Zeta Potential of Influent Particles as the Diagnostic Tool for Aptness of Influent to Rapid Sand Filters

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Abstract— Rapid sand filters, which are begin used unanimously for filtration in community water supply, are basically designed to remove particles by mechanisms other than straining. Surface removal in upper layer of sand beds is a curse to the depth filtration. The pretreatment, comprising of chemical coagulation and subsequent sedimentation, is presumed to make filter influent water apt for depth filtration. However inadequate pretreatment is a common fact, which results in unexpected poor performance of rapid sand filters. The zeta potential is a measure of surface charges on colloidal particles. Surface charges of particles are crucial for transport as well as attachment of particles to collecting sand grains. In this view an attempt is made in the present study to monitor zeta potential of particles in settled water at the Miraj Water Treatment Plant at Miraj-416416. The equipment Zeta Meter - 4, (U. S. A.) with computer interface and zeta potential software was used. It was found that the effluent turbidity as well as overall performance of rapid sand filters is strongly dependent of zeta potential of influent particles. Further the laboratory studies are carried out for improving aptness of influent water. Feasibility of techniques to improve quality of influent on field scale is also deliberated. The guidelines for operating are developed and use of zeta potential as a diagnostic operating parameter is presented.

Keywords-*zeta potential; pretreatment; surface charge;coagulation;rapid sand filtration.*

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I. INTRODUCTION

There is scarcity of pure water in nature. The impurities occur in three progressively finer states - suspended, colloidal and dissolved matter, where colloidal particles are those that are smaller than about 1 μm. Small suspended and colloidal particles and dissolved constituents will not settle in a reasonable period of time. Particles that won't settle are stable particles and chemicals must be used to help remove them. Different methods of treatment such as filtration are required for their removal or reduction to acceptable limits. Coagulation, flocculation and clarification as well as filtration are interdependent stages of the solids separation phase of water treatment

The purpose of coagulation and flocculation is to condition impurities, especially non-settleable solids and colour, for removal from the water being treated. Coagulating chemicals cause nonsettleable particles to clump together to form floc. In the coagulation process, chemicals are added which will initially cause the colloidal particles to become destabilized and clump together. In case of rapid sand filter, sand media may not be efficient in removing fine or submicron particles including colloids, bacteria, and viruses because of electrostatic repulsion arising from the fact that both the particles and the sand media are negatively charged. Small particles close to 1μm also have poor transport, impairing their removal. In primary coagulation the coarser particles having size more than 1μ get destabilized through gravity.(Bean et.al.,1963)However the minute particles of 1μ or smaller in size cannot settle through gravity because electric charges surrounding around the particles are predominate and, therefore, cause repulsion between the particles. So that electrokinetic charges prevent particles from joining into groups of greater mass so that particles cannot settle. The reduction of electrokinetic charges of these micro particles will reduce the repulsive forces between media grains and influent particles. This will enhance the attachment of micro particles to media grains

According to Indian drinking water standards (IS 10500:2004) the acceptable limit of turbidity of water after treatment was 5 NTU and it is revised to 1 NTU according to Indian drinking water standards (IS 10500:2009, 2012). To achieve desired drinking water standards there is need to modify the conventional water treatment by adopting appropriate alteration. Postsedimentation water from water treatment plant contains submicron particles including small colloids. These particles are unable to agglomerate, require large detention time for agglomeration and settling. By adopting secondary coagulation to postsedimentation water, these particles are destabilized i.e. zeta potential of these particles is so reduced that they can easily clump together and can be removed by adopting filtration. In this view it is proposed to assess surface charges of settled water and attempts will be made to destabilize settle water in order to make it appropriate for filtration.

II. Materials and Methods

A. *Methodology adopted for sampling*

Settled water sample was collected from tube settler basin of Miraj water treatment plant.

B. *Coagulants used for destabilization*

Alum, PAC (polyaluminium chloride)

C. *Measurement of Zeta potential*

Zeta meter 4.0 is equipment manufactured by Zeta-Meter, Inc. 765 Middlebrooks Avenue, USA. It was used for zeta potential measurement.

