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Application of Natural Product (Aloe Vera) in Coagulation-Flocculation Procedures, for Water Treatability Study

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Abstract-The natural substance and alum were tested in the process of water treatability at Palmichada stream (Colombia), where Aloe Vera showed good performance in every assay due to the great versatility of its composition, which aids in the coagulation as well as in the flocculation process. Regardless of the turbidity of the water sample analyzed, the Aloe Vera solution proved to be a poor primary coagulant.The solution of Aloe Vera as coagulation aid achieved a decrease up to 20% of the optimal dose of aluminum sulfate in water samples in medium turbidity and up to 40% of the optimal dose of alum in high turbidity samples at Palmichala stream,andexceeding 95% turbidity removal. In the same way, when applied as a flocculation aid in conjunction with alum, the blend caused a reduction of 20% in the optimal dose of alum and removed turbidity up to 96% from the raw water. Introducing the Aloe Vera solution in coagulation – flocculation procedures avoids the generation of any non-treatable wastes or changes in the natural taste of water. These processes are easy to operate and require minimum maintenance. Design and operation parameters were calculated for small plants in rural areas when applying the experimental results from this study. Raw water with medium-level turbidity (45,5 NTU) required 56mg/l of alum with 5mg/l of Aloe Vera blend as a coagulation aid while water with a high-level turbidity (101 NTU) required 24mg/l of alum with 14mg/l of Aloe Vera blend as a coagulation aid in order to achieve more than 90% turbidity removal.

Keywords **– water treatment procedures, Aloe Vera, coagulation-flocculation.**

I. INTRODUCTION

Water is a vital resource, but presents a worrisome depletion in recent times. Adequate water supplyfor human consumption isa concern, since mostof this resource is found in oceanswhere the highsalt contentmakes it unsuitable for drinking. Features such as growing population, increased economic activities and industrialization have resulted in high demand for drinking water and the subsequent misuse of this natural resource, which is severe. This hinders thetreatabilityprocess and increaseswater treatmentcosts. For these reasons, coagulation-flocculationproceduresassociated withother processesare of great importancein order to separate contaminating componentsandachieving high degreesofdrinking water quality.

Aluminum sulfate (alum) has beenthe chemical coagulant used for drinkingwater treatments due tothe lowcosts, attainability andcomfortable handling. However, continuous use of alum has caused several problems affecting human health. Studieshave shown thataluminum is oneof the causes for Alzheimer'ssyndrome [1]. In addition, aluminum sulphategeneratesinconveniencesbecause of thelarge amounts of sediments, which may be regarded as highlyhazardous waste [2],[3],[4]. Anotheradverse characteristic ofaluminum sulfateis the permanencein the drinking waterlife-cyclethat are presentinnatural water resources, animals, people and plants [5].Owing to various problems generated by the use of alum, new alternatives for drinking water treatments should be studied. [6],[7].

Colombia holds diverse natural resources, which are able to offer various alternative methods to treat water.This studyaims to promotethe use of naturalsubstances in drinking water treatments through easy applicable methods suitable forsmall populationsthat require them. [8]In the past two decades, an innovative drinking water treatment strategy using natural coagulants has shown high reliability for coagulation - flocculation techniques achieving high efficiency in turbidity removal and color whileproviding additional advantages such as low cost and manageability, e.g.Okra gum, dry flowers of CalotropisProcera, few plant seeds of the species *Logania-*

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ceae-Strychnos potatorum and Moringaceae-Moringa Olifera and Moringa stenopetala have been used to clarify turbid water. [9], [10], [11], [12].

In the current study, an aloe(*AloeVera*) blend containing meaningfulcontentsof ions andpolymers was applied during the coagulation-flocculationprocedures [13].Aloe has health-givingproperties.The extract contains helpful polysaccharides and glycoproteins,which have immune-stimulating, antimicrobial and anti-inflammatory properties. Besides, this natural product has been used to treat intestinal problems like stomach ulcers and help fast wound healing [14], [15], [16], [17]. Moreover, *Aloe Vera* does notchange the natural taste of water. This plant is abundant in both Colombia and many other territories because it can grow in most of the environments and presents accelerated playback [18].

