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# An Investigation into Settling Pattern of Suspended Solid Matter in Fresh Water a Case Study of Ureje Rivers, Ado-Ekiti

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**Abstract:** In order to investigate the settling pattern of particles in suspension, series of experiment were conducted on surface water samples from Ureje river in Ado-Ekiti, Ekiti State, Nigeria. Flocculent particles were observed to be present in quiescent settling column from the concentration dept time. Mixing effect was significant, resulting in about 10% removal while the specific mixing times effect selected for evaluation under a constant dosage showed 80% removals. This shows that alum dosage selected for evaluation will cause 80% removal. However, when operating near the optimum of the mixing time or alum dosage, the influence of these parameters is less significant. The results also suggest the presence of a fraction of suspended matter in surface water which is not readily removable by gravity settling.

**Key words:** Investigation, setting pattern, solid matter, fresh water, Ado-Ekiti

## INTRODUCTION

The treatment of water for consumption has been in practice for the past years. Water treatment for community started in Scotland in the term of settling operations followed by filtration (Collins *et al*., 1987; George, 1979; John and Warren, 1965).

However, within 40 to 50 years, scientific research has improved the understanding of the principles involved in water treatment and this led to the development of better equipment and an overall increase in operating efficiency in water treatment (Cox, 1964; George, 1979).

Generally, all natural water will require some degree of treatment in order to meet modern drinking water standards. The nature and extent of treatment will depend on the quality of raw water and the intended use (Camp, 1946; Collins *et al*., 1987; Cox, 1964).

Every river carries an erosion history of the journey it traveled, thus the concentration of solids and organic materials in surface water (Fox, 1949; George, 1979). A typical plant, treating turbid surface water with organics includes the following processes: Screening/commination, aeration mixing, coagulation, flocculation, sedimentation, filtration, absorption and disinfection (Bechteler and Schrimpf, 1982; Bhargava and Rajapopal, 1989; George, 1979). Conventional water treatment plants in Nigeria employ the processes above.

The largest and most evident contribution to water pollution is made by the presence of various solids. There solids need to be removed in order to eliminate problems both to the consumers and the distribution systems (Outreach Department, 1997; Zanoni and Blomquist, 1975).

Two different principles can be applied to the separation of solid particle, from water. These are:

- The direct use of gravity in the form of sedimentation, where the determining factors are the size and specific weight of the particles. This defined by discrete setting and by stroke law (Hazen, 1904; Imame *et al*., 1983; Ostendorf, 1986; Outreach Department, 1997; Schamber and Larock., 1981; Zanoni and Blomquist, 1975).

$$Vs = \sqrt{\frac{g(\rho s - S_S)d^2}{18\pi}}$$

Where
Vs = Settling velocity, g =Acceleration due to gravity, ρs = density of solid, d = diameter of solid particles η = viscosity

- Filtration or screening (Collins *et al*., 1987; Cox, 1964).

## MATERIALS AND METHODS

**Raw water sample:** Raw water sample for this research is collected from Ureje river in Ado-Ekiti and currently serve as water source for municipal water treatment in Ado-Ekiti, Ekiti State; Nigeria. The final result presented is the average characteristics of the suspensions from the source (Zanoni and Blomquist, 1975). Results obtained in the experiment agreed with experimental data of researchers.

Three experiments were performed on the raw water sample.

**Experiment I:** This is to determine the effect of mixing on the process of sedimentation.

**Experiment II:** To study the effect of mixing time on the settling behaviour of suspended solids in suspension.

**Experiment III:** This investigates the effect of the coagulant dosage on the settling patterns of suspended solids in the suspension.

## RESULTS AND DISCUSSION

**Experiment I (Mixing experiment):** Turbidity measurements of samples drawn from the sampling ports at various detention times are given in the tables alongside the percentage concentration of particles

Turbidity of samples (NTU) for mixing experiment on Ureje River (Table 1-3 and Fig. 1).