Fig.1 Zeta meter 4.0

D. *Laboratory Experimentation*

Jar test apparatus was used for coagulation and flocculation. Jar tests were carried out on settled water from Miraj water treatment plant by using above mentioned coagulants at optimum pH 7.2.Theoretically if the Zeta Potential is reduced to near zero (+/- 5mV) the repulsive forces are so reduced that the particles will tend to agglomerate and with continued agitation, will become large enough to settle. For that Initial zeta potential of settled water and zeta potential after coagulation was measured.

III. Results and Discussions

A. *Jar test results and zeta meter readings(postsedimention water)*

TABLE I.OPTIMUM COAGULANT DOSE AND RESIDUAL TURBIDITY

Sample No.	Settled water Turbidity (NTU)	Optimum Coagulant Dose (mg/l)		Residual Turbidity (NTU)	
		Alum	*PAC*	*Alum*	*PAC*
1.	12.4	40	2	2..86	3.45
2.	11.8	40	3	2.17	3.20
3.	13.1	40	2	2.56	3.52
4.	13.8	40	2	2.97	3.56
5.	11.3	40	4	2.24	3.18
6.	12.6	40	3	2.64	3.34
7.	13.2	40	2	2.70	3.48

TABLE II. ZETA POTENTIAL VARIATION

Sample No.	Settled water Zeta potential (mV)	Zeta potential after postsedimentation coagulation (mV)	
		For Alum	*For PAC*
1.	-20.83	-11.32	-9.12
2.	-19.36	-10.19	-8.73
3.	-23.72	-11.96	-9.38
4.	-24.82	-11.86	-9.21
5.	-19.69	-10.14	-8.72
6.	-21.26	-11.20	-8.64
7.	-22.80	-11.81	-9.16

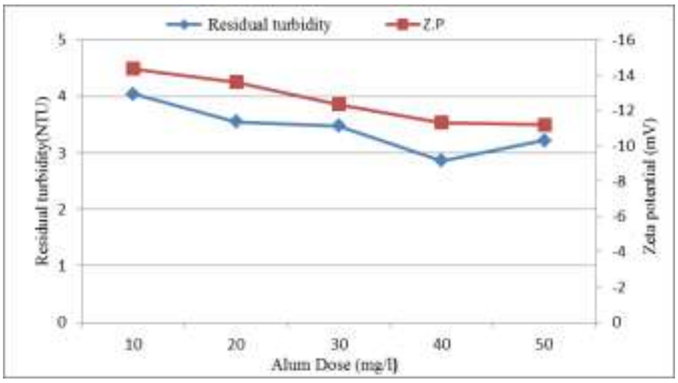

Fig.2 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity (Sample No.1, Settled water Turbidity = 12.4 NTU)

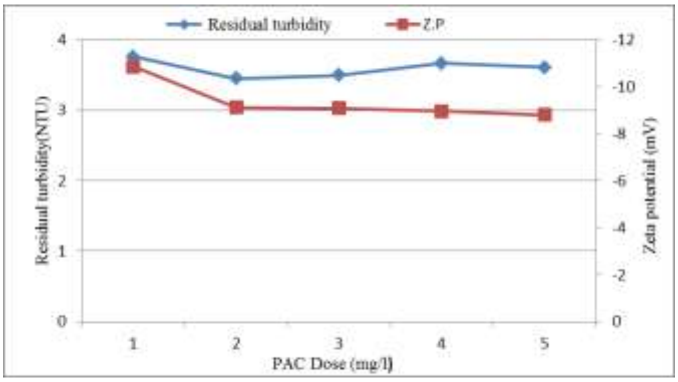

Fig. 2 b. PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity (Sample No.1, Settled water Turbidity = 12.4 NTU)

