STUDY OF TYPE –II SUSPENSIONS WITH MORINGA OLEIFERA & ALUM COAGULANTS USING SETTLING COLUMN ANALYSIS

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Abstract— A study is carried out in a specially designed two settling columns to study effect different parameters on Type –II suspensions namely different diameter of settling column, different initial turbidity samples, and the different coagulants used for effective sedimentation. The optimum dosage of coagulants such as Alum, Moringa Oleifera, and blend of Alum and Moringa Oleifera coagulant is determined by conducting jar Test. Experiments are carried out in the settling columns with the optimum coagulant dosage for three different initial turbidities such as 100 NTU, 400 NTU, and 900 NTU showed that the coagulation with blended coagulant Alum & Moringa Oleifera is better than Alum. It is observed that for no coagulant and with all the coagulants, as the initial turbidity increases the percentage removal efficiency also increases. And for the larger diameter settling column, the removal efficiency is more as compared to the smaller diameter of the settling column. Also the new modified average method is developed for finding the overall removal efficiency. This is new methodology for analysis of column settling data.

Index Terms— Coagulation, flocculation, Settling column test, Alum, Moringa Oleifera, blended coagulant.

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1. INTRODUCTION

There are wide varieties of processes available for the treatment of raw water. The exact choice of process will depend upon the availability and economics of water supply. Coagulation-flocculation followed by sedimentation, using chemical coagulant is a very common treatment method used mainly in water treatment practices. Sedimentation is used to remove suspended solids from the water by gravitational settling of the solids through the water. It is the most commonly used process in the field of water treatment. The investments of settling tank in this field are probably about one third of the total capital investment for treatment. Despite the importance of the process, current understanding of the principles involved has progressed so slightly that there is no such thing in practice as the economic design of the tanks from a function point of view. The dimensions of the most settling tanks are fixed on the basis of standard detention periods. Settling characteristics of the suspension to be removed are rarely considered in the design of settling tanks.

The purpose of this work is to study the settling column analysis of Type –II suspensions for the effect of different diameter of settling column, the effect of different initial turbidity samples, and the effect of different coagulants used for effective sedimentation.

Recently there has been more interest, especially in developing countries, in possible application of natural coagulants. Use of Moringa Oleifera (Drum sticks) as natural coagulant is reported to have many advantages over chemical coagulants e.g. Alum. Use of chemical coagulants has constraints of pH and alkalinity. However, Moringa Oleifera has been reported to be free of these constraints. Sludge produced with Moringa Oleifera is reported to be four to five times compact than that produced with alum. Moringa oleifera is a tropical multipurpose tree that is commonly known as the miracle tree [1].

Moringa is a plant with interesting properties [2], [3] and is known to be a natural coagulant since 1979 [4]-,[5],[6],[7],[8],[9]. Among many other properties, M. oleifera seeds contain a coagulant protein that can be used either in drinking water clarification [10] or wastewater treatment [11]. It is said to be one of the most effective natural coagulants and the investigation on these kinds of water treatment agents is growing nowadays[12]. Researchers have identified the coagulant component from M. oleifera seed extract as a cationic protein [13],[14]. It is thought to consist of dimeric proteins with a molecular weight in the range of 6.5–14 k Da.

Using the crude extract as coagulant presented problems of residual dissolved organic carbon (DOC) [15] which makes its use in drinking water not feasible.

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It is therefore necessary to purify the coagulant [16].

However, the direct application of this isolated agent is not possible under the hypothesis of sustainable and appropriate technology [17]. Consequently, the search for simple and low cost purifications procedures as well as the use of the coagulant in combination with other coagulants and treatment processes needs to be adopted [18]. Some examples of drinking water treatment using crude extract in pilot plant set up have been conducted [19]. However, today we need to improve the water quality, because such vegetable coagulants are probably best suited to Water treatment developing countries [20], [21], [22].

The aim of this study is not only to optimize the use of Moringa oleifera as a natural coagulant in treatment of surface water, but also to eliminate the organic matter accumulated in water treated with Moringa. The advantage of using these seeds of Moringa is to allow the substitution of imported flocculants by a local product which is easily accessible. Therefore it would save substantial foreign exchange for developing countries. On the other hand, this flocculent, unlike alum, is completely biodegradable, which may be interesting in the context of the REACH regulation and sustainable development.

The use of Moringa Oleifera as a coagulant is mostly used in water treatment that too on small scale and major work has been reported in laboratory scale water treatment that too on small scale. The Moringa oleifera is not used in field because of the some drawbacks of Moringa oleifera as it requires large amounts of seeds for small water treatment plant. Also the settling time is more. if the blended coagulant of Moringa oleifera & alum is used then the drawbacks of alum and moringa oleifera is reduced and this blend coagulant gives best results.[23], [24],[25]. These advantages of natural coagulant Moringa Oleifera, in the present study is used for settling column test in addition to traditional coagulant – Alum. And also the blend of these two coagulants Alum & Moringa Oleifera is used.

