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# Application of synthetic polyelectrolytes in turbidity removal from water

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ABSTRACT

One of the promising technologies for the removal of suspended particles is coagulation and flocculation. The present study is aimed to examine the effect of alum as a coagulant in conjunction with polyelectrolytes as a coagulant aid for removal of turbidity from different water samples. The tests were carried out for four water samples i.e. well water, pond water, river water and canal water having 96NTU, 189NTU, 249NTU and 333NTU turbidity respectively. A conventional jar test was conducted for removal of suspension by determining the optimum mixing intensity and proper dosage. The four different polyelectrolytes used here are magnafloc LT-31, magnafloc LT-27, accofloc A-110 and aronfloc C-510.The aim of this research paper is to evaluate the effect of these synthetic polyelectrolytes used as coagulation and flocculation aids in different turbid water and determination of their effectiveness for the treatment of water. Results of these evaluations reveal that LT-31has shown better flocculation strength than other three polyelectrolytes in pond and river water for pH values of 8.22 and 8.68. On the other hand accofloc A-110 has shown best result in well water and canal water for pH values of 7.10 and 7.65 respectively. We demonstrate an efficient approach for optimization of coagulation-flocculation process which is appropriate for raw water treatment.



## 1. Introduction

Treatment of natural water and sewage is closely linked to the environment and is therefore an actual present day problem. One of the natural pollutants in water is suspended particles. The presence of this parameter will cause turbidity in water. In general, the turbidity is stable enough so that gravitational forces will not cause precipitation of these particles. So they need special treatment to remove them from the aqueous medium (Khan, et al., 2011; Bolto, 1995). This stable system can be destabilized by the application of coagulation (Bernhardt et al., 1996). But inorganic coagulant alone is not sufficient enough to get the best results

Table1: Summary of chemical family, charge type, molecular weight and form of polyelectrolytes

| Name of polyelectrolytes | Chemical family | Charge | Molecular Weight | Form |
|---|---|---|---|---|
| Magnafloc LT-31 | Cationic polyacrylamide. | High degree of cationic. | High mol. Wt. | Liquid |
| Magnafloc LT-27 | Copolymers of sodium acrylate and acrylamide. | Medium degree of anionic. | High mol. Wt. | Powder |
| Accofloc A-110 . | Anionic polyacrylamide | High degree of anionic. | Very high mol. Wt. | Powder |
| Aronfloc C-510 | Poly acrylic ester | Medium degree of cationic. | Low mol. Wt. | Powder |

(Mahavi et al., 2005) because most essential drawback involved by this technique is low efficiency, large amount of sludge and high level of water mineralization. Presently polyelectrolytes have been applied in the water treatment because it is a novel technique used for the removal of turbidity (Ghosh et al., 1985; Lurie&Rebhum, 1997). Polyelectrolytes are inexpensive organic polymeric flocculants which can be used for water purification in combination with inorganic coagulants (Narkis et al., 1991; Letterman & Pero, 1990). From the engineering point of view, application of coagulation and flocculation plays a major role in surface water treatment by reducing turbidity, organic compounds and clay particles (Narita et al., 2001). 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 (Kam& Gregory, 2001).

The present study was designed with a view to ascertain the role of four different commercially available polyelectrolytes used as coagulation-flocculation aids in four different water sample having different turbidity and pH. The chemistry of waste water has a significant effect on the performance of polyelectrolytes. The selection of the type of polyelectrolyte for use as coagulant and flocculants aid is generally an important task. There are many polyelectrolytes available from numerous manufactures with a wide variety of physical and chemical properties. In this study, the effectiveness of two different types of magnafloc known as LT-31 & LT-27 and two different types of accofloc known as accofloc-A -110& aronfloc C-510 were used in conjunction with alum for the removal of turbidity in well water, pond water, river water and canal water. It has been found from literature survey that significant work have been done in the chemistry of waste water by magnafloc family of polyelectrolytes (Mahvi et al., 2005, Masud et al., 2005), however, scanty information is available in literature on the role of accofloc polyelectrolytes in water treatment. The present study is designed to emphasize and re-verify the commonly used magnafloc family of polyelectrolytes and compare the performance of magnafloc and accofloc polyelectrolytes at different level of turbidity from different water sources. The characteristics of all the four polyelectrolytes have been tabulated in Table 1.

