Enhanced Removal of Turbidity in Thermal Power Plant

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***Abstract*—This paper describes the testing, implementation and interim results of a full-scale coagulant changeover from Aluminum Sulfate (Alum) to Poly Aluminum Chloride (PAC) at a large conventional water treatment plant in thermal power plant. Research was conducted at The Koradi Thermal Power Plant last year to determine if a coagulant other than Alum would work better. Two inorganic coagulating agents, alum, & polyaluminum chloride (PAC) were used to clarify samples; samples of raw water collected from Pench river, seasonwise, of different turbidity. Jar testing and pilot plant work conducted determined that the 18% Al_2O_3 non-sulfated and PAC would perform quite well. A one year full-scale PAC trial, using existing infrastructure was initiated in August-2014. Water quality and operational data was used to determine the effectiveness of the PAC over the different seasons.**

***Index Terms*— Alum, Coagulating Agents, Natural Organic Mater, Pench River, PolyAluminum Chloride, Total Suspended Solids.**

I. INTRODUCTION

Absolutely pure water is rarely, if ever, found in nature. The impurities occur in three progressively finer states - suspended, colloidal and dissolved matter. Coagulation, Flocculation and Clarification as well as Filtration are interdependent stages of the solids separation phase of water treatment. Clarification, which may be by settlement or flotation, is the unit step used immediately before filtration.Chemical dosing which is optimal means that the conditions for coagulation are the optimum; the floc formed may be suitable for the method of clarification in use.

In the past Alum has worked very well to clarify the water but as water quality guidelines become more stringent, Alum is proving to be less effective. Surface Water generally contains suspended colloidal solids and living organisms like bacterias & viruses. Coarser materials such as sand and silt can be eliminated to a considerable extent by plain sedimentation, but finer particles, such as those between 1-100 mm, must be chemically coagulated to produce larger flocks which are removable in subsequent settling and filtration. In considering the aggregation of particles in a colloidal dispersion, there are two distinct steps: 1) Particle transport to affect particle contact & 2) Particle destabilization to permit attachment.

There are many substances which react suitably with water to produce such an effect, known as coagulants. The precipitate so formed in the water is called the flock. The larger and heavier the flock is, the quicker the rate of settlement. Commonly used coagulants in water treatment are: Aluminum based, such as aluminum sulfate ($Al_2(SO_4)_3.18H_2O$), sodium aluminates (Na_3AlO_3), and poly aluminum chloride $[Al_2(OH)xCl_{6-x}]n$, Coagulants based on Iron, such as ferric sulfate ($FeSO_4.7H_2O$), and ferric chloride ($FeCl_3$), & Poly-electrolytes, which are long-chain synthetic polymers with a high molecular weight.

Chemistry:

The chemistry of PAC is quite different than liquid Alum. Alum is Aluminum Sulfate bonded to approximately 14 water molecules and has the formula $Al_2SO_4 \cdot 14H_2O$. When Alum is added to water, hydrolysis occurs forming several monomeric Alumna species including Al^{3+}, $Al(OH)^{2+}$, $Al(OH)_{4\,-}$ before precipitating to the solid phase amorphous Aluminum hydroxide ($Al[OH]_{3(am)}$). The intermediate species formed are highly dependent on water pH, temperature, available alkalinity and the nature of the inorganic and organic particles in the water. The fact that Alum needs to go through the hydrolysis reaction makes it very dependent on water pH, temperature and available alkalinity.

II. EXPERIMENTAL WORK

Jar test which is widely used to evaluate the performance of coagulants and is to determine the optimum chemical conditions in terms of coagulant dose and pH for treatment of the water. It is probably the most important routine test carried out at a treatment works employing coagulation and flocculation as part of the treatment process. The results should be used for control of the treatment plant, but not necessarily for prediction of plant operating rates, final turbidity and total (as distinct from soluble) coagulant levels. The interpretation of test results involves visual and chemical testing of the clarified water.

A. Alum stock solution Preparation-

As stated above, alums, (consisting of 17 to 19% Al_2O_3) were used. For such, a 1% alum solution was prepared by dissolving 1.0 grams of crystal alum in 1liter of distilled water (1000 ppm),100 ml of 1000ppm sample makeup to 1.0 L by using distill water(100 ppm stock solution)

B.Poly aluminum Chloride (PAC) stock solution Preparation-

1% PAC solution was prepared by dissolving 1.0 grams PAC powder in 1 liter of distilled water (1000 ppm),100 ml of 1000 ppm sample makeup to 1.0 L by using distill water (100 ppm stock solution)

C. Turbidity Test

Turbidity meter used to measure turbidity. Turbidity level was considered as the criteria of index for water clarity. Before testing, samples of untreated raw water collected from Pench River and of different turbidity such as 148, 543,811 and 2194 NTU.

