International Journal of Innovative Research in Science and Engineering
Vol. No.2, Issue 03, March 2016
www.ijirse.com
ISSN: 2454-9665

COMPARATIVE STUDY OF ALUM AND FERRIC CHLORIDE FOR REMOVAL OF TURBIDITY FROM WATER

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ABSTRACT

Turbidity is a principle physical characteristic of water. It is caused by suspended matter or impurities that interfere with the clarity of the water. These impurities may include clay, silt, finely divided inorganic and organic matter, soluble coloured organic compounds, plankton and other microscopic organisms. Excessive turbidity in drinking water is aesthetically unappealing and may also represent a health concern. Turbidity can provide food and shelter for pathogens. ***Problem statement:*** *Turbid waters, containing colloidal particles, are normally treated bycoagulation-flocculation followed by sedimentation.Alum and Ferric Chloride, which are the mostcommon types of chemical coagulants in water treatment plants worldwide, wereinvestigated with the aim of determining their capabilities to reduce turbidity of drinking water.Turbidity was added to water with the help of kaolin clay. Optimization of coagulation process may assure removal of turbidity to a level below water quality standards in most cases.* ***Approach:*** *In this study, the effectiveness of Alum and Ferric Chloride was evaluated at different pH values of 5, 7, 9 and coagulant dosage 10 mg/l to 60 mg/l to find optimal operational conditions for turbidity of 50 NTU, 100 NTU and 250 NTU turbid waters. A set of jar test experiments was conducted tofind the optimal pH and coagulant dosage.* ***Results:*** *Results showed that coagulation processcould remove turbidity from 50 NTU to 250 NTU turbid waters effectively, using relatively lowlevels of Alum and Ferric Chloride (20-40 mg/l).* ***Conclusion/Recommendations:*** *Results showed that turbidity removal is dependent on pH,coagulant dosage, as well as initial turbidity of water for both used coagulants. The highest turbidityremoval efficiency was within 86.7-98.9 % for Alum and 91.8-98.32 % for Ferric Chloride over theapplied range of turbidity. Turbidity removal efficiency was higher for Ferric Chloride compared toAlum at optimum conditions. Both applied coagulants demonstrated promising performance in turbidity removal from water.*

Keywords: Coagulation process, turbidity, Alum, Ferric Chloride, synthetic water

I. INTRODUCTION

Water is an inseparable resource of human life. Life without water cannot exist. It is the right of every human being to have clean and safe water for drinking and domestic uses. But rapid growth of population, urbanization and industrial as well as agricultural activities have increased water pollution, particularly in recent decades. Due to all these activities the demand for clean and safe water is increasing. Coagulation, flocculation, sedimentation, filtration and disinfection are the most common treatment processes used in the production of drinking water. Coagulation/flocculation processes are of great importance in separation of solid particles from the water. The coagulation process occurs due to addition ofcoagulants in water to destabilize colloidalparticles. It requires rapid mixing to quickly mix the coagulant and flocculation process. Flocculation is the formation of aggregates of the destabilized colloidal particles and requires gentle mixing to allow effective collisions between particles to form heavy flocs which can be removed from water by sedimentation. Colloidal particles are small suspended particles in water which cannot be settled or removed by gravity due to their light weight and the charge they carry. These particles cause turbidity to water. Turbidity may contain many contaminants like pathogenic organisms. Turbidity is also associated with many pollutants of concern to human health e.g., metals or some synthetic organic chemicals. Thus, effective turbidity elimination is necessary to ensure removal of many health-related contaminants. In addition effective removal of turbidity may increase the efficiency of further water treatment processes. Alum and Ferric Chloride are the most commonly used chemical coagulants worldwide in the water treatment plants. Findings on various coagulation processes have been reported in literature.In this study two coagulants, namely Alum and Ferric Chloride, which are the most common types of coagulants in used in water treatment plants, were studied with the aim of determining their capabilities to reduce turbidity of synthetic water. Their effectiveness was evaluated at different pH values and coagulant dosage to find optimal operational conditions for different turbid waters. The removal of turbidity from water is important because colloids may directly or indirectly threaten the human health.

