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# Importance of Mixing Device in Coagulation-Flocculation Process & Its Effect on Treatment Parameters in Plant Operation

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**ABSTRACT** –Coagulation- Flocculation is the most widely used process for reduction of suspended solids at any waste water plant. Mixing devices play an important role in through mixing of coagulant and floc formation. Reverse Osmosis is emerging as a process to make plant zero discharge which also enhances environmental sustainability. This process requires very low TSS as the membranes are subjected to chocking. The report has been prepared for a pharmaceutical company waste water. The conventionally treated wastewater was further treated for Total Suspended Solids (TSS) reduction prior to tertiary treatment like Reverse Osmosis. Combination of various coagulants coagulant aidand pretreatment was used to reduce TSS. This was done by regular coagulation flocculation method at optimum pH.Differences in results of laboratory and pilot plant study is highlighted here due non provision of similar mixing device.
**Key Words:** Coagulation-Flocculation, Mixing Devices, Total suspended solids (TSS),

## I.  INTRODUCTION

Reverse Osmosis process is widely used to remove TDS andas a treatment for reuse of waste water. It is suitable to reduce TSS upto a desirable limit to prevent choking of reverse osmosis membrane. The desirable limit for TSS and turbidity is 50 ppm and ≤20 NTU respectively.TSS includes both the suspended and colloidal solids. Coagulation – Flocculation process is a major process for TSS reduction. Mixing devices are equally important in the process to achieve desired results.

In waste water treatment plants, chemical coagulation is usually accomplished by the addition of trivalent metallic salts such as $AL_2(SO_4)_3$ or $FeCl_3$. Four mechanisms generally occur namely Ionic layer compression, adsorption and neutralization of colloid charge by adsorption of counter ions on the surface of the colloid, bridging of colloidal particles via polymer addition, entrapment of colloidal particles by sweeping floc.

Rapid or Flash mixing is the process by which a coagulant is rapidly and uniformly dispersed through the mass of water. Chemical reactions occur immediately after the addition of coagulants, forming active coagulant species. The active species promotes the destabilization and the contact of suspended colloids through 'rapid-mixing'**ChichuanKan et.al**. Here colloids are destabilized and the nucleus for the floc is formed. Slow mixing brings the contacts between the finely divided destabilized matters formed during rapid mixing. Velocity gradient 'G' and detention time 't' are the decisive parameters for dispersion and mixing of coagulant as well as floc formation.The parameter expressing mixing intensity is called the velocity gradient or G-value (s-1). Recommended Gvalue for rapid mixing is minimally 1500 s-1. Mixing intensity and time has the significant effect of the mechanisms, **O.P. Sahuet. al.**

Further flocculation devices also provide contact sites for large floc formation. "Optimum flocculation is mainly achieved under the conditions of proper coagulation, optimum pH range, proper level of mixing intensity and adequate net mixing time", **Kamal L. Nahhas**. This report has been prepared for a pharmaceutical company. The wastewater is generated from produce of active pharmaceutical ingredients (API), antibiotics and anti-TB and contains trace amount of inorganic and organic components, ammonia salt, phosphorous, sulphur, alcohols etc.

| Parameter | Raw waste water (ppm) | Treated waste water (ppm) | RO Requirement (ppm) |
|---|---|---|---|
| pH | 8.5-9.0 | 7.0-8.5 | |
| TSS | 1000-1250 | 500 | 50 |
| TDS | 5000-6000 | 4500-5500 | - |
| Turbidity | | 208 NTU | ≤20 NTU |

Note – Values indicated are average values
**Table 1. Waste water characteristics and disposal limits**

## II.  MIXING DEVICES, MATERIALS AND METHODS

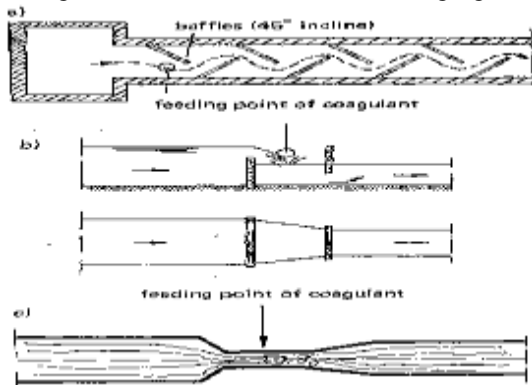Mixing devices are shown in the following figure