Type II settling is the settling of particles that flocculate as they settle. Flocculation, which produces larger particles, causes the settling velocity of the particles to change as they settle. Lacking theory to satisfactorily explain these phenomena, experiments are usually conducted in pilot-scale columns to determine the over-flow rate required for a given removal. O'Connor and Eckenfelder [26],[27] introduced the traditional method of data analysis. In that method, concentration data from a settling column experiment are converted to percentage removals at various times and depths. These percentage removal data are plotted on a graph of depth versus sampling time. Isoremoval contour lines are constructed on this graph. At any time, these data can be numerically integrated over the depth of the column to determine the overall removal. These overall removal values can be plotted versus overflow rate. Empirical scaling factors are used to extrapolate these results for design.

A drawback to this method is of drawing the contour lines are manual and subjective. Although some graphing programs can be used to objectively produce the contour lines, the actual calculation still requires estimating values from this graph. This method has been adopted and modified by many environmental engineering Researchers [28],[29],[30],[31]. Their method used a graphical integration of the experimental data to determine overall removal versus overflow rate at various depths in the column.

Also some researcher developed Mathematical Equation for settling column analysis [32]. Although these methods give comparable answers to those of the traditional method, it has not seen extensive use in water and wastewater treatment.

But as per the Alphonse E. Zanoni [33] unlike the discrete settling of non flocculent suspensions, the settling behavior of the flocculent suspension is not amenable to mathematical description using physics law such as those Newton's and Stokes. Thus it has been common practice to employ laboratory column testing as the basis for the design of settling basin or the performance evaluation of the existing basin handling flows containing flocculent suspension.

Using this theory P Krishnan [34] suggested simple method where there is no need for the development of isopercentage lines. The Suspended solids data collected at various column depths for each sampling period can be directly used to obtain the average solid removal in the column. Although this method gives comparable answers to those of the traditional method, it has not seen extensive use in water and wastewater treatment. Because finding suspended solids concentration at every sample depth at constant time interval is difficult, tedious and time consuming. So to overcome drawbacks of this method the authors would like to suggest a slight modification in the settling column test procedure. In the modified method only the turbidity of sample is considered at every sample depth at constant time interval. Percentage turbidity removal data collected at various column depths for each sampling period can be directly used to obtain the average turbidity removal in the column. The results obtained using this method is very close to the graphical traditional method [23].

2. MATERIALS AND METHODS

Tree dried Moringa Oleifera seeds are procured from local trees. Good quality seeds are then picked up and crushed to fine powder. From these seeds extract is prepared.

2.1 Preparation of Seed Extracts:

5 gm of seed powder is mixed with 500 ml distilled water for 2 minutes. Then mixture is mixed in the rapid mix unit for 20 minutes at 120 rpm. Then, solution is filtered through Muslin Cloth. Resulting stock solution is of 10000mg/l (1%) concentration. Fresh stock solutions are prepared every day for the one day's experimental run.

2.2 Preparation of 1% Alum Solution:

1 gm of the Alum is mixed with 100 ml of distilled water. This mixture is stirred for 5 minutes.

2.3 Preparation of 1% Lime Solution:

1 gm of the Lime is mixed with 100 ml of distilled water. This mixture is stirred for 5 minutes.

2.4 Preparation of turbid water sample:

5gm of Kaolin clay is mixed to 500 ml distilled water. Mixed clay sample is soaked for 24 hrs. Suspension is then stirred in the rapid stirrer so as to achieve uniform and homogeneous sample. Resulting suspension is found to be colloidal and used as stock solution for preparation of turbid water samples. Everyday stock sample of kaolin clay is diluted with tap water to desired turbidity.

2.5 Preparation of Moringa Oleifera & Alum Solution:

Moringa Oleifera & Alum Solution are prepared separately and entered separately with Alum first and Moringa Oleifera a couple of seconds later. But, for preparation of blend coagulant the optimum dosage found for different initial turbidity samples are taken as base line and different proportions of alum and Moringa Oleifera are tested for removing the turbidity from jar test, then it is observed that for 100 NTU initial turbidity, the optimum dose of the Alum is reduced to 75 % and the optimum dose of the Moringa Oleifera is reduced to 40 % then this blended coagulant gives the minimum residual turbidity. Similarly for 400 NTU & 900 NTU initial turbidity, the optimum dose of the Alum is reduced to 62.5 % and the optimum dose of the Moringa Oleifera is reduced to 25 % then this blended coagulant gives the minimum residual turbidity.

Jar test Apparatus is used to determine the optimum dosage of coagulant. Jar tests are performed as per Bureau of Indian Standards. IS 3025(PART 50): 2001. Digital Turbidity Meter manufactured by Lovibond is used. Two Settling columns of diameter 30 cm & 18.5 cm with six sampling ports of 12 mm in diameter are used. Total height of column is 1.2 m and the sampling ports are provided at depth 0.1m, 0.3m, 0.5m, 0.7m, 0.9m, and 1.1m from top to bottom of column (Fig. 2).