D. pH Test

River water's pH was undertaken before and after water treatment with both types of coagulants, but there were no significant changes in the resultant pH. raw water was 8.2

E. Alkalinity Test

Alkalinity of river water sample was tested after addition both types of coagulants, but there were no significant changes in the resultant alkalinity of PAC.

III. RESULTS AND DISCUSSION

Table I- Performance of Alum and PAC
(Summer Season-Average)
(Source-Pench River, Turbidity-148, pH-8.21)

Alum mg/l	**0**	**5**	**10**	**20**	**30**	**35**
Residual Turbidity NTU	148	101	65	17	08	05
Reduction %	0	31.75	56.08	88.51	94.59	96.62
pH	8.21	8.12	7.75	7.42	7.33	7.21
Alkalinity ppm	158	152	146	138	129	120
T.S.S. ppm	29	22	18	12	07	05
PAC mg/l	**0**	**5**	**10**	**20**	**25**	-
Residual Turbidity	144	101	18	11	04	-
Reduction %	0	29.86	87.5	92.36	97.22	-
pH	8.21	8.20	8.16	8.12	8.10	
Alkalinity ppm	158	154	151	146	144	
T.S.S. ppm	29	23	16	11	04	

Table II- Performance of Alum and PAC
(Winter Season-Average)
(Source-Pench River, Turbidity-543, pH-8.21)

Alum mg/l	**0**	**5**	**10**	**20**	**30**	**40**
Residual Turbidity, NTU	543	166	78	37	18	05
Reduction %	0	69.42	85.63	93.18	96.68	99.08
pH	8.21	8.11	7.73	7.44	7.34	7.19
Alkalinity ppm	92	89	85	82	78	72
T.S.S. ppm	44	32	20	14	09	06
PAC mg/l	**0**	**5**	**10**	**20**	**25**	**30**
Residual Turbidity, NTU	541	99	47	21	11	04
Reduction %	0	81.70	91.31	96.11	97.96	99.26
pH	8.21	8.20	8.16	8.10	8.06	8.03
Alkalinity ppm	92	91	88	86	84	82
T.S.S. ppm	44	30	19	11	05	02

Table III- performance of Alum and PAC (Pre-Monsoon Season-Average) (Source-Pench River, Turbidity-811, pH-8.12)

Alum mg/l	**0**	**10**	**20**	**40**	**50**	**55**
Residual Turbidity, NTU	811	302	103	23	11	04
Reduction %	0	62.76	87.29	97.16	98.64	99.50
pH	8.12	7.90	7.77	7.52	7.37	7.25
Alkalinity ppm	90	84	77	69	64	61
T.S.S. ppm	57	46	33	14	08	04
PAC mg/l	**0**	**05**	**10**	**20**	**30**	**40**
Residual Turbidity, NTU	809	459	241	86	13	05
Reduction %	0	43.26	70.21	89.36	98.39	99.38
pH	8.12	8.02	7.93	7.80	7.71	7.63
Alkalinity ppm	90	86	82	79	76	72
T.S.S. ppm	58	44	29	13	07	03

Table IV- Performance of Alum and PAC (Monsoon Season-Average) (Source-Pench River, Turbidity-2194, pH-8.10)

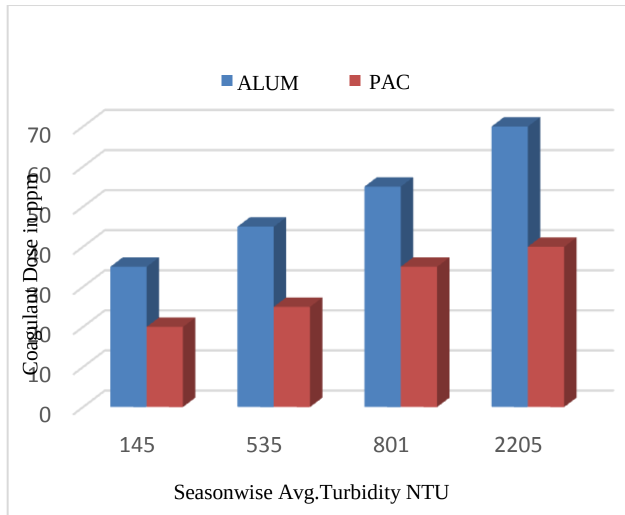
Alum mg/l	**0**	**20**	**40**	**50**	**60**	**70**
Residual Turbidity, NTU	2194	254	92	39	18	05
Reduction %	0	88.42	95.80	98.22	99.17	99.78
pH	8.10	7.83	7.68	7.52	7.40	7.27
Alkalinity ppm	96	78	63	56	49	40
T.S.S. ppm	74	61	42	26	12	06
PAC mg/l	**0**	**10**	**20**	**30**	**40**	**45**
Residual Turbidity, NTU	2199	284	86	41	13	05
Reduction %	0	87.08	96.08	98.13	99.40	99.77
pH	8.10	8.03	7.95	7.87	7.79	7.68
Alkalinity ppm	96	91	82	79	76	72
T.S S. ppm	74	41	23	15	08	04