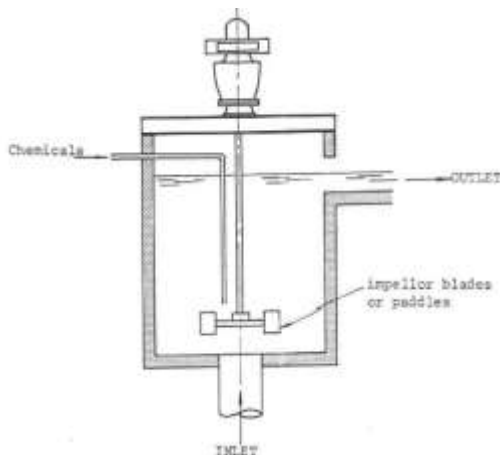**Fig 1. Hydraulic Mixing Devices**



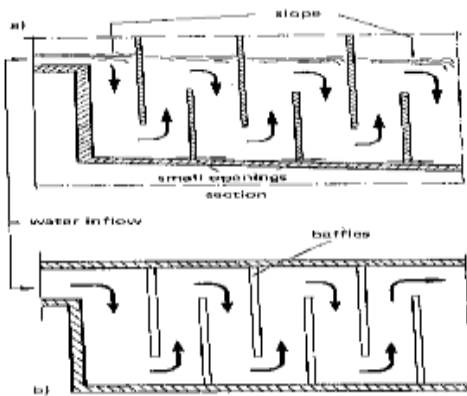**Fig 2. Mechanical Mixing and Flocculation Device**



**Fig 3. Hydraulic Flocculation Devices**

All lab experiments were conducted with the mechanical devices i.e jar test apparatus & magnetic stirrer. **The laboratory jar test is modelled after coagulation process used in most water treatment plants. (EE by Peavy, Rowe, Tchbanoglous).** However the pilot plant was provided with hydraulic mixing device i.e pipe with bend & slope to provide a velocity of 1-1.5  m/s and a baffled chamber for flocculation. The coagulant was added at the outlet of SST and sedimentation chamber with baffled inlet was built for flocculation & sedimentation. It should be noted that there was no turbulence at the point of coagulant addition. **The study herewith shows how the result varies from laboratory to plant and highlights the importance of providing similar mixing devices.**
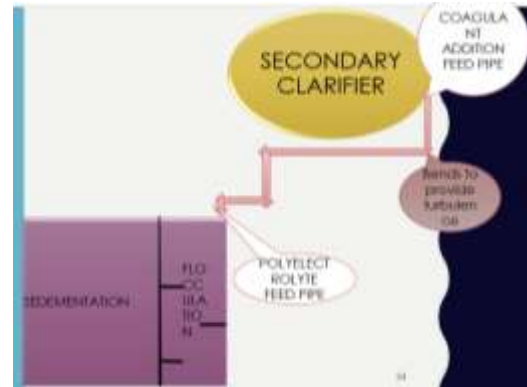


**Fig 4. Mixing provision at plant**

Effluent samples were taken from outlet of conventionally treated wastewater of a pharmaceutical company. Every time fresh grab samples were taken for the experiment. Chemicals were purchased from a local supplier of industrial category. It includes alum, polyaluminium chloride (PAC), ferric chloride (FeCl3), anionic polyelectrolyte (Zetag 4145), clay, activated carbon, lime, microsand (100-150μm size) ,(ballasted flocculation).

Stock solution of 5% strength (5 ml in 100 ml distilled water) of alum, PAC and FeCl3 , 0.05% strength (0.05 gm in 100 ml distilled water) of polyelectrolyte was  prepared.  Feed solution of lime 10% strength (10 gm in 100 ml) and clay, activated carbon, microsand were added by weight.