The projectrepresents a new strategy for drinking water treatments and contributesinwater treatability (especially insmall towns),sincethere are no recordsofa treatment plantfor drinking waterinColombia that employs a natural product during coagulation procedures asprimary coagulant or as a coagulation-flocculation aid.Similarly, important savings can be achieved by reducing the amount of alum required and thus, mitigating the negative effects.

II. METHODOLOGY

Initially, a water sample taken from Palmichala stream in Bucaramanga-Colombia was analyzed to obtain the turbidity, color, alkalinity and pH values, which are fundamental for drinking water treatments. Then, flocculation-coagulation tests were carried out with alum as the coagulant. Assays allowed finding the optimal dose when varying the alum dose every 10mg/l from 20 mg/l to 90 mg/l. obtaining the optimal dose allowed the optimal concentration by applying the following solutions: 0.5%, 1.0%, 3.0%, 5.0%, 7.0% and 10.0%. Finally, both velocity gradients for rapid and slow mix were determined based on the criteria established by the Pan American Center for Sanitary Engineering and Environmental Sciences (CEPIS) shown in table 11-6 section 1.

The *Aloe Vera* blend was tested as a primary coagulant and coagulation-flocculation aid. For each water sample and assay, a parallel test with aluminum sulfate was carried out as the reference coagulant. The optimal dose of the Aloe Vera was determined by employingjar tests. The appropriate optimal dose was determined by testing different concentrations of aloe solution (0.5%, 1.0%, 3.0%, 5.0%, 7.0% and 10%), In the coagulation aid tests, the *Aloe Vera* blend was dosed with the alum simultaneously in the rapid mixing, while in the flocculation aid tests, alum was first applied in the rapid mixing.*Aloe Vera* was added in the slow mixing solution to find the optimal dose of *Aloe Vera* blend in both cases.

Subsequently,a reductionofthe optimal alum dosewas calculatedat 20%, 40%, 50% and60%, with simultaneous addition of the aloe blend in the process. During this stage, the optimal timeandsedimentation rate offloc particles were analyzed. Todetermine the optimal timeofsedimentation, turbidity was measuredinthe sample extracted at a distance of 6 comforts the upper water level. The sedimentation rate values were calculated with the formula: Vs = (h/T) [19][20]
Where:
h = specific depth sampling in (cm).
T = sampling time in (s).
Finally, the sedimentationcurvewas plotted with sedimentation rates and remaining turbidity values for each case.
Everyjar testassaywas performed with control raw water (without coagulant addition) in an EQ flocculator equipment ref. F6-300.

Finally, parametersofdesignandoperation for drinking water treatment plants were calculated takinginto accountthe efficiency of turbidity removal and the savingsinthealuminum sulphate dose as a result of the addition of the naturalcoagulant. The procedure for coagulation-flocculation treatments was performed according to the CEPIS Manual and the Technical Regulations for the Drinking Water Sector and Basic Sanitation (RAS 2000), section 2, and title C, purification systems. [21]
The amount of coagulant required for 1 month in a drinking water treatment plant was determined in the following way:

- Incoming flow rate (l/month) x volume (l) of coagulant aid per liter of water = Total liters of coagulant aid solution required for 1 month of operation.

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- Total liters of coagulant solution required per month of operation x kilograms of coagulant required to make 1 liter of coagulant solution = Kilogram of coagulant required in 1 month.

The overview of the methodology used in the project is illustrated in Figure 1.

III. RESULTS AND DISCUSSIONS

3.1 Tests on a sample of raw water with *medium turbidity*

Initial tests on the water sample are reportedin Table1.

Dueto the very low valuesof turbidity in Palmichada stream, the results shown in table 1 for this raw watersample were consideredmediumturbidity andhighcolor.Inall assays, the target parameterswere measuredaftercoagulation-flocculationprocesseswithout filtration or chlorination and were compared with current Colombian 2115 environmental regulation. [21]

3.1.1 Aluminum sulfate in a *medium turbidity* water sample

Results on thecoagulation-flocculationtests using the aluminum sulfateas reference coagulantare summarizedin Table 2.The table includes the optimal dose, optimum concentrationandvelocity gradientsused in all the testingproceduresappliedfor thiswater sample.