Mainly the scope of the work is to deal with the effect of different type of initial turbidity samples, different diameter of settling columns, different types of coagulants and settling characteristics of the flocculated water. Entire work is divided into different stages viz. optimum dose determination for different types of coagulants with different initial turbidity samples viz. 100 NTU (Low), 400 NTU (Medium) and 900 NTU (High), effect of different diameter of settling columns on settling characteristics of different flocculent suspensions, and development of new modified method for overall turbidity removal efficiency.

3 EXPERIMENTATION METHOD

3.1 Optimum dose determination:

Finding the optimum dose of i) Alum ii) Moringa Oleifera iii) Alum & Moringa Oleifera blend using Jar – Test apparatus. Three different turbidity samples (100 NTU, 400 NTU, and 900 NTU) are used. Graphs of Residual turbidity versus dosage of coagulant are plotted to determine the optimum dose of coagulant.

3.2 Effect of different diameter of settling columns:

The samples of 100 NTU, 400 NTU, 900 NTU initial turbidity are filled in two settling columns of diameters 18.5 cm and 30 cm and then the optimum dosage determined earlier is added in these settling columns. The sample is allowed to settle. After 20, 40, 60, 80, 100, 120, 140, 160, & 180 minutes intervals, the samples are drawn from each sampling port from top to bottom & residual turbidity of each sample is measured. Settling column test is also carried out for no coagulant as control, also for Alum, Moringa Oleifera and Blend Coagulant Alum & Moringa Oleifera.

3.3 Modified method for overall turbidity removal efficiency:

The modified Methodology is developed for finding the overall turbidity removal efficiency. Using all the available data the overall removal efficiency is calculated by modified Method and it is compared with the values of overall removal efficiency calculated from Graphical Method. The Verification of this Method is carried out using the Linear Regression analysis.

4 RESULTS AND DISCUSSION

4.1 Optimum Dose:

For Alum (Fig. 3) it is observed that the optimum dosage required for the initial turbidity 100 NTU is 40 mg/lit. Further addition of dosage beyond 40 mg/lit showed slight increase in the residual turbidity. This overdosing results in the saturation of the polymer bridge sites. This in turn gives rise to the restabilization of destabilized particles which ultimately results in the higher residual turbidity. Then for 400 NTU and 900 NTU initial turbidity the optimum Alum dose is 90 mg/lit and 180 mg/lit respectively.

For Moringa Oleifera coagulant (Fig. 4) the optimum dose of the Moringa Oleifera for initial turbidity 100 NTU, 400 NTU and 900 NTU are 100 mg/lit, 180 mg/lit and 300 mg/lit respectively.

From the Fig. 5, it is observed that for 100 NTU initial turbidity the optimum dose of the Alum and M.O. blend is 10 mg/l and 60 mg/l. For 400 NTU turbidity it is 30 and 130 mg/l. Similarly for 900 NTU turbidity it is 60 mg/l and 180 mg/l.

4.2 Settling Column Test:

The graphs of Depth vs. detention time for percent removal of turbidity are plotted as shown in Fig. 1. Such 24 graphs are plotted for different initial turbidity samples, different diameter of settling column and different coagulants. The comparison of overall turbidity removal efficiency of all coagulants at constant time interval is shown in the Graphs of

