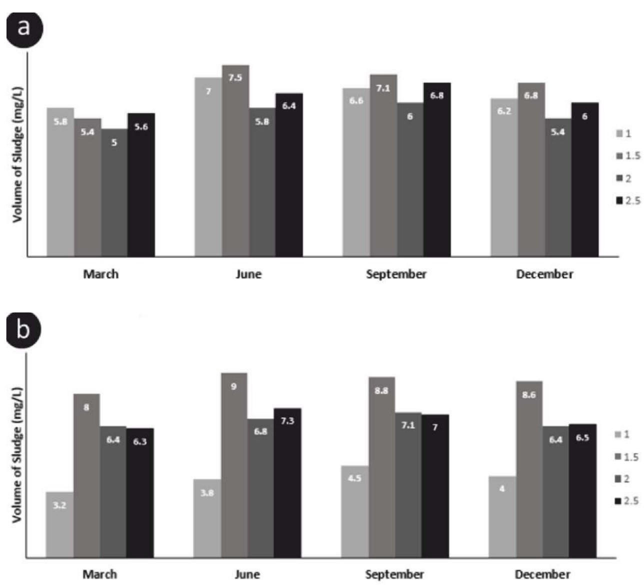

Figure 6. *Volume of sludge present in pond water after treatment with (a) organopol 5470C and (b) chemfloc 430A*

removal percent was 94% with organopol 5470C and it was 89.5% with chemfloc 430A.

Turbidity is generally removed by coagulation and polymer adsorption techniques. Organopol 5470C can adsorb strongly on negatively charged surfaces despite electrostatic repulsion. It generally occurs in the presence of divalent ions. Chemfloc 430A is an anionic polyelectrolyte with high charge density and high molecular weight. Charge density and molecular weight play an important role in polymer bridging. It has been found from the result that bridging is more important

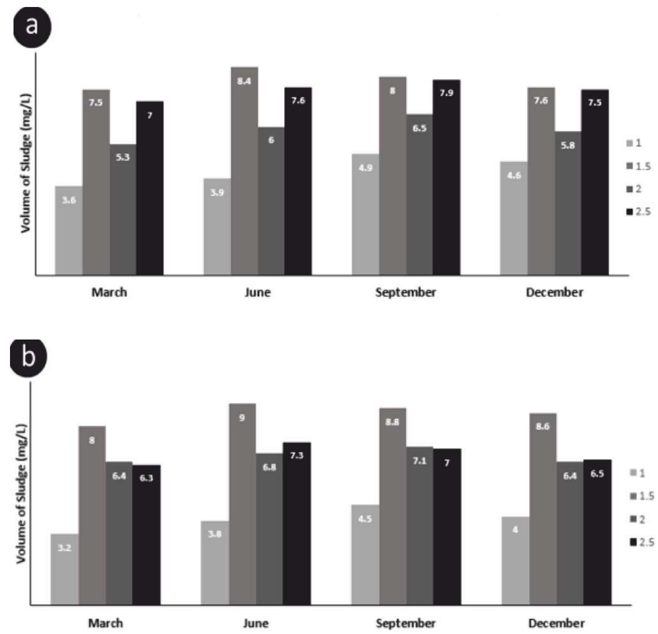

Figure 7. *Volume of sludge present in river water after treatment with (a) organopol 5470C and (b) chemfloc 430A*

as compared to charge neutralization at a pH range of 8.0-8.3. On the other hand, organopol is more effective at a pH range of 7-8.0. The high cationicity of organopol can destabilize suspended particles to promote the growth of rapid and large floc. Because of its cationic nature, it works through charge neutralization; interparticle bridging and hydrophobic floc. Throughout the experiments, the pH value of water sample treated with organopol 5470C and chemfloc 430A changed by only ±0.2. Timing of addition of coagulants and coagulant aids is an important criterion for effective performance.

Figures 6 and 7 show volume of sludge obtained after the treatment with alum and polyelectrolytes in pond and river water, respectively. Figure 6 shows the volume of sludge production in pond water with organopol 5470C and chemfloc 430A, respectively. The trend of sludge production shows that maximum sludge was obtained when percent removal was highest with both polyelectrolytes. It can be analyzed from the result that in case of pond water that sludge removal was found to be highest in treated water sample of June 2018 followed by March, September and December 2018 with organopol 5470C. However, trend is slightly different with chemfloc 430A. It was found to be highest in water sample of June followed by March, December and September 2018 in pond water. The results showed that quantity of sludge is in the order of June > September> December> March 2018 in river water with both polyelectrolytes, namely organopol 5470C and chemfloc 430A. The overall amount of sludge production with alum and polyelectrolytes show that the amount of sludge produced was the highest when percentage of removal of turbidity was highest in both cationic and anionic polyelectrolyte.