Table V Comparative dose to decrease turbidity5 NTU

Sr. no	Turbidity NTU(Avg)	Alum mg/l	PAC mg/l	% consumption of PAC against Alum
1	148	35	25	71.42%
2	543	40	30	62.50 %
3	811	55	40	72.72%
4	2194	70	45	64.28 %

Average PAC consumption =67.73% ~70%

Graph1 Comparative dose to decrease turbidity 5 NTU



From the Table No. I to V and Graph- I the performance of different types of coagulants was observed on the clarity of river water. Thus, the effect of the coagulating agents, on the pH, alkalinity and T.S.S. of the treated water was tabulated. The effects of increasing doses of coagulants on water samples were determined. These figures show the increased removal of water impurities with an increase in the dose of all types of agents. However, the PAC produced the lowest water impurities. During the experiment, it was noted that during the PAC treatment flocks formed rapidly and the sludge produced was more compact than that of the alum. This could be due to the great ease of PAC hydrolysis as compared to that of alum. PAC emits polyhydroxides with long molecular chains and great electrical charges in the solution, thus maximizing the physical action of flocculation. The coagulation can then be carried out by neutralizing the negative charges on colloids by the ionic sites and then causing a decrease in zeta potential without changing the pH or alkalinity of water. Coupled with a low range of dosing, the PAC produced better results than either of the alum coagulants.

Present study & results focuses on reduction of turbidity of river/surface water used in Thermal Power Plants in huge quantity especially in India, the South Asian Tropical Country.

Residual Turbidity: - By applying the optimal dose of coagulation chemical reagent is realized the turbidity decreased. The data show that the dosage of PAC required for raw water treatment was less than alum (average consumption is approximately 70% i.e. 30% less than alum).During the experiment, it was noted that during the PAC treatment flocks formed rapidly and the sludge produced was more compact than that of the alum. This could be due to high molecular weight &hydrolysis of PAC as compared to that of alum.

Total Alkalinity- Alkalinity refers to the acid-neutralizing capacity of water, and is a general indication of water's buffering capacity. Alum is more acidic than PAC, and therefore, results in greater alkalinity consumption after addition. For PAC, alkalinity consumption is related to basicity. Higher basicity PAC will consume less alkalinity than low or medium basicity ones.

Effect of alum on water alkalinity indicates that as the amount of alum increases, the alkalinity of samples decreases very rapidly; this is because of SO_4^{2-}ions to form H_2SO_4 acid. This not in case of polyaluminum chloride as it has high molecular weight chain, so no considerable reduction in alkalinity. Hence no necessity of lime addition to maintain the alkalinity.

Effect of pH- pH plays an important role in coagulation/flocculation process using inorganic coagulants. Thus, pH must be controlled to establish optimum conditions for coagulation.

The change of solution pH occurred because the metal coagulants are acidic and they can consume large amounts of raw water alkalinity, dependent on the coagulant type. Higher alkalinity means more OH^- could be provided to meet the consumption of coagulant hydrolysis; solution pH is then more stable as coagulant was added. Similarly, with P.A.C., as the degree of hydrolysis is more, lesser reduction in pH is observed in comparison with alum.

IV. CONCLUSION

Experimental results showed that the dosage of PAC required for river water treatment was less as compared to alum at all levels of turbidity. Operation treatment using PAC gave excellent results as measured by rapid formation of flocks and compact sludge, and a shorter time for sedimentation. However, there were no significant changes in the pH & alkalinity of the solution after treatment with PAC. PAC also, has a wide range of dosage, and it may be well-suited to a wide range of turbidity. Thus, as compared to alum, it has better coagulation effects and found to be economical in determining the optimum dose during changing raw water quality periods. The PAC agent performed better compared to alum and might be considered a good alternative to alum for raw water treatment in thermal power plants.

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