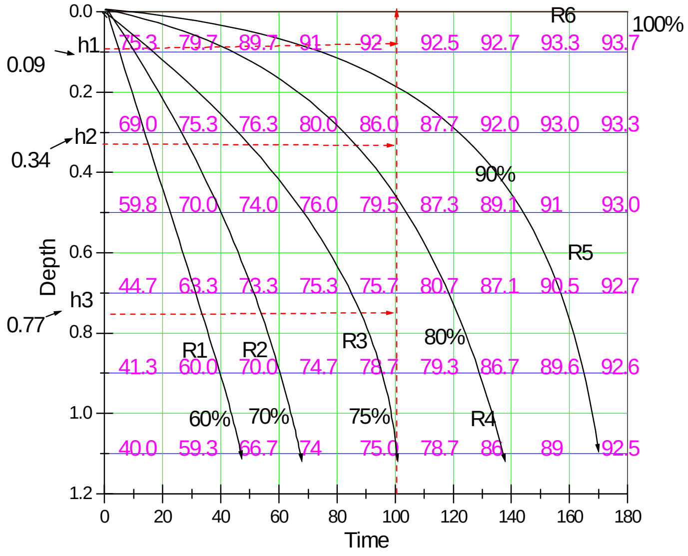


Fig. 1 Sampling Depth Vs. Detention Time

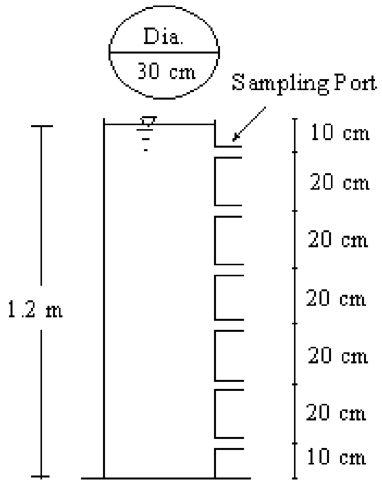


FIG. 2 Sketch of Settling Column

FIG. 3 OPTIMUM DOSE OF ALUM

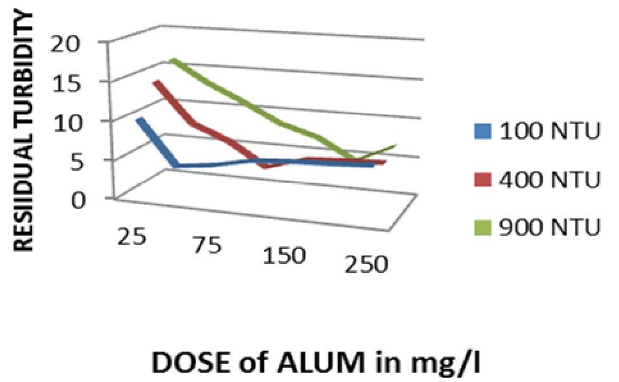


FIG. 4 OPTIMUM DOSE OF M.O.