## 2. Material and methods

Four different water samples from four different sources i.e. from a well and a pond of Palwal (Haryana), bank of Yamuna River and Kheri canal, Faridabad have been collected. Tests have been performed at 27±3$^{o}$C throughout the research work. First of all, the turbidity of all water samples have been measured with the help of turbidity meter (Hanna HI93703, U.S.A). The turbidity of well water, pond water, river water and canal water was found to be 96NTU, 189NTU, 249NTU and 333NTU respectively. The pH value of well water, pond water, river water and canal water was measured with the help of pH meter (Hanna HI 8314, U.S.A) and it was found to be 7.10, 8.22, 8.68 and 7.65 respectively. The other chemical tests and analysis were done according to the standard methods for the examination of water (APHA, 1995), which have been tabulated in Table 2.

Table 2: Analysis of raw water samples at 27±3$^{o}$C

| Water sample | pH | TDS (ppm) | E.C. (Siemens) | Turbidity (NTU) |
|---|---|---|---|---|
| Well water | 7.10 | 810 | 1.0 | 96 |
| Pond water | 8.22 | 511 | 0.8 | 189 |
| River water | 8.68 | 849 | 1.4 | 249 |
| Canal water | 7.65 | 210 | 0.3 | 333 |

Alum was obtained in our laboratory from Central Drug House Pvt. Limited (India) and solution was prepared by dissolving 10g alum ($Al_2(SO_4)_3.18H_2O$) in distilled water and solution was made up to 1L. 1 ml of this stock solution gives concentration of 10mg/L. A conventional jar test apparatus, the Phipps and Bird six – paddle stirrer with illuminated base was used for jar test with 2 L square Plexiglas jars. All tests were carried out with 1 L sample of water in 2 L jar. All jars were filled with 1 L of water and placed on each slot. Alum was added in each beaker at various doses and agitated at 100 rpm for one min. The mixing speed was reduced to 50 rpm for 7.5 min followed by 20 rpm for7.5 min. At this stage, the desired dosage of polyelectrolyte (as coagulant aid) was added. The polyelectrolytes magnafloc LT-31 and magnafloc LT-27 are from Ciba specialty chemicals, U.K whereas accofloc A-110 and aronfloc C-510 are obtained from Alchemy substance (MT aqua polymer range, Japan)**.**It was found that polyelectrolyte should be added after the mixing of alum, because poor performance was obtained when polyelectrolyte and alum are added simultaneously. After sedimentation for 30 min, an aliquot of 10 mL was taken out from the mid depth of the beaker and residual turbidity was determined. The process was repeated in turn, with all water samples for four polyelectrolytes.

**3. Result and Discussion**

Jar test was conducted on well water, pond water, river water and canal water having turbidities of 96NTU, 189NTU, 289NTU and 333NTU respectively. Results on optimization of alum dosages for four different types of water are shown in Table 3. Optimum dosage of alum for well water is 10mg/L whereas for pond and river water, it is 7.5mg/L. The dosage for canal water is 5mg/L. Above this dosage the suspension shows the tendency to re-stabilize. In the present study it was observed that as turbidities of water sample increased, the optimum dosage of alum is decreased. This is in close agreement with Mehdinejad et al(Mehdinejad et al., 2009).

Table 3: Optimum alum dosage in different water samples at temp 27±3$^{o}$C

| Water sample | Dosage of alum (mg/L) |
|---|---|
| 1. Well water | 10 |
| 2.Pond water | 7.5 |
| 3.River water | 7.5 |
| 4. Canal water | 5 |

In order to decrease the residual concentration of aluminum in treated water and further decrease in turbidity value, different polyelectrolytes have been used as a coagulant aid in conjunction with alum. It was found that coagulant aid should be added in water sample after the mixing of alum, because poor performance was obtained when polyelectrolyte and alum are added simultaneously**.** This is in close agreement with Mehdinejad et al (Mehdinejad et al., 2009).

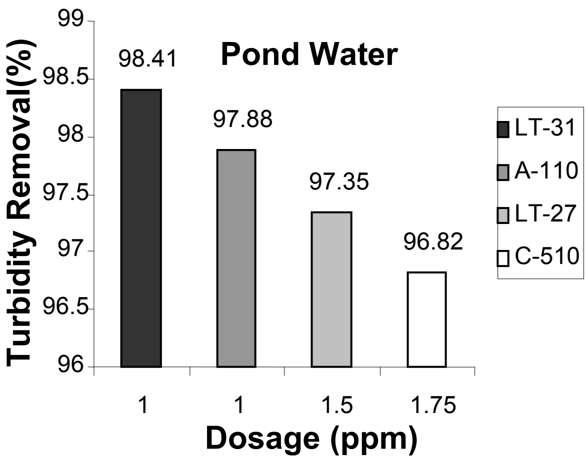


Figure 1: Effect of different polyelectrolytes on turbidity removal in pond water