II. MATERIALS AND METHODS

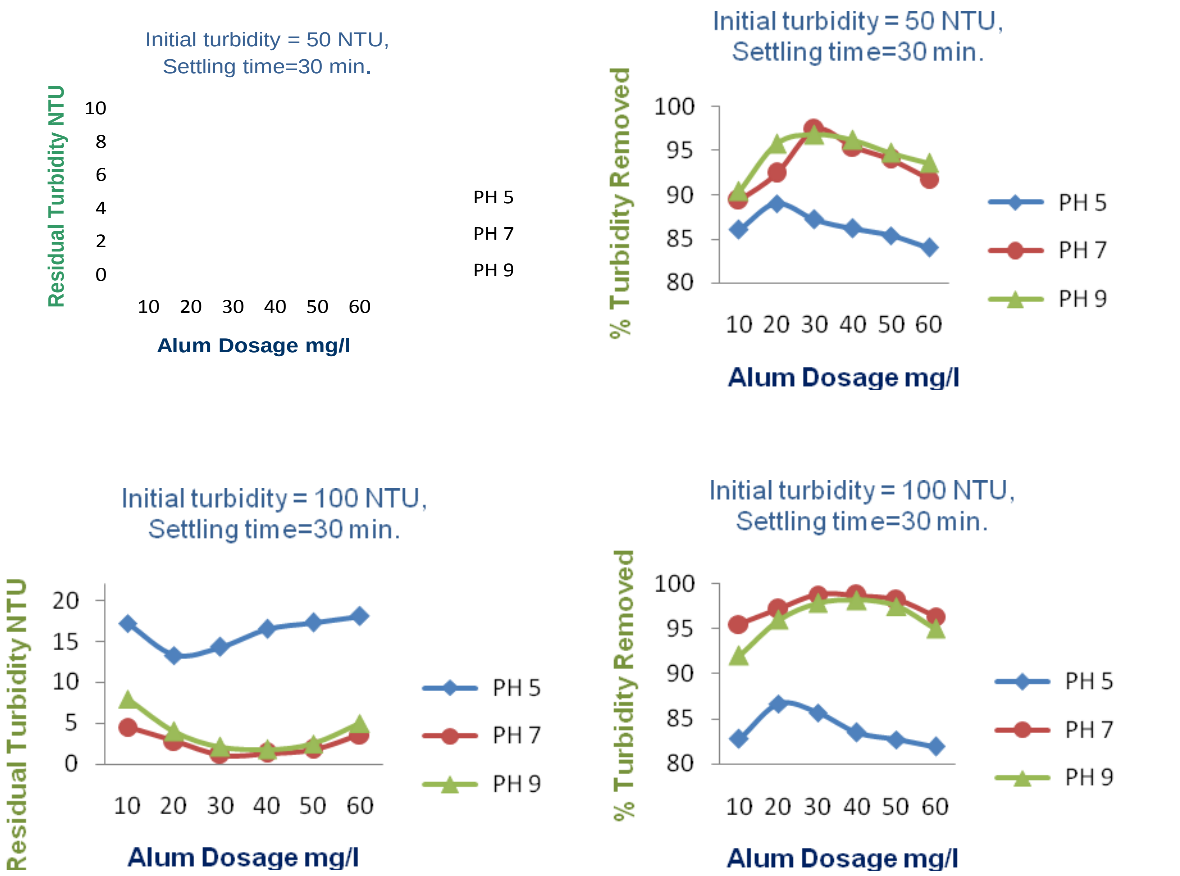
Jar test experiments were conducted fordifferent pH values of 5, 7, and 9. Aluminium Sulphate ($Al_2(SO_4)_3.18H_2O$) and Ferric Chloride ($FeCl_3.\ 6H_2O$) were used in the current study, as the most common types of coagulants used in many water treatment plants around the world. For the preparation of raw turbid water Kaolin clay was mixed to distilled water. Mixed clay sample was allowed for soaking for 24 hrs. Suspension was then stirred in the rapid stirrer so as to achieve uniform and homogeneous sample. Resulting suspension was found to be colloidal and used as stock solution for preparation of turbid water samples. As per the requirement stock sample of kaolin clay was diluted to tap water to obtain desired turbidity.Sodium hydroxide and sulphuric acid were used for adjusting the pH of turbid water. Stock solutions of 1% Alum and Ferric Chloride were prepared. 500 ml of prepared synthetic turbid were placed in a 1000 ml beaker and stirred at150 rpm for 2 min (rapid mixing). The mixing speedwas reduced to 15 rpm for 20 min for flocculation (slowmixing).Any flocthat was formed was allowed to settle for 30 min in the beakers itself.Supernatant samples were taken from 20 mm below the water surface for turbidity measurements. Supernatant turbidity was measured with a digital turbidity meter of Equiptronics make and expressed in Nephelometric Turbidity Units (NTU). Residual turbidity was used as the indicator of performance. The optimum pH and dose for turbidity removal with both Aluminium Sulphate and Ferric Chloride were attained by the jar test experiments. All jar test experiments were conducted at room temperature. Experimental characteristics for the jar test experiments in this research were summarized in Table 1.