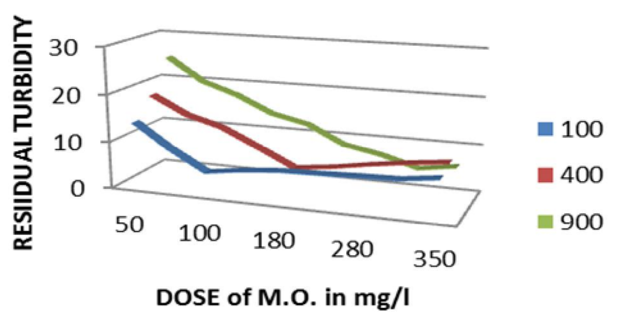


FIG.5 OPTIMUM BLEND DOSE OF ALUM-MO

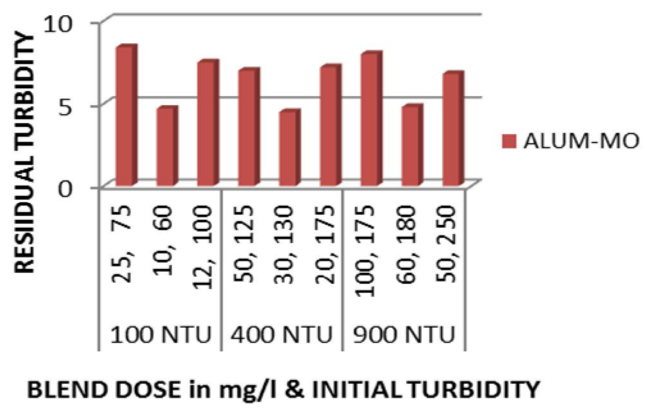


FIG. 6 Time Vs % Overall Efficiency
Turbidity 100 NTU & Dia . 18.5 cm

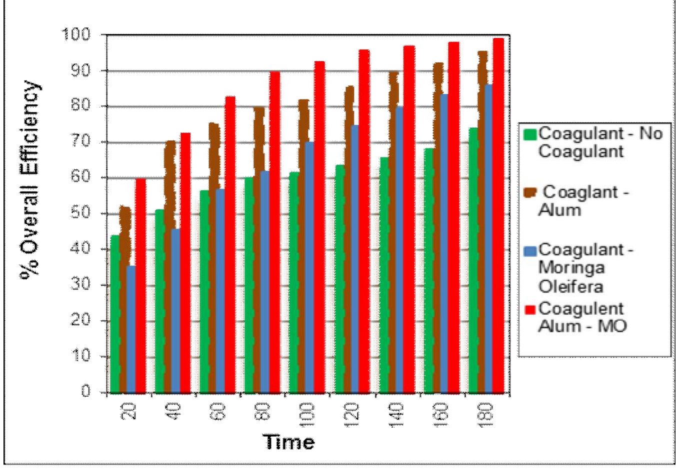


FIG. 7 Time Vs % Overall Efficiency
Turbidity 100 NTU & Dia . 30 cm

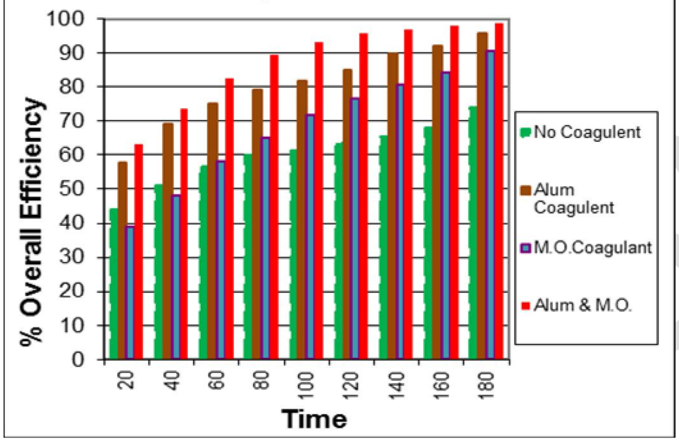


FIG. 8 Time Vs % Overall Efficiency
Turbidity 400 NTU & Dia . 18.5 cm

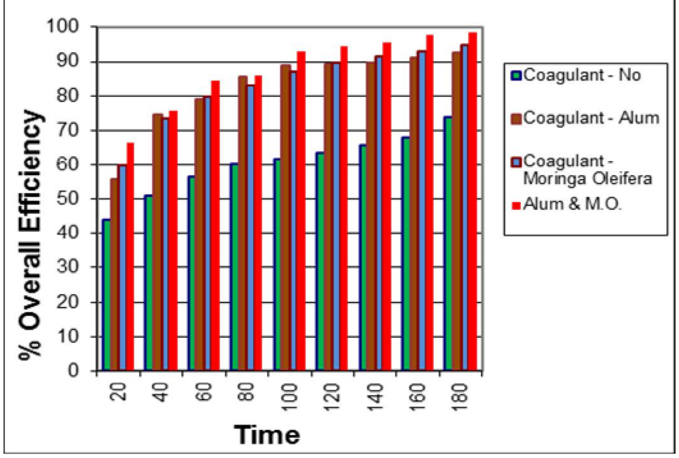


FIG. 9 Time Vs % Overall Efficiency
Turbidity 400 NTU & Dia . 30 cm

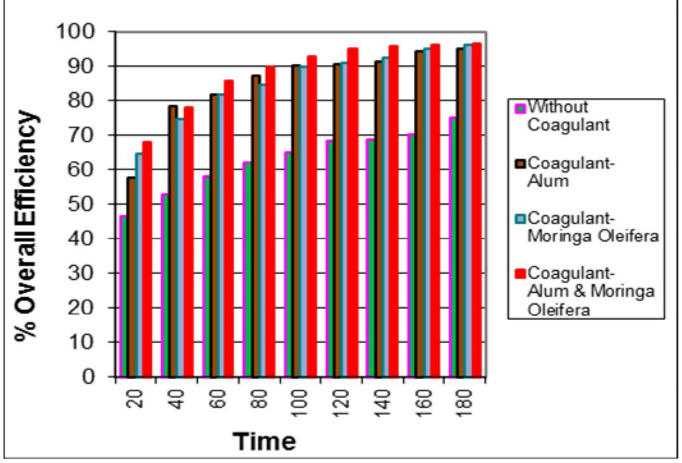


FIG. 10 Time Vs % Overall Efficiency
Turbidity 900 NTU & Dia . 18.5 cm

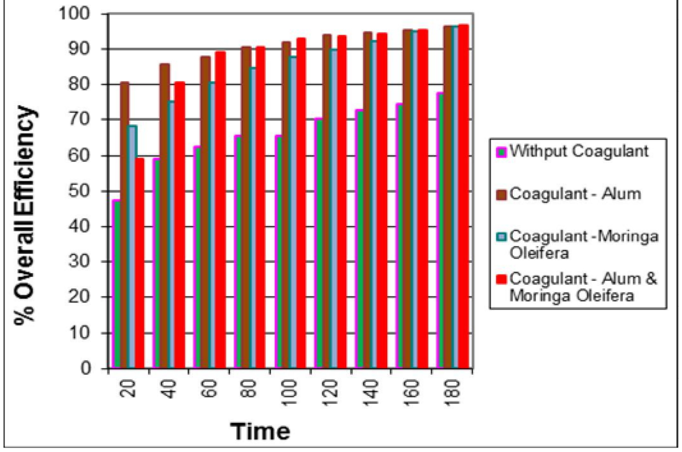
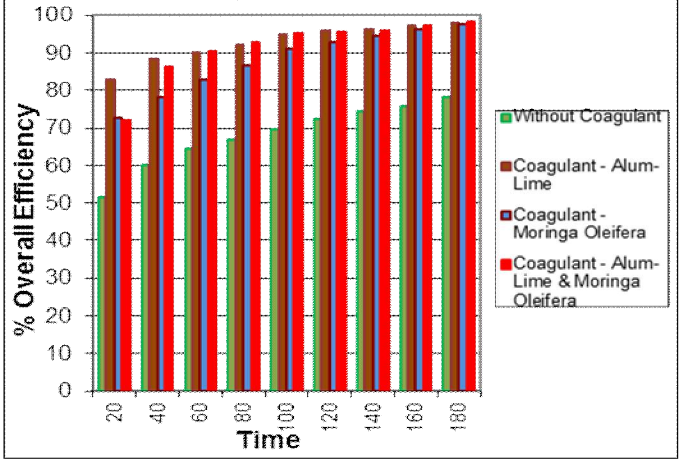