The performance of all four polyelectrolytes in all four water sample have been shown in Figures 1 to 4. Figure 1 shows the effect of four polyelectrolytes on pond water, whereas Figure 2 represents the turbidity removal efficiency of four polyelectrolytes in river water. These figures represent efficiency of polyelectrolytes in turbidity removal from raw water in the range of magnafloc LT-31> accofloc A-110> magnafloc LT-27> aronfloc C-510. LT-31 has advantages over other three polyelectrolytes. The results have shown that the desirable pH range for removing turbidity with magnafloc LT-31 is about 8. This agrees well with earlier studies (Masud et al., 2005).

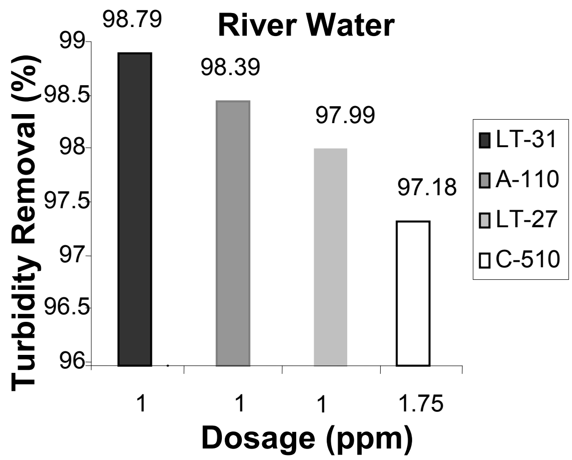


Figure 2: Effect of different polyelectrolytes on turbidity removal in River water

LT-31 is a cationic polyelectrolyte having high molecular weight and high charge density. High charge density and high molecular weight cationic polymers are normally found to be more effective in the turbidity removal because it can effectively flocculate suspended particles which are negatively charged through adsorption and charge neutralization. After jar test, the pH value of water sample treated with LT-31 changed only about ±0.1.

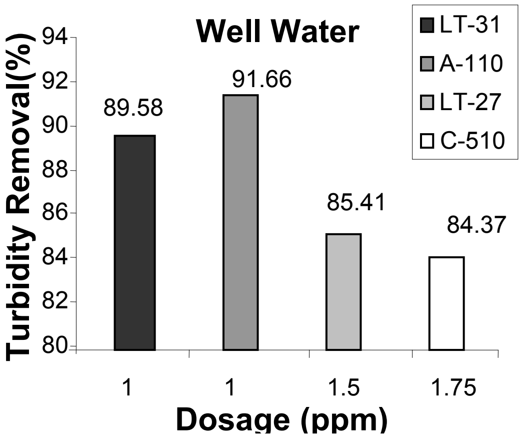


Figure 3: Effect of different polyelectrolytes on turbidity removal in well water

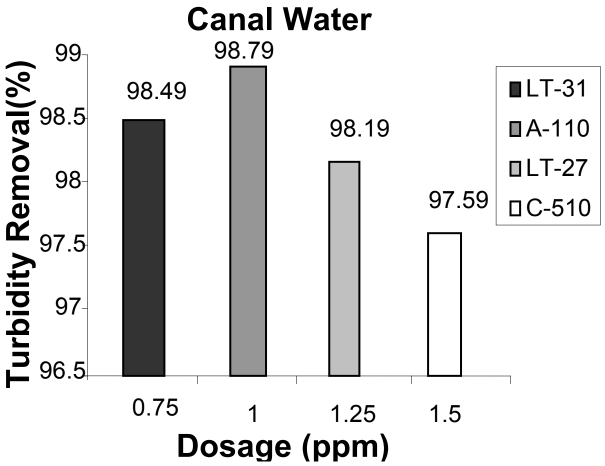


Figure 4: Effect of different polyelectrolytes on turbidity removal in canal water

However, accofloc A-110 showed better result than LT-27 and aronfloc C-510 because A-110 is strong anionic polyelectrolyte with high molecular weight. Molecular weight and charge density also play an important role in polymer bridging. Higher the molecular weight as well as charge density, more effective is the bridging. The result obtained in the lab studies showed that pH value of treated water with accofloc A-110 had changed marginally (±0.1) like magnafloc LT-31. However LT-27 has shown poor performance vis-à-vis LT-31 and A-110. LT-27 is high molecular weight medium anionic polyelectrolyte. The result may be poor because it is having less charge density than A-110 and polymer bridging cannot be strong without high charge density. The pH value of treated water with LT-27 had changed to the extent of ±0.2. The aronfloc C-510 has shown poorest result among all the polyelectrolytes. Although the pH values of treated water had changed only about ±0.1 with aronfloc C-510. The dosage of aronfloc C-510 was also more as compared to the other polyelectrolytes. It may be due to its very low molecular weight which adversely affects the removal of suspended particles from water. Flocculation by high molecular weight polyelectrolyte is much improved as compared to low molecular weight polyelectrolytes. The result is in close agreement with Bolto and Gregory (2007).