Table 1: Experimental characteristics for jar test experiment conducted in this study

Characteristic	Description
Coagulants	Aluminium sulphate & Ferric Chloride
Coagulant dose range	10 – 60 mg/l
pH values	5, 7 & 9
Initial turbidities	50 NTU, 100 NTU & 250 NTU
Rapid mixing	2 minutes at 150 RPM
Slow mixing	20 minutes at 15 RPM
Settling time	30 minutes

III. RESULTS

Figure 1 presents turbidity removal efficiency as a function of Alum dose at pH values of 5, 7, and 9. Initial turbidities of water samples were adjusted to be 50, 100, 250 NTU. High initialturbidities were considered in this research becausesuch high turbiditiescommonly occur in manystorm waters. Low turbiditywaters are usually hard to coagulate due to lowconcentrations of stable particles and sometimesturbidity is synthetically added to the water to formheavier flocs which can be settled. However, in thecurrent study the lowest applied turbidity (50 NTU) wasnot too low to disturb coagulation process.



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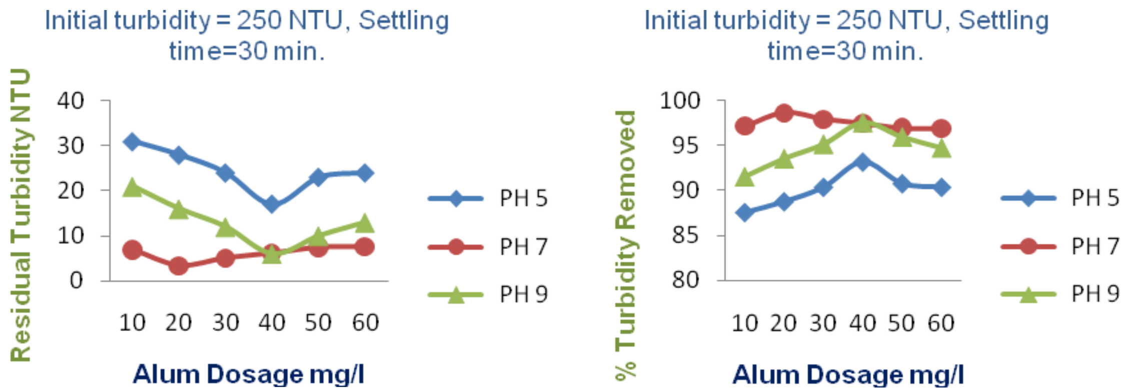
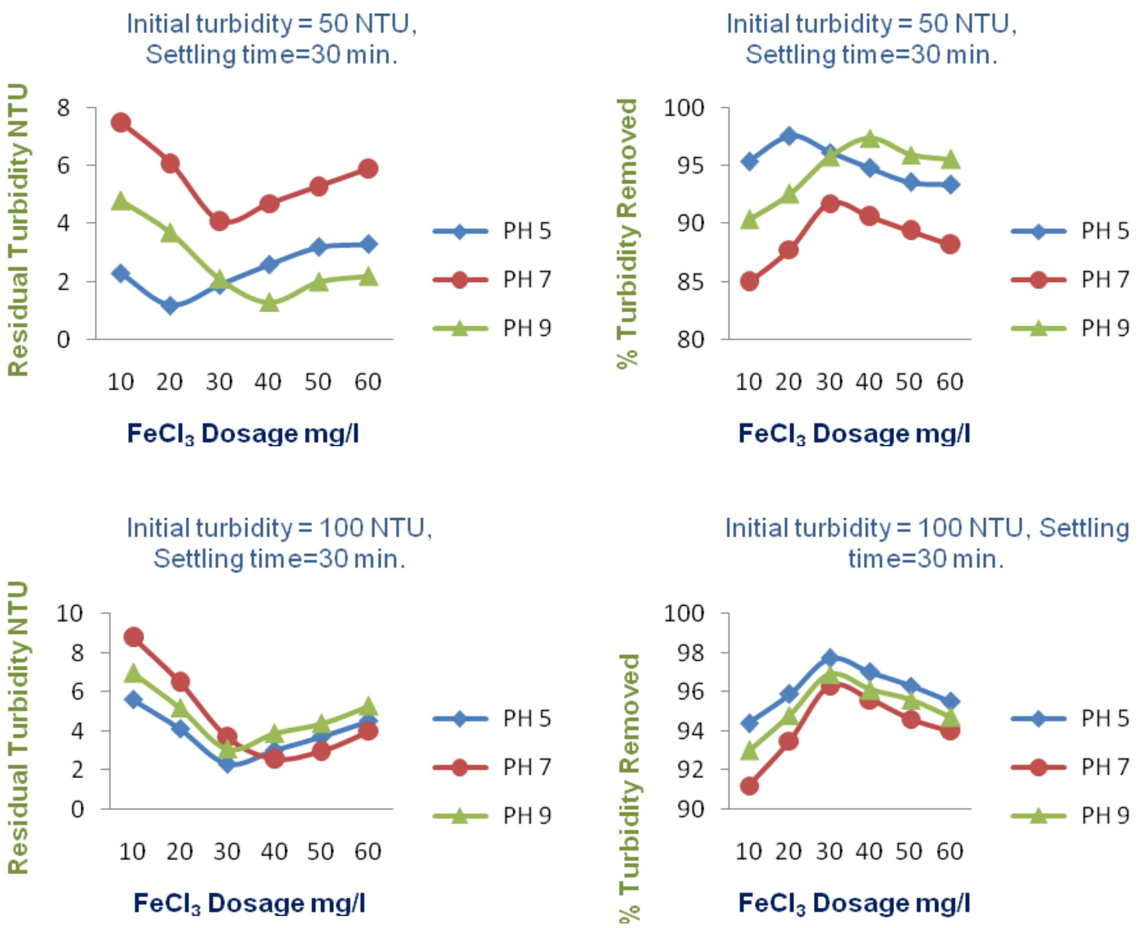