FIG. 11 Time Vs % Overall Efficiency
Turbidity 900 NTU & Dia . 30 cm



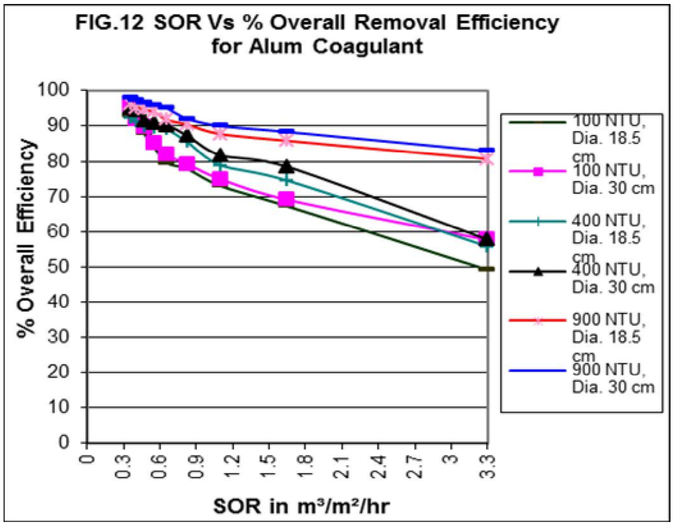


FIG.12 SOR Vs % Overall Removal Efficiency for Alum Coagulant

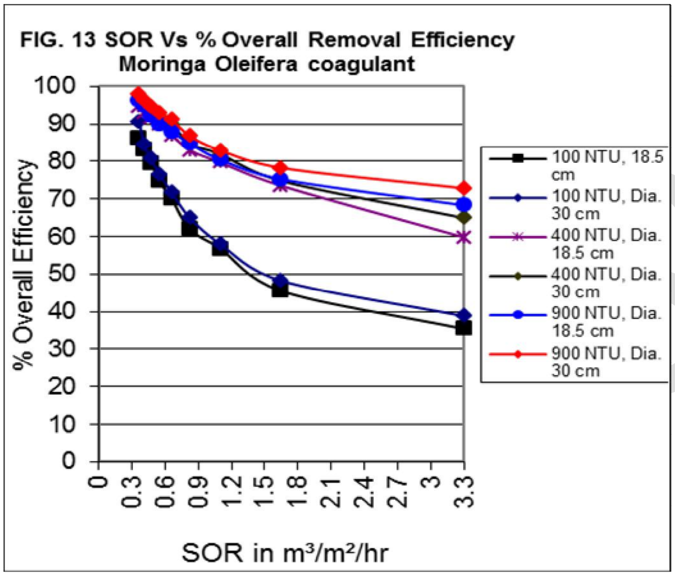


FIG. 13 SOR Vs % Overall Removal Efficiency Moringa Oleifera coagulant

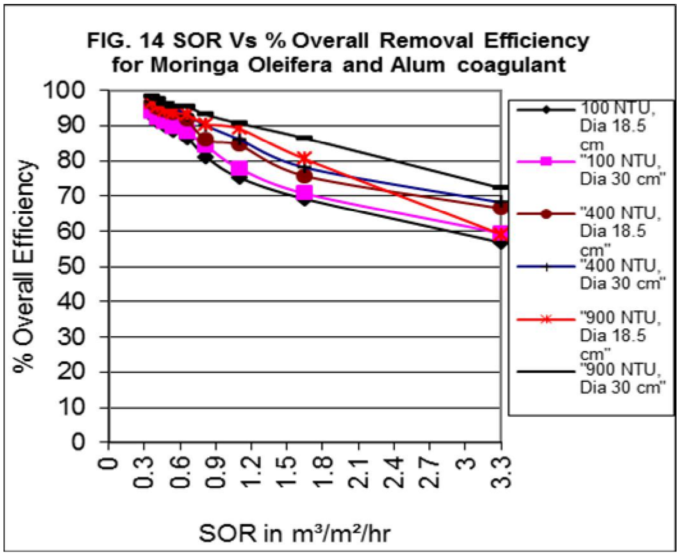


FIG. 14 SOR Vs % Overall Removal Efficiency for Moringa Oleifera and Alum coagulant