Experiment were carried out at optimum pH of 7.5 to 8.5. Optimum results of Alum+Polyelectrolyte, PAC + Polyelectrolyte, Lime in addition to the above combination was implemented at pilot plant to optimize the R.O plant and to study the reliability of laboratory results.

### A.  COAGULATION AND FLOCCULATION

Coagulant PAC, alum was mixed rapidly at 200 rpm for 1 minute. At the end of rapid mixing polyelectrolyte was mixed followed by slow mixing/flocculation for 10 minutes at 30-50 rpm speed. The generation of flock could be watched during this process. Flock was allowed to settle for

30 minutes before withdrawing the samples for analysis. This procedure was performed several times so that the optimum dose of the adsorbent, coagulant and flocculent can be determined.

### B. COAGULATION AND FLOCCULATION WITH PRETREATMENT

Desired amount of pretreatment material (lime) was added and mixed with waste water at 200 rpm for 1 minute. Contact time of 15 minutes for lime. Further addition of coagulant, flocculent was followed as per above coagulation and flocculation process.

### C. ANALYTICAL ANALYSIS

25 ml sample of coagulated waster water was filtered through whatman 42 filter paper for TSS measurement. Final pH and turbidity was measured by pH and turbidity meter respectively. The residue on the filter paper was dried at 103°C for 1 hour. The increase in the weight of the filter paper represents the TSS.

Calculation

mg total suspended solids/L

$$= \frac{(A-B) \times 1000}{\text{sample volume, mL}}$$

where: A = weight of filter + dried residue, mg, and   B = weight of filter, mg.

## III. RESULTS AND DISCUSSION

Optimum  pH: - 7.0 to 8.5

### A. COAGULATION AND FLOCCULATION

#### a. Alum+polyelectrolyte

Optimum dose was 300(alum)+3 (poly) ppm. TSS was reduced from 500 to 160 ppm in lab and to 200 at plant.

| Coagulant | Dose ppm | Polyelectrolyte ppm | Initial SS | Final SS in lab | Final SS @ plant | % Efficiency in lab | % Efficiency at plant | % Difference in efficiency | Remark |
|---|---|---|---|---|---|---|---|---|---|
| Alum | 200 | 1.5 | 500 | 360 | | 28% | | | |
| Alum | 200 | 2 | 500 | 240 | | 52% | | | |
| Alum | 400 | 1.5 | 500 | 240 | | 52% | | | |
| Alum | 400 | 2 | 500 | 280 | | 44% | | | |
| Alum | 300 | 2 | 500 | 240 | | 52% | | | |
| Alum | 300 | 3 | 500 | 160 | 200 | 68% | 60% | 8% | Optimum Dose |
| Alum | 400 | 4 | 500 | 160 | | 68% | | | |

**Table 2. Alum+polyelectrolyte resultchart**

#### b. PAC+ Polyelectrolyte

Optimum dose was 250(PAC)+1.5(poly) ppm. TSS was reduced from 500 to 120 ppm in lab and to 160 ppm at plant. An enhanced dose was

also tried i.e.450 (PAC)+3.0(poly)for reduction of turbidity also. 84% TSS reduction was observed.

| Coagulant | Dose ppm | Polyelectrolyte ppm | Initial SS | Final SS in lab | Final SS @ plant | % Efficiency in lab | % Efficiency at plant | % Difference in efficiency | Remark |
|---|---|---|---|---|---|---|---|---|---|
| PAC | 50 | 1 | 500 | 280 | | 44% | | | |
| PAC | 100 | 0.5 | 500 | 280 | | 44% | | | |
| PAC | 100 | 1 | 500 | 200 | | 60% | | | |
| PAC | 150 | 1 | 500 | 200 | | 60% | | | |
| PAC | 150 | 0.5 | 500 | 200 | | 60% | | | |
| PAC | 200 | 0.5 | 500 | 160 | | 68% | | | |
| PAC | 200 | 1 | 500 | 160 | | 68% | | | |
| PAC | 250 | 1.5 | 500 | 120 | 160 | 76% | 68% | 8% | Optimum Dose |
| Enhanced PAC | 400 | 2 | 500 | 120 | | 76% | | | |
| Enhanced PAC | 500 | 2 | 500 | 120 | | 76% | | | |
| Enhanced PAC | 450 | 3 | 500 | 80 | 120 | 84% | 76% | 8% | Optimum Dose |
| Enhanced PAC | 500 | 3 | 500 | 80 | | 84% | | | |