Fig. 1: Turbidity removal by Alum dose for pH values of 5, 7 and 9 for different values of turbidity.

Figure 2illustrates the effect of Ferric Chloride dose on turbidityremoval at pH values of 5, 7, and 9. Initial turbidities of water samples were adjusted to be 50, 100, 250 NTU.



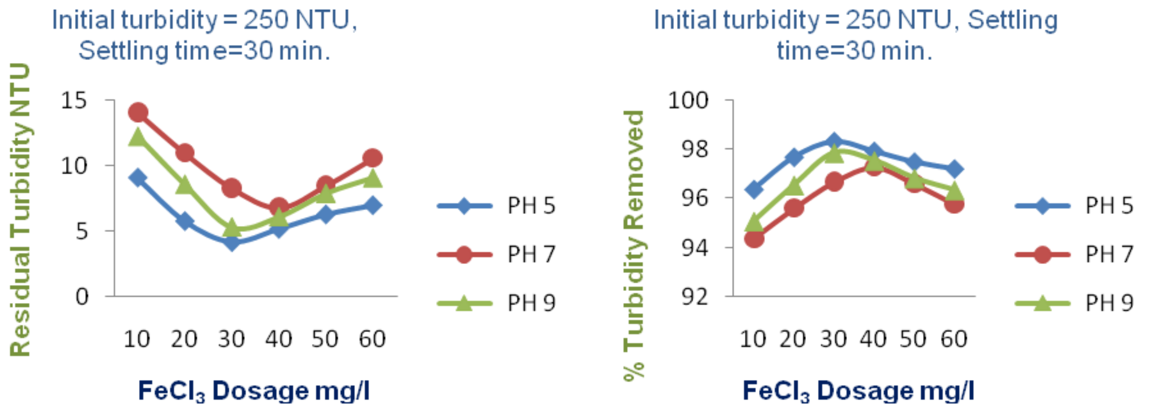


Fig. 2: Turbidity removal by Ferric Chloride dose for pH values of 5, 7 and 9 for different values of turbidity.