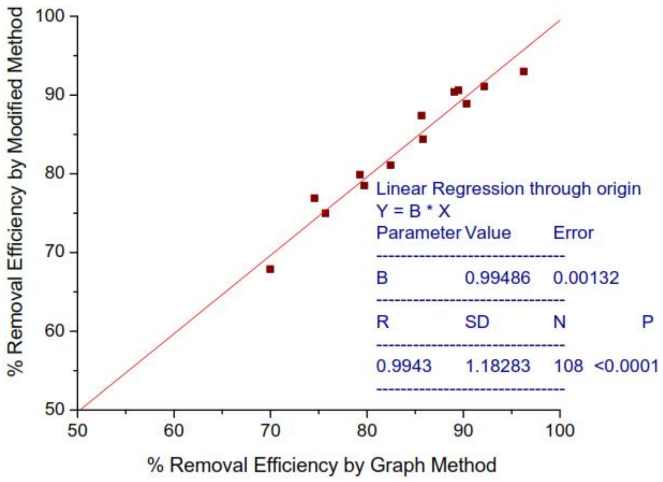


FIG.15 Linear Regression for Graph & Modified Method

Time Vs % Overall Efficiency for Turbidity 100 NTU, 400 NTU, 900 NTU, & Dia. 18.5, Dia. 30 cm. From these graphs overall turbidity removal efficiency is determined at constant time interval.

4.2.1. Effect of coagulant: Alum, M.O. and blend of alum and M.O. are used to study the effect of type of coagulant. The fig. 6 - 11 shows the comparison of overall turbidity removal efficiency at constant time interval of all these coagulants. observed that the maximum removal efficiency is obtained by Alum and M. O. blend. Then compared to it, the overall turbidity removal efficiency decreases in order of Alum, M.O. and finally it is least for no coagulant. From all these graphs it is observed that the blend of Alum and M.O. gives the best result as compared to the traditional Alum. For 100 NTU initial turbidity, Alum dose is reduced up to 70 % and for 400 NTU, 900 NTU initial turbidity Alum dose is reduced up to 65 %. So this can reduce all the drawbacks of the Alum.

4.2.2 Effect of surface area: Two settling columns of diameter 18.5 cm and 30 cm are used to study the effect of surface area.

It is observed from all graphs that for the larger diameter of settling column the removal efficiency is more as compared to the smaller diameter of the settling column. It is observed from the graph that alum and M.O. blend gives more turbidity removal efficiency for 30 cm diameter settling column. As the initial turbidity increases the removal efficiency also increases for larger diameter settling column. This is because the wall effects are more pronounced in smaller diameter column. But not to the extent that might have been anticipated.

4.2.3 Effect of Initial Turbidity: From the Graph, it is observed that for all the coagulants as the initial turbidity increases, the percentage overall turbidity removal efficiency also increases. The reason is, as the turbidity increases rate of the settlement of the particles also increases.

For all initial turbidity samples, turbidity removal efficiency is found to be increasing order of no coagulant, alum, M.O., and blend.

The maximum turbidity removal efficiency obtained for no coagulant at SOR 0.367 $m^3/m^2/hr$ in the settling column. For 100 NTU, 400 NTU and 900 NTU initial turbidity, the removal efficiency of larger settling column diameter (30 cm) are as 72.69 %, 75.68 % and 79.37 % respectively.

With alum, for 100 NTU, 400 NTU and 900 NTU initial turbidity, the maximum turbidity removal efficiency of larger settling column diameter (30 cm) are as 96.24 %, 95.93 % and 98.25 % respectively.

With M. O. coagulant, for 100 NTU, 400 NTU and 900 NTU initial turbidity, the maximum turbidity removal efficiency of larger settling column diameter (30 cm) are as 90.98 %, 96.48 % and 98 % respectively.

With Alum and M. O. coagulant blend, for 100 NTU, 400 NTU and 900 NTU initial turbidity, the maximum turbidity removal efficiency of larger settling column diameter (30 cm) are as 95.14 %, 97.02 % and 98.6 % respectively.

4.2.4 Effect of Surface Overflow Rate (SOR): The effect of surface overflow rate on different diameter, different coagulants and different initial turbidity samples is studied with the help of settling column test. The SOR is varied from 0.3 to 3.3 $m^3/m^2/hr$. The graphs of % overall turbidity removal efficiency vs. SOR are plotted. (Fig. 12, 13, 14). It is observed that the turbidity removal efficiency is more for 30 cm diameter settling column. Surface overflow rate is calculated by using the formula SOR = Depth of settling column / Detention Time.

For all coagulants and for the both diameter of settling column, it is observed that as the SOR increases the overall turbidity removal efficiency decreases. It is also observed that the overall removal efficiency increases with increase in initial turbidity and increases in increase in diameter of settling column.

4.3 Modified average Method : To explain this method alum coagulant is considered. Using optimum dose of coagulant, the settling column test is carried out. The turbidity readings obtained at various sampling depths at constant time interval.

The graphs of percent removal of depth vs. detention time is constructed as shown in Fig. 1 and from these graph overall removal efficiency is calculated at constant time interval by graphical Method. The overall removal efficiency at constant time interval is calculated by using the formula.

Removal Efficiency R at time 100 min.