3.1.2 Aloe blend in a*medium turbidity* water sample

The Aloe blend was tested as primary coagulant and flocculation-coagulation aid as well as in the gradualreduction of the optimal dose of the reference coagulant (alum).

3.1.2.1Estimate of aloe blend as primary coagulant

Initially, the optimal dose and concentration of aloe solution as the primary coagulant were tested. The final results of these experiments are summarized in Table 3.

Although floc formation by interaction between colloids and cations existing in the *Aloe Vera* solution was observed during the jar tests, high turbidity and residual color was found at the end of the process. Thus, the aloe blend was not helpful as primary coagulant. (See Figure 2)

3.1.2.2 Estimate optimal dose of aloe blend as coagulation aid. Simultaneous amounts of aloe blend and optimal alum dose during the jar trials in the rapid mix, showed the optimal dose of aloe blend as coagulation aid.

The optimal dose for the aloe blend as coagulation aid was 5 mg / l, which left a residual turbidity of 1.87 NTU and color of 50 UPC in the water sample with mid- turbidity. The results indicate good performance of this substance as a coagulation aid in this water sample. It is probable that the metal ions present in the composition of *Aloe Vera* highly supported the rapid mixing phase for colloid destabilization.

3.1.2.3 Estimation of the optimal dose for aloe blend as coagulation aid simultaneous to reduction of the optimal dose of alum. Jar tests were performed in the same water sample (45.5 NTU) to identify the optimal dose for aloe blend as coagulation aid with simultaneous reductions at 20%, 40%, 50% and 60% in the optimal dose for alum respectively. (Table 4)

20% reduction of the optimal dose of alum as primary coagulant with 5mg/l of aloe optimal dose pointed better resultscorresponding to 96.5% turbidity removal.In general terms, aloe blend performed excellent results as coagulant aid, where turbidity removal was more than 90% even when the alum optimal dose was reduced in 60%. (Table 4)

3.1.2.4 Estimation of the optimal dose for *Aloe Vera*blend as flocculation aid. After adding the optimum dose of alum inrapid mix in the jar test, aloe blend was added to start the slow mixing.

The optimal dose of aloe blend as flocculation aid was 12 mg / l, leaving a residual turbidity of 1.69 NTU and color of 50 UPC.

3.1.2.5 Estimatethe optimal dose of *Aloe Vera*as flocculation aid simultaneous to reduction of the alum optimal dose.Jar tests were performed in the same water sample (45.5 NTU) to identify the optimal dose for aloe blend as flocculation aid with a simultaneous reduction of the alum**optimal dose at 20%, 40%, 50% and 60%** (Table 5).

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Considering that 40% to 80% of the composition of Aloe Vera is resins, high elimination of color and turbidity can be explained by adsorption of colloids during slow mixing.The reduction on the optimal dose of alum by adding aloe blend was favorable up to 50% leaving turbidity removal more than 90%. The best result was for 20% reduction of the optimal dose ofalum and 1.72 NTU of the residual turbidity and thereby, complying with current Colombian standard (2,0 NTU) for this parameter.

Testing applied on the aloe blend in medium turbidity wateris summarized in Graph 1. The greater turbidity and residual data and thus, the less favorable results are represented by the usage of aloe blend as primary coagulant. Likewise, best results occur with the use of this natural substance as coagulation or flocculation aid even when the alum dose is reduced in both cases up to 20%. Efficiency on the sedimentation rate variation curves ispresented in Graphs 2 to 5.

In sedimentation process, large floc was decreased first, represented by higher sedimentation rate and then by settling out the smallest particles where sedimentation rates were lower. Graph 2 shows a good performance of alum as primary coagulant, which leads theformation of large floc with rapid sedimentation. The low sedimentation rate corresponds to the slow elimination of turbidity caused by thesmaller floc, leaving at the end of the process 3.11 NTU of remaining fraction of turbidity and 0,004 cm/s sedimentation rate. The comparison between graph 2 and graph 3, illustratesthe poor performance of the *Aloe Vera* blend as primary coagulant by slow sedimentation of the floc. Thisis proved by high fraction of remains turbidity (between 31 NTU and 34 NTU) and low-speed sedimentation that may indicate the presence of large quantity of colloids without flocculation in water.The best result was recorded in 25 minutes, when the remnants fraction of turbidity achieved 31 NTU at a velocity of 0, 004 cm/s.(Graph 3).