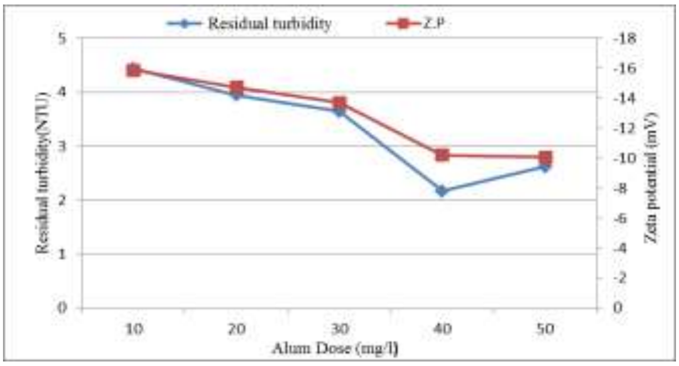

Fig.3 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity (Sample No.2, Settled water Turbidity = 11.8 NTU)

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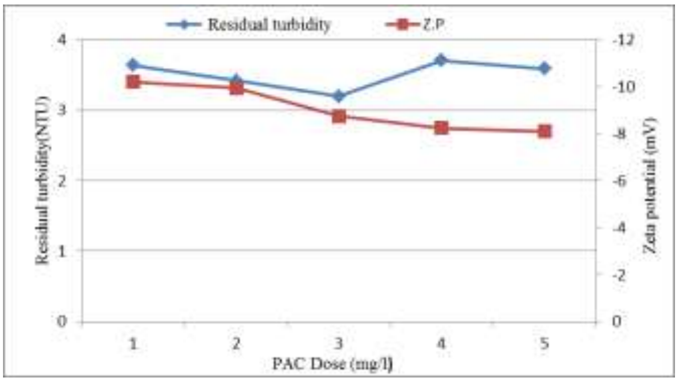

Fig.3 b. PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity
(Sample No.2, Settled water Turbidity = 11.8 NTU)

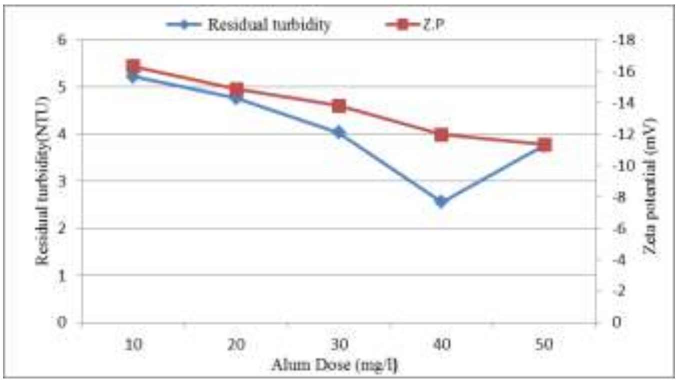

Fig.4 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity
(Sample No.3, Settled water Turbidity = 13.1 NTU)

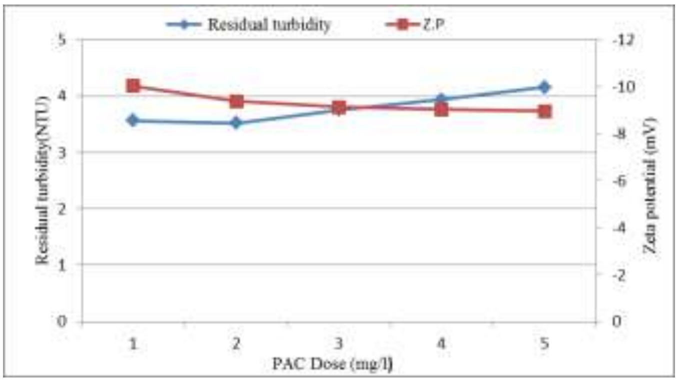

Fig.4 b. PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity
(Sample No.3, Settled water Turbidity = 13.1 NTU)