Table 1: Turbidity of samples (N.T.U) for mixing experiment

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 130 | 127 | 124 | 121 | 118 |
| 1.2 | 129 | 126 | 125 | 123.5 | 121 |
| 1.8 | 130 | 128 | 127 | 126 | 123 |
| 2.4 | 133 | 132 | 130 | 129 | 127 |

Table 2: Average percent concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 97.7 | 95.4 | 93.1 | 90.9 |
| 1.2 | 97.7 | 96.9 | 95.7 | 93.8 |
| 1.8 | 98.5 | 97.7 | 96.9 | 94.6 |
| 2.4 | 99.0 | 97.7 | 97.0 | 95.5 |

Table 3: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 2.3 | 4.6 | 6.9 | 9.2 |
| 1.2 | 2.3 | 3.1 | 4.3 | 6.2 |
| 1.8 | 1.5 | 2.3 | 3.1 | 5.4 |
| 2.4 | 1.0 | 2.3 | 3.0 | 4.5 |
| Average | 1.78 | 3.08 | 4.33 | 6.33 |

Table 4: Turbidity of samples (N.T.U) for mixing experiment for 20 sec

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 91 | 74 | 58 | 33 | 31 |
| 1.2 | 98 | 79 | 66 | 34 | 34 |
| 1.8 | 107 | 83 | 69 | 42 | 38 |
| 2.4 | 202 | 189 | 145 | 78 | 75 |

Table 5: Average percent concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 81.3 | 63.7 | 36.3 | 34.1 |
| 1.2 | 80.6 | 67.4 | 34.7 | 34.7 |
| 1.8 | 77.6 | 64.5 | 39.3 | 35.5 |
| 2.4 | 93.6 | 71.8 | 38.6 | 37.1 |

**Experiment II (Mixing time experiment):** Results obtained for water samples subjected to various mixing times (Table 4-13 and Fig. 2-5).

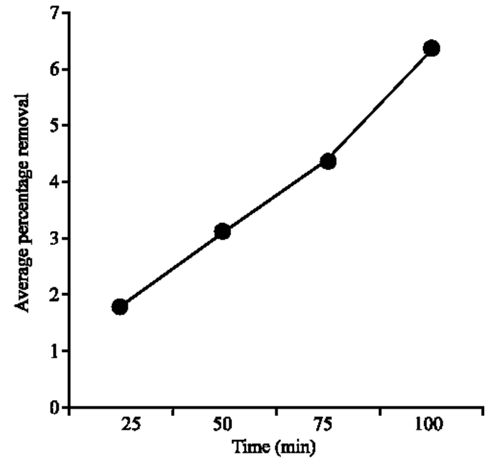


Fig. 1: Turbidity of samples (N.T.U) for mixing experiment on Ureje River

Table 6: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 100 | 25 | 50 | 75 |
| 0.6 | 18.7 | 36.3 | 63.7 | 65.9 |
| 1.2 | 19.4 | 32.6 | 65.3 | 65.9 |
| 1.8 | 22.4 | 35.5 | 60.7 | 65.3 |
| 2.4 | 6.4 | 28.2 | 61.4 | 64.5 |
| Average | 16.73 | 33.15 | 62.78 | 64.65 |

Table 7: Turbidity of samples (NTU) for mixing time experiment (60 sec)

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 99 | 54 | 38 | 29 | 23 |
| 1.2 | 114 | 65 | 46 | 39 | 32 |
| 1.8 | 132 | 88 | 53 | 48 | 39 |
| 2.4 | 167 | 146 | 73 | 51 | 59 |

Table 8: Average percent concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 54.6 | 38.4 | 29.3 | 32.2 |
| 1.2 | 57.0 | 40.4 | 34.2 | 28.1 |
| 1.8 | 66.7 | 40.2 | 36.4 | 29.6 |
| 2.4 | 87.4 | 43.7 | 30.5 | 35.3 |

Table 9: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 45.4 | 61.6 | 70.7 | 76.8 |
| 1.2 | 43.0 | 59.6 | 65.8 | 71.9 |
| 1.8 | 33.3 | 59.8 | 63.6 | 70.4 |
| 2.4 | 12.6 | 56.3 | 69.5 | 64.7 |
| Average | 33.58 | 59.33 | 67.4 | 70.95 |

Table 10: Turbidity of samples (NTU) for mixing time experiment (100 sec)

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 84 | 28 | 25 | 20 | 18 |
| 1.2 | 97 | 40 | 39 | 37 | 23 |
| 1.8 | 124 | 54 | 52 | 44 | 36 |
| 2.4 | 142 | 69 | 67 | 60 | 55 |