IV. DISCUSSION

The best performance of Alum was observed at pH 7 over the selected range of turbidity but its performance decreased to some extent at pH values of 5 and 9. Coagulation efficiency of Alum at pH 9 was almost close to that of at pH 7. The highest turbidity removal was attained at pH 7 when 20 mg/lAlum was used for initial turbidity of 250 NTU. The best performance of Alum in removing turbidity from water was obtained at pH 7 followed by pH 9. The coagulation efficiency of Alum remained almost constant within the dosage range of 20-40 mg/l at pH values of 5, 7 and 9. (Fig.1) In other words, results showed that Alum dosage range for good coagulation was almost wide in this study. Generally, Aluminium and iron salts rapidly hydrolyse in water to give a range of products including cationic species, which can be absorbed by negatively charged particles and neutralize their charge. This is one mechanism whereby particles can be destabilized, so that flocculation can occur. Overdosing can disrupt this phenomenon, therefore fairly precise control of coagulant dosage should be considered in water treatment plants. At the optimum condition (optimal dose and pH), turbidity removal efficiencies of Alum were 97.4, 98.8, 98.64percent for initial turbidities of 50, 100, and 250 NTU, respectively. Results indicated that turbidity removal efficiency was varied by pH, Alum dose and initial turbidity of water. The obtained results are in accordance with those obtained by Volk *et al*. (2000) which indicated that the pH of coagulation was the most influential parameter which affected removal of turbidity from water.Results indicated that turbidity removal efficiency was decreased to some extent by increasing initial turbidity level from 50-100 and 250 NTU. Application of higher Alum dosage range may improve turbidity removal from relatively high turbidity waters. However it should be considered that coagulation with Alum may increase Aluminium concentration in drinking water as reported in many texts. Aluminium in coagulated drinking water has been regarded as a subject of human and environmental health concern.Ferric Chloride wasfurther studied in detail to improve coagulation efficiency as well as obtaining of minimum residual Aluminium in treated water. The coagulation efficiency of ferric chloride increased within the dosage range of 10-30 mg/l at pH values of 5, 7 and 9. (Fig. 2) The best performance of Ferric Chloride was observed at pH 5 and subsequently pH 9. The optimum coagulant dosage for initial turbidity of 50 NTU was obtained when 20 mg/lFerric Chloride was used. However, the highest turbidity removal efficiency for initial turbidities of 100 and 250 NTU was achieved when

30 mg/lFerric Chloride was used, respectively. Turbidity removal efficiencies of Ferric Chloride at the optimal pH and Ferric Chloride dosage were 97.6, 97.7, and 98.32percent for initial turbidities of 50, 100 and 250 NTU, respectively. The highest turbidity removal efficiency for Ferric Chloride was almost constant (more than 90%) over the selected range of turbidity. Results showed that turbidity removal is dependent on pH, coagulant dosage, as wellas initial turbidity of water for both Alum and Ferric Chloride. Variation of pH considerably affected turbidity removal. When pH was kept around its optimal value (5 and 9 for Ferric Chloride and 7 for Alum) the highest turbidity removal was achieved. It should be noted that rapid mixing parameters including time and intensity of mixing, as well as slow mixing parameters may also affect turbidity removal efficiency in coagulation process. Results indicated that performance of Alum was almost same as that of Ferric Chloride and turbidity removal efficiency displayed an almost similar pattern for both Alum and Ferric Chloride. Coagulation and flocculation process is a primary and cost-effective process in water treatment plants which can effectively remove turbidity for different turbid waters when operational condition is optimized. Optimization of pH and coagulant dose may increase the coagulation efficiency and reduce the sludge volume and subsequently sludge management costs.Both Alum and Ferric Chloride demonstrated promising performance in turbidity removal from water.

V. CONCLUSION

The jar test experiments were performed on varying values of turbidity of water. The coagulation experiments using Aluminium Sulphate and Ferric Chloride indicated that coagulation process effectively removed turbidity from water using 20-40 mg/l of the used coagulants. The optimum pH value for turbidity removal was found 5 and 9 and 7and 9, respectively, for Ferric Chloride and Alum resulting in the maximum turbidity removal. The highest turbidity removal efficiency was within 97.4 – 98.64 % and 97.6 – 98.32 %, respectively for Alum and Ferric Chloride over the applied range of turbidity. Generally results showed that turbidity removal efficiency was almost same forAluminium sulphate and Ferric Chloride at optimum conditions. Turbidity removal efficiency was sufficient to meet national drinking water limits of India (5 NTU) at optimum Alum and Ferric Chloride dose for waters with initial turbidity of 50 NTU to 250 NTU. Application of different dosage and alternative coagulants to meet allowable limits should be further studied. However, national standards vary among different countries. Here, the coagulation process and turbidity removal was considerably affected by pH, coagulant dosage, as well as initial turbidity of water for both Alum and Ferric Chloride. Turbidity removal using both coagulants seemed to bemore influenced by pH variation than coagulant dosage.Investigation the influence of rapid mixing parameters,time and intensity of mixing, as well as slow mixingparameters on turbidity removal by Alum and Ferric Chloride can also be studied further.

ACKNOWLEDGEMENT

Special thanks to Dr. M. V. Jadhav, Mr. U. P. Naik, and Dr. G. K. Kharate for their kind support and motivation.

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