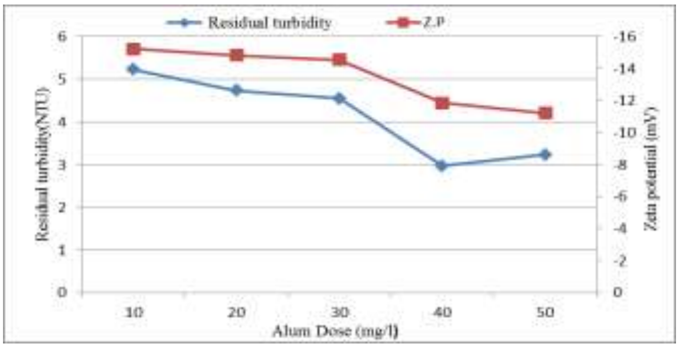

Fig.5 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity
(Sample No.4 Settled water Turbidity = 13.8 NTU)

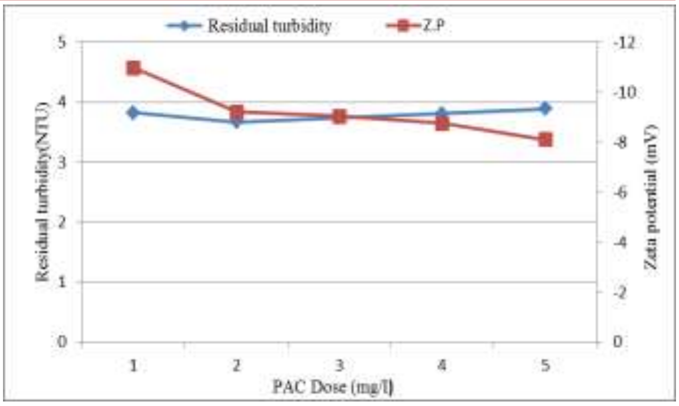

Fig 5.b.PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity
(Sample No.4, Settled water Turbidity = 13.8 NTU)

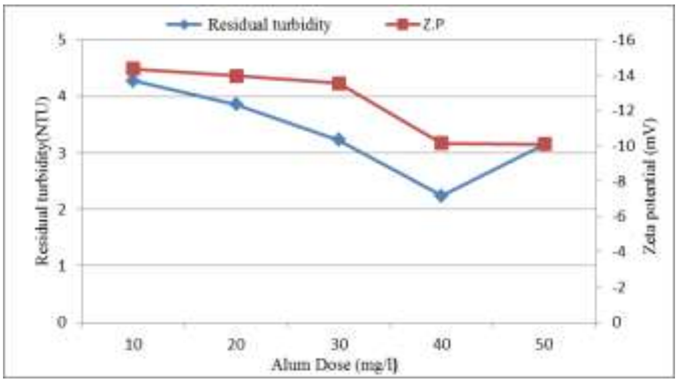

Fig.6 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity
(Sample No.5, Settled water Turbidity = 11.3 NTU)

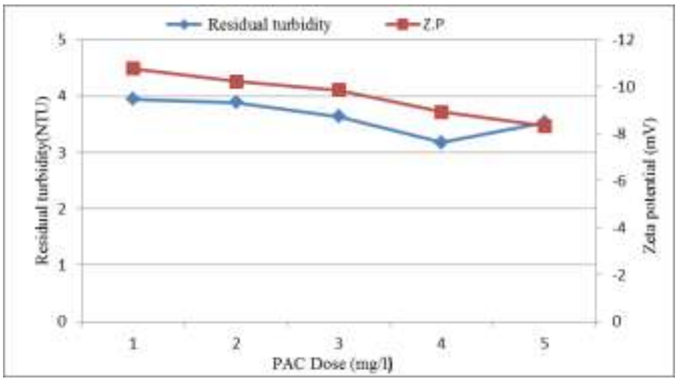

Fig.6 b. PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity
(Sample No.5, Settled water Turbidity = 11.3 NTU