**Table 3. PAC+polyelectrolyteresult chart**

### B. COAGULATION AND FLOCCULATION WITH PRETREATMENT

#### a. Lime+PAC+polyelectrolyte

Optimum dose was 350(Lime)+300(PAC)+2.0(poly) ppm. TSS was reduced from 500 to 80 ppm in lab

Optimum dose was 325(lime)+300(alum)+3.0(poly) ppm. TSS was reduced from 500 to 80 ppm in lab and 160 ppm at plant.

| Pretreatment method | Coagulant | Dose ppm | Coagulant ppm | Poly ppm | Initial SS | Final SS | Final SS @ plant | % Efficiency | % Efficiency @ plant | % Difference | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Lime | PAC | 200 | 250 | 1.5 | 500 | 160 | | 68% | | | |
| Lime | PAC | 250 | 300 | 1.5 | 500 | 120 | | 76% | | | |
| Lime | PAC | 300 | 300 | 2 | 500 | 120 | | 76% | | | |
| Lime | PAC | 350 | 300 | 2 | 500 | 80 | | 84% | | | |
| Lime | PAC | 400 | 300 | 2 | 500 | 80 | | 84% | | | |
| Lime | ALUM | 200 | 200 | 2 | 500 | 160 | | 68% | | | |
| Lime | ALUM | 250 | 200 | 2.5 | 500 | 120 | | 76% | | | |
| Lime | ALUM | 300 | 250 | 3 | 500 | 120 | | 76% | | | |
| Lime | ALUM | 325 | 300 | 3 | 500 | 80 | 160 | 84% | 68% | 16% | Optimum dose |
| Lime | ALUM | 350 | 300 | 3 | 500 | 80 | | 84% | | | |

**Table 4. Lime+Alum/PAC+polyelectrolyte Result**

## VI. SUMMARY

| COAGULANT+AID+FLOCCULENT | OPTIMUM DOSE | % EFFICEINCY IN LAB | % EFFIECINCY AT PILOT PLANT | DIFFERENCE |
|---|---|---|---|---|
| ALUM+POLY | 300+3 | 68 | 60 | 8 |
| PAC+POLY | 250+1.5 | 76 | 68 | 8 |
| LIME+ALUM+POLY | 325+300+3 | 84 | 68 | 16 |
| ENHANCED PAC +POLY | 450+3 | 84 | 76 | 8 |



**Table 5. Summary & Chart**

NOTE – Optimum dose of all four combination was tried at pilot plant for a almost a month. The readings showm here are average reading. The % variation from lab experiment in TSS reduction was from 8% to 16%.

Enhanced coagulation, in which PAC (450)ppm+(3.0)polyelectrolyte ppm was adopted at plant level looking to the feasibility inmixing, operation and TSS reduction. The coagulants were mixed by hydraulic mixing. As per the summary it is clear that the difference in result was considerable due to non-provision of suitable mixing device hence highlights its importance.

## VII. CONCLUSION

It can be concluded that the combination of enhanced PAC+polyelectrolyte (450+3.0) ppm was most suitable at 7.0-8.5for TSS reduction. The same dose can be further tried by providing hydraulic mixing device such as hydraulic jump by parshall flume or overflow weir. Mixing device governs the rapid mixing of coagulant in waste water and hydrolysis. Similarly floc formation also depends on the mixing parameters. Result of the study clearly shows how the mixing device play an important role in proper functioning of the process and plant. Thus for optimization of coagulation-flocculation process at plant proper provision of mixing device is equally important as the choice of coagulant.

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