$R = r_0 + (1/H) \times \{h_1 \times (R_6-R_5) + h_2 \times (R_5-R_4) + h_3 \times (R_4-R_3)\}$

$= 75 + (1/1.1) \times \{0.09\ (100-90) + 0.34\ (90-80) + 0.77\ (80-75)\}$

$= 82.45\ \%$

Also the Overall Removal Efficiency is determined by Modified Average Method as follows

Removal Efficiency R at time 100 min.

R = Average of percentage removal Turbidity at time t.

$R = (92 + 86 + 79.5 + 75.7 + 78.7 + 75) / 6$

$= 81.1\ \%$

In this Study the overall removal efficiency is determined using the Modified average Method and it is verified by comparing the values of overall removal efficiency calculated from Graphical Method. it is observed that the results obtained using this method are similar or very close to the graphical traditional method. Only 1 % or 2 % of variation occurred some times.

P. Krishnan developed this Average Method first time, but he applied this Method on suspended solid concentration readings measured from the sampling depth of column. As we know finding the suspended solid concentration is very lengthy and complicated method and consumes lot of time and will not get the accurate results. Also this method applied to other available data of various researchers, it gave variation in the Results of overall removal efficiency. Due to these disadvantages of this Method, some modification is made in the methodology. And the New Modified average Method is developed. In this Method the measured turbidity readings obtained from the sampling depth of settling column are used. This Modified average Method gives very quick and much accurate results of overall removal as compared to Krishnan Method.

Also Linear Regression analysis is carried out for verification of this modified Method. All the values of overall removal efficiency obtained from both the methods are used for Linear Regression analysis. The Linear Regression graphs for Alum coagulant shown in the Fig. 15. The Correlation Coefficient Rc is 0 .99, means all values of overall removal efficiency obtained from the modified method are very close to values of overall removal efficiency obtained from the Graph Method.

The percentage turbidity removal is computed on each sample and is plotted as a number against time and depth as elevations plotted on survey grid. The graphs between the plotted point curves of equal percentage (isopercentage lines) turbidity removal are drawn. These lines represent equal fractions of removal.

The curvilinear lines indicate the flocculent settling or Type II settling. This means the velocity of settling solid fraction is changing with time. If the settling is truly discrete the lines could be straight. Each line represents the settling behavior for the given fraction of solids.

Also the settling behavior of the flocculent suspension is not amenable to mathematical description using physics law such as those Newton's and Stoke's. Thus it has been common practice to employ laboratory column testing as the basis for the design of settling basin or the performance evaluation of the existing basin, handling flows containing flocculent suspension. The general methodology for conducting the column settling tests as well as the graphical procedure for data analysis and interpretation are examined for different coagulants in particular natural coagulant. Particular consideration is given to the effects of different column diameter, different initial turbidity samples and different coagulants used. In addition, settling characteristics of the column tests is observed on the basis of the test run included in this study plus experience gain with other column settling tests.

5 CONCLUSION

In general results indicate the greater removals are predicted with larger diameter of column. Apparently the wall effects are more pronounced in the smaller diameter columns. But not to the extent that might have been anticipated. Also it is observed that as the initial turbidity of sample increases, the overall percentage turbidity removal efficiency also increases.

The overall turbidity removal efficiency at constant time interval of all these coagulants shows that the maximum turbidity removal efficiency is obtained by blended coagulant Alum and M. O. Then it decreases slightly for Alum, and then for M.O. and finally it is least for no coagulant.

It is observed that blended coagulant Alum and M. O. gives maximum turbidity removal efficiency as compared to the traditional Alum coagulants at minimum settling time. Here in this blending process the Alum dosage is reduced up to 75 % for 100 NTU initial turbidity sample and up to 62.5 % for medium and high turbidity (400 NTU and 900 NTU) samples. Also the cost of the treatment is decreased by using the natural coagulant (M.O.) instead of traditional coagulant (Alum). Thus it can be concluded that the blended coagulant i.e. Alum and Moringa Oleifera is the best coagulant which gives the maximum turbidity removal efficiency.

The Modified average method is developed for overall removal efficiency. This is new methodology for analysis of column settling data. Necessity to develop this new method because of some draw backs of old graphical Method such as the accuracy of the result developed in the old traditional graphical method depends to the great extent on the development of isopercentage lines it is time consuming & tedious. The actual data obtained during experiment is lost while developing the of isopercentage lines. The isopercentage lines are often drawn as a Line which is best fit, because of the scatter of the data from the column settling which results in the variation in overflow rates, settling velocity, detention time and suspended solids removal.

To eliminate the subjective nature of the development of isopercentage lines, this new Modified Average Method is suggested as simplified method where there is no need for the development of isopercentage lines. Percentage turbidity removal data collected at various column depths for each sampling period can be directly used to obtain the average turbidity removal in the column. The results obtained using this method is similar or very closer to the graphical traditional method. The Verification of this Method is carried out using the Linear Regression analysis.

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