Table 11: Average percent concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 33.3 | 29.8 | 23.8 | 21.2 |
| 1.2 | 41.2 | 40.2 | 38.0 | 23.7 |
| 1.8 | 43.6 | 41.9 | 35.5 | 29.0 |
| 2.4 | 48.6 | 47.2 | 42.3 | 38.7 |

Table 12: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 66.60 | 70.20 | 76.20 | 78.60 |
| 1.2 | 58.80 | 56.80 | 61.60 | 76.30 |
| 1.8 | 56.40 | 58.10 | 64.50 | 71.00 |
| 2.4 | 51.40 | 52.80 | 57.70 | 61.30 |
| Average | 58.33 | 60.23 | 65.08 | 71.80 |

Table 13: Average percentage removal for various mixing

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Mixing time (sec.) | 25 | 50 | 75 | 100 |
| 20 | 16.73 | 33.15 | 62.78 | 64.65 |
| 60 | 33.58 | 59.33 | 67.40 | 70.95 |
| 100 | 58.33 | 60.23 | 65.08 | 71.80 |

Table 14: Alum dosage experiment

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 121 | 111 | 109 | 106 | 89 |
| 1.2 | 122 | 113 | 112 | 108 | 92 |
| 1.8 | 129 | 123 | 120 | 116 | 105 |
| 2.4 | 309 | 302 | 293 | 287 | 266 |

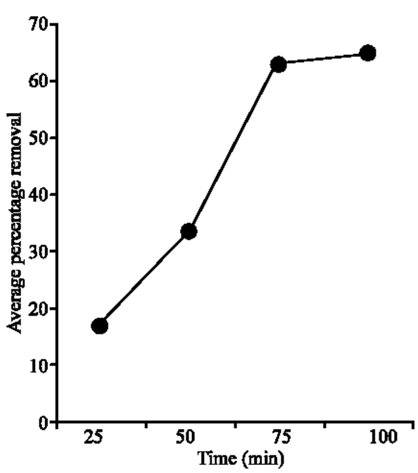


Fig. 2: Turbidity of samples (N.T.U) for mixing time experiment (20 sec)

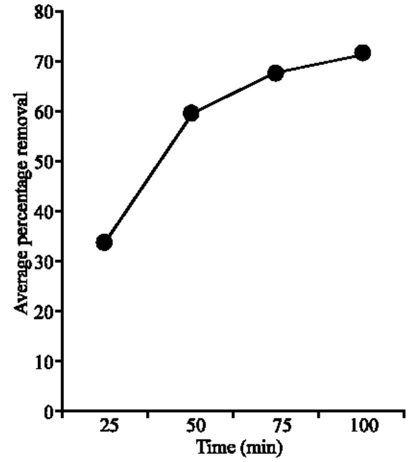


Fig. 3: Turbidity of samples (N.T.U) for mixing time experiment (60 sec)

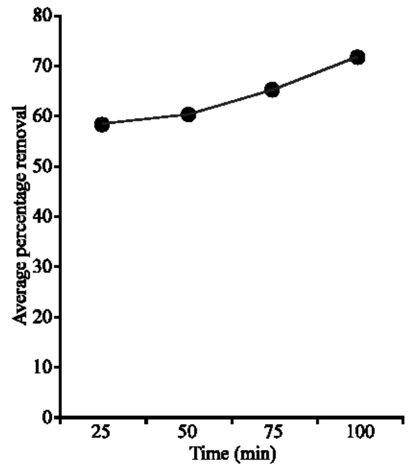


Fig. 4: Turbidity of samples (N.T.U) for mixing time experiment (100 sec)

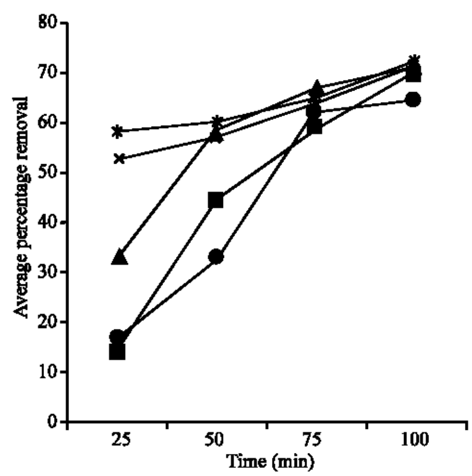


Fig. 5: Turbidity of samples (N.T.U) for mixing time experiment of various mixing time

**Experiment III Alum dosage experiment:** Turbidity of samples (N.T.U) for Alum Dosage Experiment (20 mg $L^{-1}$ river Ureje) (Table 14-26 and Fig. 6-8).