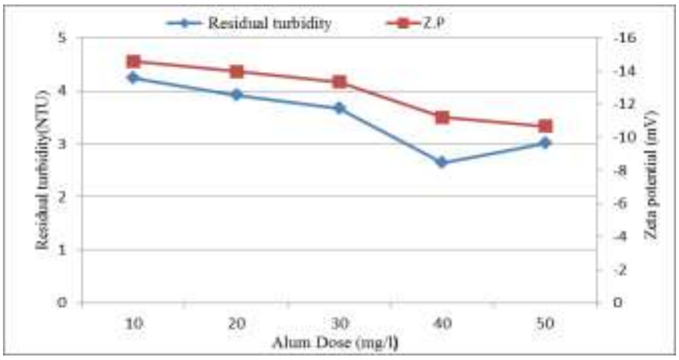

Fig.7 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity
(Sample No.6, Settled water Turbidity = 12.6 NTU)

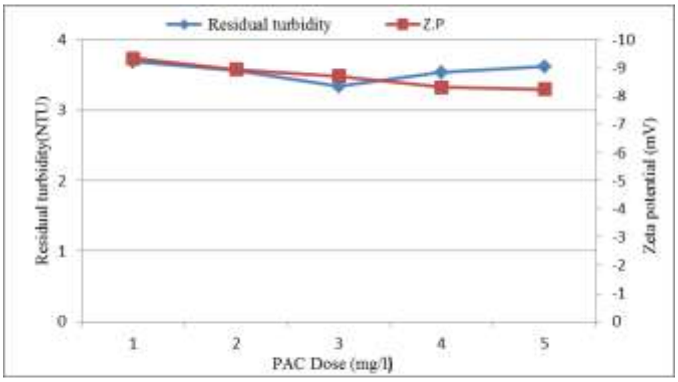

Fig.7 b. PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity (Sample No.6, Settled water Turbidity = 12.6 NTU)

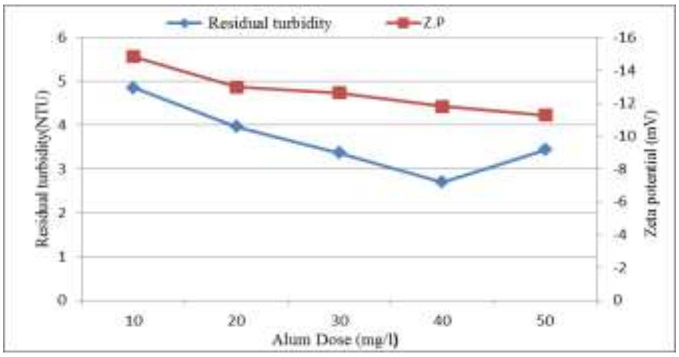

Fig.8 a. Alum Dose vs. Zeta Potential and Alum Dose vs. Residual Turbidity (Sample No.7, Settled water Turbidity = 13.2NTU)

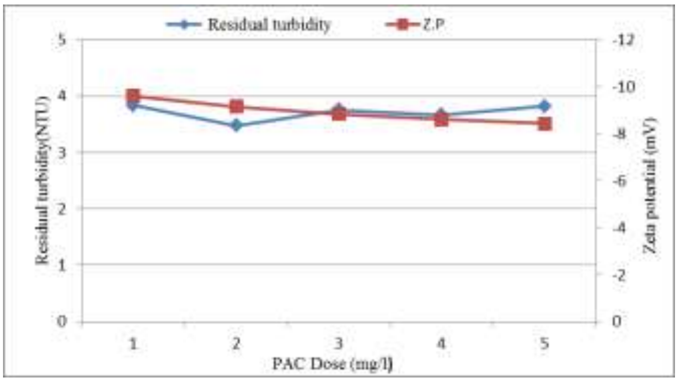

Fig.8 b. PAC Dose vs. Zeta Potential and PAC Dose vs. Residual Turbidity (Sample No.7, Settled water Turbidity = 13.2 NTU)

The several samples of settled water from Miraj water treatment plant were collected. The range of variation in zeta potential in case of settled water was lying in between -19.36 to -24.82 mV. A suspension has slight stability when it's Zeta Potential Ranges between -21 to -30 mV. Thus based on above study it can be concluded that the initial sample has slight stability. The samples of settled water were coagulated with alum and PAC independently and following results were obtained.