Figure 3 and Figure 4 show the efficiency of four polyelectrolytes in turbidity removal in well water and canal water. The trend is slightly different in these two water samples as compared to pond and river water. The efficiency of polyelectrolytes in turbidity removal are in the sequence of accofloc A-110> LT-31> LT-27> aronfloc C-510. Here, accofloc A-110 has shown the best result in well and canal water having pH value 7.10 and 7.65 respectively. The pH of water seems to be a critical factor in the turbidity removal. Accofloc A-110 appears to be highly effective in the pH range of 7.10 to 7.65, because every coagulant aid is having its desirable pH range which can only be found out by experimentation. The order of removal of turbidity by LT-27 and aronfloc C-510 is in same sequence in well and canal water as is in pond and river water. Summary of optimum dosages of various polyelectrolytes in different water samples for the removal of turbidity has been summarized in Table 4.

Table 4: Optimum dosages of various polyelectrolytes in different water sample for turbidity removal at 27±3$^{o}$C

| **Types of Polyelectrolytes** | **Pond Water** | | **River Water** | | **Well Water** | | **Canal Water** | |
|---|---|---|---|---|---|---|---|---|
| | **Dosage (ppm)** | **Removal of Turbidity (%)** | **Dosage (ppm)** | **Removal of Turbidity (%)** | **Dosage (ppm)** | **Removal of Turbidity (%)** | **Dosage (ppm)** | **Removal of Turbidity (%)** |
| magnafloc LT-31 | 1 | 98.41 | 1 | 98.79 | 1 | 89.58 | 0.75 | 98.49 |
| accofloc A-110 | 1 | 97.88 | 1 | 98.39 | 1 | 91.66 | 1 | 98.79 |
| magnafloc LT-27 | 1.5 | 97.35 | 1.5 | 97.99 | 1.5 | 85.41 | 1.25 | 98.19 |
| aronfloc C-510 | 1.75 | 96.82 | 1.75 | 97.18 | 1.75 | 84.37 | 1.50 | 97.59 |

## 4. Conclusion

On the basis of experimental result, it has been noted that polyelectrolyte in combination with alum can be successfully used for treating water of different turbidities. Residual turbidity was obtained to below standard levels by alum in conjunction with polyelectrolytes. It was also found that efficiency of water treatment through polyelectrolytes is influenced with characteristics of flocculants, molecular weight and charge density of polyelectrolytes, flocculants and coagulant dosage and pH value of turbid water. It was concluded from the present work that in pond and river water, the efficiency of polyelectrolytes are in the order of magnafloc LT-31> accofloc A-110> magnafloc LT-27> aronfloc C-510 at pH 8.22 and 8.68 respectively, whereas in well and canal water, the efficiency of polyelectrolytes are in the sequence of accofloc A-110> magnaflocLT-31 > magnaflocLT-27> aronfloc C-510 at pH 7.10 and 7.65 respectively. It was also observed that at high initial turbidity, the performance of alum in conjunction with polyelectrolyte was much more effective than at low turbidity. Overall results indicate that it is an efficient approach for optimization of coagulation - flocculation process and appropriate for raw water treatment.

## 5. Application and Significance

Turbidity is one of the most unaesthetic parts of any type of the water; whether it is an industrial water, waste water or surface water. The variation in the turbidity of water at different levels makes it difficult to handle. This cannot be removed successfully by the use of alum only. Hence it is imperative to use coagulant aid like different types of polyelectrolytes. Here, single polyelectrolyte along with alum has been used at different levels of turbidity. This technique reduces the amount of inorganic coagulant significantly. Therefore it can be understood from the present study that polyelectrolytes can be successfully applied in the removal of turbidity in low, medium as well as high turbid water. So far as industrial sample is concerned a combination of more than one polyelectrolytes shall be explored, which will widen its application. It should be understood from the result being provided that this paper is explorative; but provides direction for further application in the chemistry of water. Hence it is significant and different from conventional studies.

Keeping in view the applicability of these polyelectrolytes for turbidity removal, it is expected that this technique can be applied for further investigation in different variety of water from different origins.

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