Table 15: Average percent concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 91.7 | 90.1 | 87.6 | 73.6 |
| 1.2 | 92.6 | 91.8 | 88.5 | 75.4 |
| 1.8 | 95.4 | 93.0 | 89.9 | 81.4 |
| 2.4 | 97.7 | 94.8 | 92.9 | 86.1 |

Table 16: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 8.30 | 9.90 | 12.40 | 26.40 |
| 1.2 | 7.40 | 8.20 | 11.50 | 24.60 |
| 1.8 | 4.60 | 7.00 | 10.10 | 18.60 |
| 2.4 | 2.30 | 5.20 | 7.10 | 13.90 |
| Average | 5.65 | 7.58 | 10.28 | 20.88 |

Table 17: Average percentage turbidity (N.T.U), remaining (20 mg $L^{-1}$)

| Time (min) | 25 | 50 | 75 | 100 |
|---|---|---|---|---|
| % Turbidity remaining | 94.35 | 92.42 | 89.72 | 79.12 |

Table 18: Turbidity of samples (N.T.U) for Alum dosage experiment (40 mg $L^{-1}$) River Ureje

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 127 | 89 | 65 | 47 | 38 |
| 1.2 | 134 | 99 | 72 | 54 | 43 |
| 1.8 | 137 | 111 | 79 | 58 | 47 |
| 2.4 | 233 | 192 | 152 | 109 | 87 |

Table 19: Average percentage concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 70.1 | 51.2 | 37.0 | 29.9 |
| 1.2 | 73.9 | 53.7 | 40.3 | 32.1 |
| 1.8 | 81.0 | 57.7 | 42.3 | 34.3 |
| 2.4 | 82.4 | 65.2 | 46.8 | 37.3 |

Table 20: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 29.90 | 48.80 | 63.00 | 70.10 |
| 1.2 | 26.10 | 46.30 | 59.70 | 67.90 |
| 1.8 | 19.00 | 42.30 | 57.70 | 65.70 |
| 2.4 | 17.60 | 34.80 | 53.20 | 62.70 |
| Average | 23.15 | 43.05 | 58.40 | 66.60 |

Table 21: Average percentage turbidity (N.T.U) remaining (40 mg $L^{-1}$)

| Time (min) | 25 | 50 | 75 | 100 |
|---|---|---|---|---|
| % Turbidity remaining | 76.65 | 56.95 | 41.60 | 33.40 |

Table 22: Turbidity of Samples (N.T.U) for alum dosage experiment (60 mg $L^{-1}$ River Ureje)

| | Elapsed time (min) | | | | |
|---|---|---|---|---|---|
| Sampling depth (m) | 0 | 25 | 50 | 75 | 100 |
| 0.6 | 110 | 50 | 30 | 25 | 21 |
| 1.2 | 123 | 60 | 38 | 29 | 28 |
| 1.8 | 135 | 75 | 46 | 36 | 32 |
| 2.4 | 211 | 134 | 88 | 69 | 58 |

Table 23: Average percent concentration

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 45.5 | 27.3 | 22.7 | 19.1 |
| 1.2 | 48.8 | 30.9 | 23.6 | 22.8 |
| 1.8 | 55.6 | 34.1 | 26.7 | 23.7 |
| 2.4 | 63.5 | 41.7 | 32.7 | 27.5 |

Table 24: Average percentage removal

| | Elapsed time (min) | | | |
|---|---|---|---|---|
| Sampling depth (m) | 25 | 50 | 75 | 100 |
| 0.6 | 54.50 | 72.70 | 77.30 | 80.90 |
| 1.2 | 51.20 | 69.10 | 76.40 | 77.20 |
| 1.8 | 44.40 | 65.90 | 73.30 | 76.30 |
| 2.4 | 36.50 | 58.30 | 67.30 | 72.50 |
| Average | 46.65 | 66.50 | 73.58 | 76.73 |