The shape of graph 4, which resembles a linear behavior, indicates a good formation of large, dense and strong floc, from the beginning of the process. At the end of the sedimentation, the fraction of the remnant turbidity was 1.34 NTU with 3,33E-03cm/s of sedimentation velocity.In this way, good performance of the *Aloe Vera* blend as coagulation aid is confirmed.

There are some fluctuations at low speed sedimentation in graph 5. It is possible that the formation of a large and dense floc at the beginning of the procedure could present a fragmentation during sedimentation process, causing higher turbidity than the initial. Still, the general trend shows the good performance of Aloe Vera blend as flocculation aid, which is reflected in the value of the residual turbidity of 2.82 NTU and the corresponding sedimentation speed of 0,003 cm/s.

Table 6 summarizes the results for optimal time of sedimentation, which highlights the performance of the Aloe Vera blend as coagulation-flocculation aid by letting low residual turbidity at an optimal time. Similar results were obtained with the primary coagulant of reference (alum).

3.2 Tests on a sample of raw water with *high turbidity*.Table 7 reports the initial conditions of the water sample taken at the Palmichala stream in wintertime, when the turbidity of the water was high.
The sample showed high turbidity and extremely high color. The pH and alkalinity were kept in the previously analyzed range.

3.2.1. Testing for aluminum sulfate in a *high turbidity* water sample.The results of the jar tests using the aluminum sulfateas the reference coagulantare summarizedin Table 8. The table includes the optimal dose, optimal concentrationandvelocity gradientsused in the entire testingproceduresappliedfor thiswater sample.

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3.2.2. Tests on the aloe blend in *high water turbidity.* All tests performed for this sample, were developed in the same way and conditions as in the previous water sample (of medium turbidity).The Aloe blend was tested as primary coagulant and flocculation-coagulation aid as well as in the gradual reduction of the optimal dose of the reference coagulant (alum).

3.2.2.1 Estimate of the aloe blend as primary coagulant. Originally, the optimal dose and optimal concentration of aloe blend were assessed as primary coagulant. The final results of these experiments are summarized in Table 9**.**

The use of *Aloe Vera* as primary coagulant blend was not efficient, due to the low percentage of turbidity and color removal.

3.2.2.2. Evaluation of the aloe blend as coagulation aid. The optimal dose of *Aloe Vera* blend applied as coagulation assistant was 10 mg/l, which left a residual turbidity of 1.89 NTU. This represents 98.1% of removal and gives compliance to the existing Colombian standard in turbidity data. Although the residual color was high, (50 UPC), removal exceeded 90%.These results confirm the good performance of Aloe Vera as coagulation aid.

3.2.2.3 Optimal dose identification for aloe blend as coagulation aid simultaneous reduction of the optimum dose of alum. The results of the optimal dose of Aloe Vera blend applied as coagulation aid simultaneous reduction of the optimal dose of alum in 20%, 40%, 50% and 60% are in the table 10.

The table 10 shows that high efficiency in removing turbidity by the primary coagulant of reference (alum) can be overcome by using only 40% of the optimal dose and applying the solution of Aloe Vera as aid for coagulation process.

3.2.2.4. Identification of the optimal dose of aloe blend as flocculation aid. In this jar tests, Aloe Vera was added at the beginning of the slow mix after adding the optimal dose of alum at the beginning of the process.The optimal dose of aloe blend as flocculation aidin high turbidity water was 11 mg / l, leaving a residual turbidity of 1.52 NTU and color corresponding to 40 UPC. In this way, the good performance of this natural substance as aid for flocculation in high turbidity water becomes evident.

3.2.2.5Identification of the optimal dose of aloe blend as flocculation aid simultaneous reduction of the alum optimal dose. Subsequent jar testsallowed determining the optimal dose of solution of Aloe Vera as flocculation aidwith a simultaneous reduction of the dose of alum in 20%, 40%, 50% and 60%. (See table 11).