Sample no.1, initial settled water turbidity was 12.4 NTU having zeta potential -20.83 mV; Fig.2 a. shows that, optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.86 NTU was obtained. Corresponding zeta potential of suspension was -11.32 mV. Fig.2 b. shows that optimum PAC dose obtained by jar test was 2 mg/l. When 2 mg/l dose was given, residual turbidity of 3.45 NTU was obtained. Corresponding zeta potential of suspension was -9.12 mV.

Sample no.2, initial settled water turbidity was 11.8 NTU having zeta potential -19.36 mV; Fig.3 a. shows that, optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.17 NTU was obtained. Corresponding zeta potential of suspension was -10.19 mV. Fig.3 b. shows that, optimum PAC dose obtained by jar test was 3 mg/l. When 3 mg/l dose was given, residual turbidity of 3.20 NTU was obtained. Corresponding zeta potential of suspension was -8.73 mV.

Sample no.3, initial settled water turbidity was 13.1 NTU having zeta potential -23.72 mV; Fig.4 a. shows that, optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.56 NTU was obtained. Corresponding zeta potential of suspension was -11.96 mV. Fig. 4 b. shows that, optimum PAC dose obtained by jar test was 2 mg/l. When 2 mg/l dose was given, residual turbidity of 3.52 NTU was obtained. Corresponding zeta potential of suspension was -9.38 mV.

Sample no.4, initial settled water turbidity was 13.8 NTU having zeta potential -24.82 mV; Fig. 5 a. shows that optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.97 NTU was obtained. Corresponding zeta potential of suspension was -11.86 mV. Fig. 5 b. shows that, optimum PAC dose obtained by jar test was 2 mg/l. When 2 mg/l dose was given, residual turbidity of 3.56 NTU was obtained. Corresponding zeta potential of suspension was -9.21 mV.

Sample no.5, initial settled water turbidity was 11.3 NTU having zeta potential -19.69 mV; Fig. 6 a. shows that, optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.24 NTU was obtained. Corresponding zeta potential of suspension was -10.14 mV. Fig. 6 b. shows that, optimum PAC dose obtained by jar test was 4 mg/l. When 4 mg/l dose was given, residual turbidity of 3.18 NTU was obtained. Corresponding zeta potential of suspension was -8.92 mV.

Sample no.6, initial settled water turbidity was 12.6 NTU having zeta potential -21.26 mV; Fig. 7 a. explains that, optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.64 NTU was obtained. Corresponding zeta potential of suspension was -11.20 mV. Fig. 7 b. shows that, optimum PAC dose obtained by jar test was 3 mg/l. When 3 mg/l dose was given, residual turbidity of 3.34 NTU was obtained. Corresponding zeta potential of suspension was -8.72 mV.

Sample no.7, initial settled water turbidity was 13.2 NTU having zeta potential -22.80 mV; Fig. 8 a. shows that, optimum alum dose obtained by jar test was 40 mg/l. When 40 mg/l dose was given, residual turbidity of 2.70 NTU was obtained. Corresponding zeta potential of suspension was -11.81 mV. Fig. 8 b. shows that, optimum PAC dose obtained by jar test was 2 mg/l. When 2 mg/l dose was given, residual turbidity of 3.48 NTU was obtained. Corresponding zeta potential of suspension was - 9.16 mV.

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CONCLUSION

It was observed that zeta potential of coagulated and settled water from Miraj WTP was enough high i.e. in the range -19 mV to -24 mV .By using alum and PAC for post sedimentation coagulation it was reduced to -5 mV to -13 mV which is more suitable for better filtration.

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