Table 25: Average percentage turbidity (N.T.U) remaining (60 mg $L^{-1}$)

| Time (min) | 25 | 50 | 75 | 100 |
|---|---|---|---|---|
| % Turbidity remaining | 53.35 | 33.50 | 24.42 | 23.27 |

Table 26: Average percentage turbidity (N.T.U) remaining for various Alum dosage Alum

| Dosage (mg $L^{-1}$) | 25 | 50 | 75 | 100 |
|---|---|---|---|---|
| 20 | 5.65 | 7.58 | 10.28 | 20.88 |
| 40 | 23.15 | 43.05 | 58.40 | 66.60 |
| 60 | 46.65 | 66.50 | 73.58 | 76.73 |

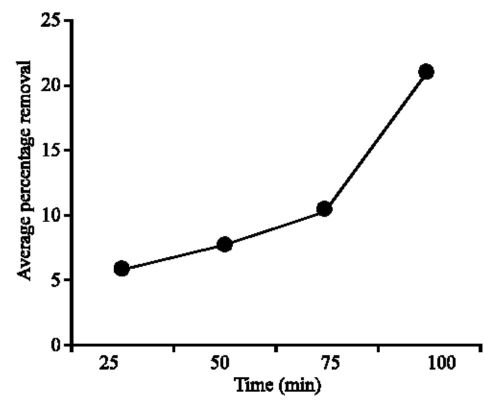


Fig. 6: Turbidity of samples (N.T.U) for alum dosage experiment (20 mg $L^{-1}$ River Ureje)

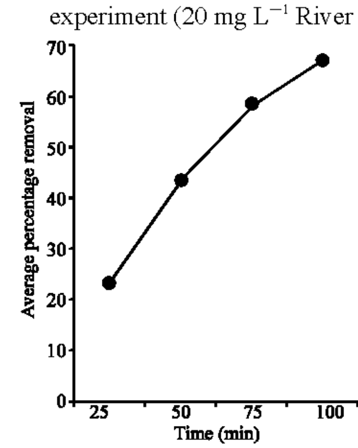


Fig. 7: Turbidity of samples (N.T.U) for alum dosage experiment (40 mg $L^{-1}$) River Ureje

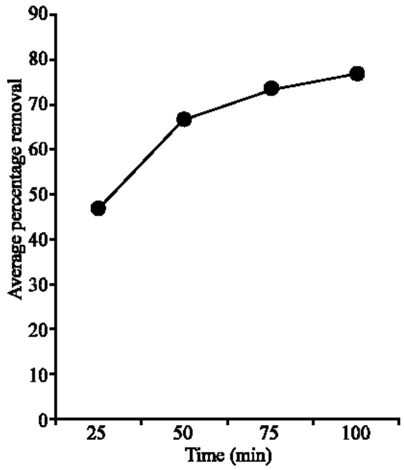


Fig. 8: Turbidity of samples (N.T.U) for alum dosage experiment (60 mg $L^{-1}$ River Ureje)

The variables investigated are mixing, mixing time and alum dosage. Three experiments were performed to observe the effect of these variables on the settle ability of river suspension. Results from concentration-depth-time studies on the suspension are discussed herein. Performance of the settling tanks for existing treatment plant on the river is also discussed.

**Mixing effects:** Summary and results of the average suspended solids removal for the source in the mixing experiments show that the effect of mixing varies for samples from the ports.

From the results, it can be seen that the degree of removal of suspended solids increases with detention time for the same depth. Conversely, the rate slows down as the detention time increases. Also, it can be seen that the degree of clarification increases with decrease in column depth for the same retention time. Hence, the shallower the column the better the degree of removable particles. Particle removal dependent on the depth of the column and the detention time. There is depreciation in this trend as the variables increases to near optimum.

Average percent removal values between 1 to 10% were obtained. This shows that effect of mixing alone did not exert a major impact upon the settle ability of the particles in suspension and would not create a significant impact on the treatment of such water.

A summary of the average percentage removal at various detention times leads to the following inferences: Under the same alum dosage pretreatment, the average percentage removal increases with the longer mixing time, the rate of change of the average percentage removal is rapid optimum. Thus, longer detention period are needed to achieve optimal results when the duration of mixing is short.