The use of solution of Aloe as flocculation aid allows the reduction in the optimal dose of alum up to 20%, complying with the residual turbidity of 1.52 NTU and the current standard in Colombia, which is 2,0 NTU. Additionally, achieving a removal of 98.5% compared to the initial water turbidity.

Graph 6 summarizes the behavior of Aloe Vera blend in all tests performed in high turbidity water.
Graph 6 highlights the steep value of the residual turbidity after application ofaloe as primary coagulant, indicating their poor performance. The use of this natural substance as coagulation-flocculation aid allowed the reductionof alum to 40% and 20% respectively, which is very favorable. (See graph 6)

The same results for sedimentation optimal time, emphasizes the performance of Aloe Vera as flocculation aid for its low residual turbidity and a similar time to the primary coagulant of reference (alum), summarized in table 12.

Recognition of design and operation parameters for coagulation/ flocculation treatments upon the use of the tested natural substance: Using the experimental results from this study, design and operation parameters were calculated for small plant in rural areas.

Design parameters. The parameters of design were calculated for an incoming flow of 1,0 l/s of raw water and for a population of 900 people with a consumption of 100 liters per capita per day according to data from the World Health Organization (WHO).

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For medium turbidity (45,5 NTU) raw water, the following parameters were considered after experimental findings:The mix at1% of the *Aloe Vera*solution blend with dosage of 5mg/l and aluminum sulfate (type B) 5% solution with dosage of 56mg/l. Hence, 1 month of operation requires 1296 liters of the Aloe Vera at 1% for coagulation-flocculation procedures. To ensure this, 12.96 kg pulp of the Aloe Vera and 2851.2 liters (142.56 kg) of 5% aluminum sulfate solution (type B) are necessary.

For high turbidity (101NTU) raw water the following parameters are required:The mix at 1% of the *Aloe Vera* solution with dosage of 14 mg/l and 5% of aluminum sulfate (type B) with dosage of 24 mg/l. Therefore,3628.8 liters (36.23 kgof aloe pulp) at 1% solution of the Aloe Vera and 1244.16 liters (62.21 kg) of aluminum sulfate solution (Type B)are required for 1 month of operation in coagulation-flocculation procedures.

Flash mix: It must last 30 sec with a gradient of 227.7s/1velocity.

Slow mix: It must last 25 min with a gradient 20 s/1 of speed.

Sedimentation: After coagulation - flocculation with the *Aloe Vera* solution, the sedimentation process should last 25 min.

Operation Parameters. Operation parameters required for the use of *Aloe Vera* blend in the coagulation-flocculation process are the following: Aloe blend mixture, dosage, application and storage.

The Aloe Vera Solution: It is necessary to obtain the liquefied juice of *Aloe Vera* that is acquired following a series of steps:
First, cut the stalk, which hangs vertically with the side of the cuthanging down, so that, the yellowish liquid (aloin), -non-essential for the process-, is removed from the stalk. Then, cut and blend the stalk without adding any solvent. Subsequently, dilute 1.0 gr. of *Aloe Vera* pulp in 100 ml of distilled water for 1% solution.

Dosage of the Aloe Vera solution: The dosage in the coagulation-flocculation process requires application of optimal dose of Aluminum Sulfate (type B) for the analyzed water and the optimal *Aloe Vera* dosedepends on water turbidity.

Application: Optimal dosage of Aloe Vera blend on jar tests and the savings of alum solution that can be achieved by the application of the aloe optimal dose as coagulation –flocculation aid should be taken into account.The *Aloe Vera* solution as a flocculant aid should be applied after adding the optimal dose of alum in jar test, when slow mixing starts. .

Storage of an Aloe Vera:The storage warehouse needs to have ventilation (windows), moisture insulators from the floor (boards), channel drain and hooks to hang the Aloe Vera stalks that are daily required.The storage room should be inside the dosage room. Size is not a determining factor. It is appropriate to make the blend of *Aloe Vera* every day to prevent properties loss. In many cases, refrigeration or storage produces oxidation and deterioration of the Aloe Vera pulp.This is why daily blend is recommended, until a deeper study about the behavior of the chemical composition of Aloe Vera is done.Aloe Vera sliced stalks may be left from one day to another in storage hanging above a drainage channel, to a relatively low height and leaving the open part upside down, so that aloin drains.