4. CONCLUSION

Based on experiments done, it has been found that polyelectrolyte in conjunction with alum can be used efficiently for treating pond water and river water having different turbidities in different seasons. It was concluded that removal efficiency is dependent upon molecular weight, charge density, dosage of polyelectrolytes and value of pH of different turbid water. It was observed from results that organofloc 5470C worked efficiently for the pH range of 7.0-8.0. However, chemfloc 430A worked efficiently for the pH range above 8.0. So, it was concluded that organopol 5470C was more efficient in pond water for March, September and December 2018. However, chemfloc 430A was more effective in pond water in June 2018. In case of river water, organopol was more impressive in the water sample of March and December 2018. However, chemfloc 430A is more efficient in the river water sample for June and September 2018. It was also observed from the result that a low dosage of alum is required for a high value of turbidity. Looking at the application of polyelectrolyte in removal of turbidities, it is concluded that this process can be applied efficiently in different kinds of water having different turbidities.

REFERENCES

1. Mahvi, A.H. and M. Razavi. 2005. Application of polyelectrolytes in turbidity removal from surface water. *American J. Appl. Sci*., 2(1):397–399.
2. Bina, B., *et al.* 2009. Effectiveness of chitosan as natural coagulant aid in treating turbid waters. *Iran J. Env. Health*. 6(4):247–252.
3. Nyström, R.S., *et al.* 2003. Flocculation of semi dilute calcite dispersion induced by anionic sodium polyacrylate – Cationic starch complexes. *Langmuir*. 19(9):3981–3986.
4. Bolto, B. and J. Gregory. 2007. Organic polymers in water treatment. *Water Res.,* 41(11):2301-2324.
5. Divakaran, R. and V.N. Pillai. 2002. Flocculation of river silt using chitosan. *Water Res*., 36:2414–2418.
6. Ganasan, V., *et al.* 1991. Trace metal concentration in water and sediments of river. *Int. J. Ecol. Env. Sci*., 17:225–236.
7. Ajmal, M., *et al.* 1995. Distribution of heavy metals in plants and fish of the Yamuna river (India). *Env. Monit. Assess*., 5:205–214.
8. Singh, S.K. and S. Kaushik. 2018. Qualitative study of Yamuna water across the Delhi stretches. *Int. J. Adv. Res*., 6(5):1127-1138.
9. Petzold, G., *et al.* 2003. Higher efficiency in the flocculation of clay suspension by combination of opposite charge polyelectrolytes. *Colloid Surface A*. 218(1):47–57.
10. Moussa, P.A. and A.I. Zouboulis. 2009. A new inorganic-organic composite coagulant, consisting of polyferric sulphate (PFS) and polyacrylamide. *Water Res.,* 43:3511–3524.
11. Tzoupanos, N.D. and A.I. Zoubouli. 2011. Preparation, characterization and application of novel composite coagulants for surface water treatment. *Water Res*., 45(12).3614–3626.
12. Tripathy, T. and B. R. De. 2006. Flocculation: A new way to treat wastewater. *J. Phys. Sci*., 10:93–127.
13. Zeng, D., *et al.* 2008. Application of chitosan flocculant to water treatment. *Carbohydr. Polym*., 71(1):135–139.
14. Buchhammer, H.M., *et al.* 2000. Nano particle based on polyelectrolyte complexes : Effect of structure on net charge on sorption capability on solved organic molecules. *Colloid Polym. Sci.,* 278(9):841–847.
15. Theodoro, J.D.P., *et al.* 2013. Coagulants and natural polymers : Perspective for treatment of water. *Plastic Polymer Tech*., 2(3): 55–62.
16. Laue, C. and D. Hunkeler. 2006. Chitosan graft acrylamide polyelectrolyte: Synthesis, flocculation and modeling. *J. Appl. Polym. Sci.,* 102(1): 885–896.
17. Yu, X. and P. Somasundaran. 1993. Enhanced flocculation with double flocculants. *Colloid Surface A*. 81:17–23.
18. Fan, A., *et al.* 2000. A study of dual polymer flocculation. *Colloid Surface A*. 162 (1):141–148.
19. Kapoor, J.K., *et al.* 2015. Optimization of coagulation-flocculation process for food industry waste water treatment using polyelectrolytes with inorganic coagulants. *J. Indian Chem. Soc*., 92:1697-1703.
20. APHA. 2012. Standard methods for the examination of water and wastewater (22nd edn). American Public Health Association, Washington, D.C.