**Effects of different alum dosage:** The results of settling experiments carried out under different alum dosage are tabulated. Three alum dosages were selected in usual administered dosage, the dosage selected are 20, 40 and 60 mg $L^{-1}$. The results obtained indicate that the degree of clarification of suspension varies with column depth and detention time. For the same detention time, the percentage of suspended solids removed decreases with increase in column depth. At a particular depth the degree of clarification increases with increases in column depth. At a particular depth, the earlier observation that the degree of clarification is a function of column depth and detention time.

It can be inferred from the results that fraction of solids removed falls between 5 and 80% but 100% removal cannot be obtained because of presence of flocculating particles in the suspension. Thus the effect of alum dosage is quite significant.

In comparing the average percentage removal with respect to time for the three alum dosages it shows that the percentage removal increases with increasing alum dosage and the rate of clarification increases as well. Therefore, alum dosage of the range 40-60 mg $L^{-1}$ are suggested for treating raw water from the source. This recommendation can be incorporated with the observation in related literature that lower coagulant dosage like higher dosage performs equally well in less turbid water.

Observations made from the analysis of the results indicate that the degree of clarification of a suspension is not independent of column depth and detention time. The shallower the column the better the degree of clarification. At the same depth, the percentage of solids removed increases with increase in detention time.

The result of this study shows that there is a small fraction of suspended solids in water which cannot be removed by sedimentation using alum coagulation on mechanical flocculation.

The settle ability of particles is not significantly influenced by mechanical mixing alone because less than 10%age removal was made in mixing experiment. In view of this, a constant alum dosage of 40 mg $L^{-1}$ was added into the suspension in the mixing time experiment. The effects of the various mixing time considered were quite significant resulting in removal of up 80% within 100 min detention.

For appreciable removal of solids, an optimal mixing time within the range 30-60 sec is recommended. This will reduce the energy required and the rate of wear of flocculator arrangement.

Percentage removal of about 80% within 100 min detention was observed in the alum dosage experiment. An increase in alum dosage resulted to higher percentage removal under short detention. However, the lower dosages begin to perform well after longer detention.

An alum dosage within the range 40 to 60 mg $L^{-1}$ is recommended for appreciable removal of solids in the treatment of raw water from the source.

## REFERENCES

Bechteler, W. and W. Schrimpf, 1982. Improved numberical model for sedimentation; J. Hydraulic Eng. Division, ASCE., 110: 234-246.

Bhargava, D.S. and k. Rajapopal, 1989. Modelling for Class 1 Sedimentation J. Environ. Division, ASCE., 115: 1191-1198.

Camp. T.R., 1946. Sedimentation and design of settling tanks: Trans Am. Soc. Civ. Engrs, III: 895-958.

Collins, M.R., G.L. AMY and C.W. Bryant, 1987. Evaluation of factors affecting performance of direct filtration, J. Environ. Eng. Division, ASCE., 113: 330-344.

Cox, C.R., 1964. Operation and control of water treatment processes: World Health Organization, Geneva.

Fox, C.S., 1949. The geology of water supply: Technical Press Ltd; London.

George Smethurst, 1979. Basic Water treatment fro Application world-wide: Thomas Telford Ltd, London.

Hazen, A., 1904. On Sedimentation transactions, ASCE., 53: 45-71.

Imame Mc. Corquodate, J.A. and J.K. Bewtra, 1983. Numerical modeling of Sedimentation Tanks J. Hydraulic Eng. Division. ASCE., pp: 109.

John, W.C. and V.J. Warren, 1965. Water Supply and pollution control, International Text book Company, Scranton, Pennsylvania.

Ostendorf, D.W., 1986. Hydraulics of rectangular clarifiers, J. Environ. Eng. Division, ASCE., 112: 939-952.

Outreach Department: National water Resources Institute Kaduna, Nigeria, 1997. Training Guide for Basic Water treatment Operations.

Schamber, D.R. and B.F. Larock, 1981. Numerical analysis of flow in sedimentation basins, J. Hydraulic Division, ASCE., 107: 753-763.

Zanoni, A.E. and M.W. Blomquist, 1975. Column Settling tests for Flocculent Suspensions J. Environ. Eng. Division, ASCE., 101: 309-318.