IV. CONCLUSIONS

The raw water of the Palmichala stream used in this project was characterized by high color, which ranged from 90 UPC up to 550 UPC and turbidity associated with the climatic conditions present at the time of sample collection, reaching up to 101 NTU in rainy seasons.

Regardless of the turbidity of the water sample analyzed, *Aloe Vera* solution proved to be a poor primary coagulant in comparison with the aluminum sulfate applied as a reference in the same jar tests.

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The solution of *Aloe Vera* as coagulation aid achieved a decrease up to 20% of the optimal dose of aluminum sulfate in water samples in medium turbidity and up to 40% of the optimal dose of alum in high turbidity samples at Palmichala stream.

Aloe Vera solution applied as flocculation aid, presented turbidity removal exceeding 95% in medium and high turbidity samples and allowing a reduction of the optimal dose of the chemical up to 20% on both tests.
The parameters found for the design and operation were: 56 mg/l of alum with 5 mg/l of liquid *Aloe Vera* as a coagulation aid in medium turbidity water and 24 mg/l of alum with 14 mg/l of liquid *Aloe Vera* as a coagulation aid in high turbidity raw water.

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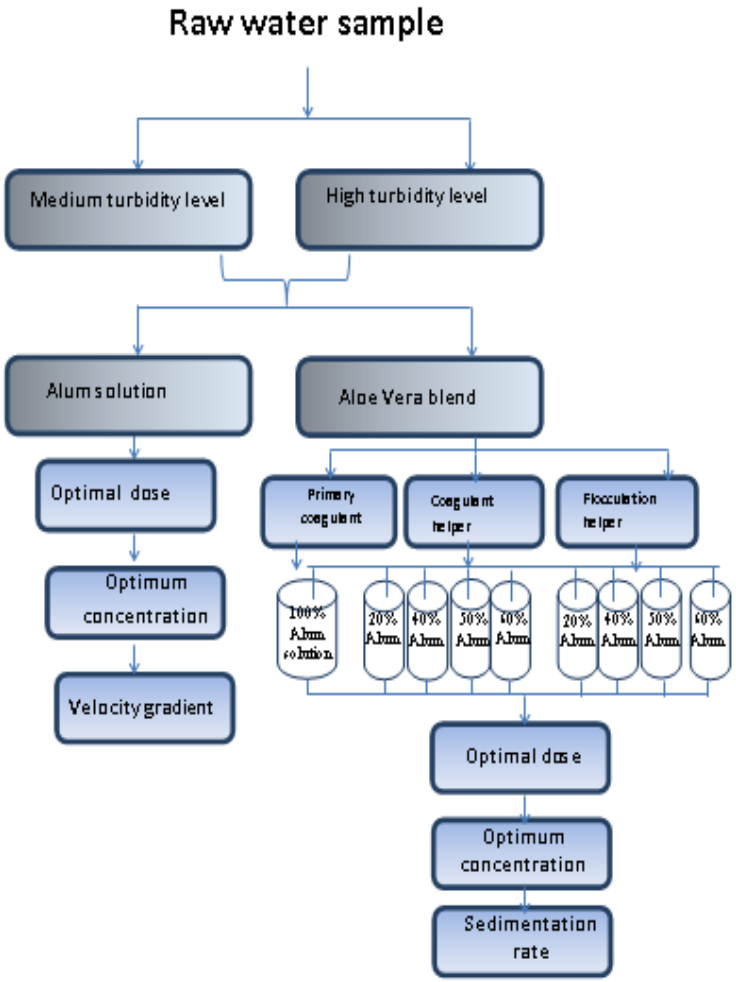

Fig 1. Methodology Overview

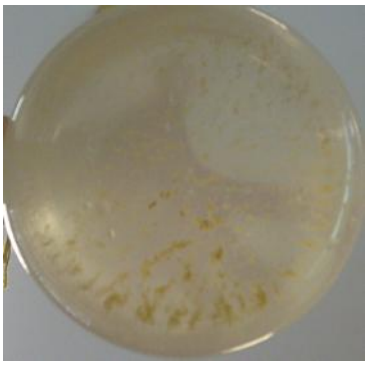

Fig 2. Floc formation by aloe blend

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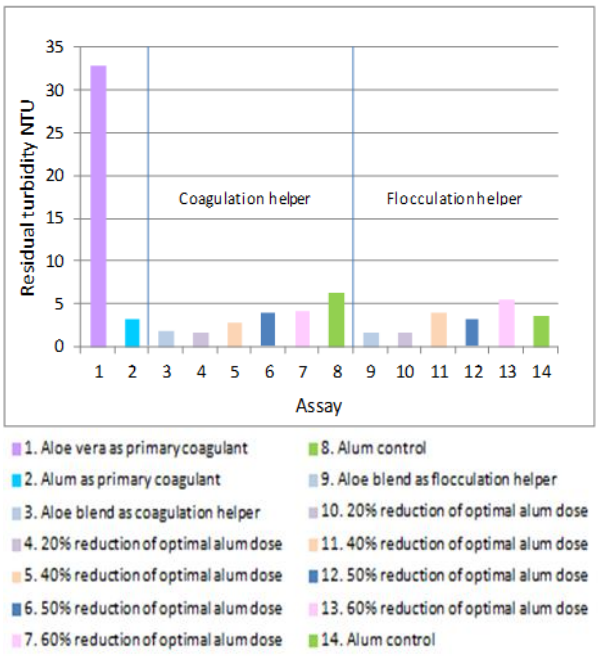
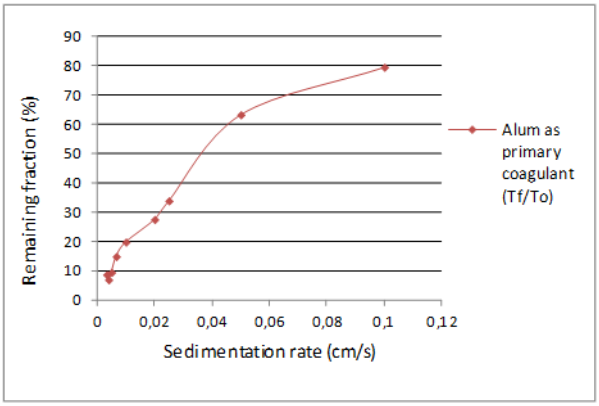
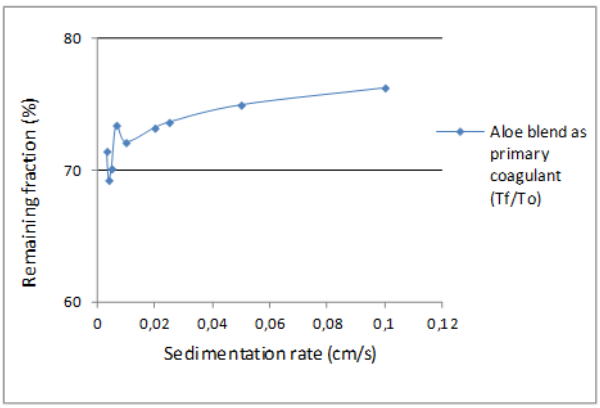


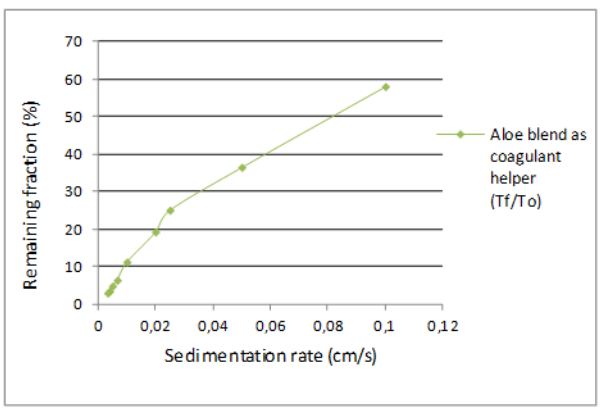
Graph 1.Summary for aloe blend testing in water of medium turbidity



Graph 2.Floc sedimentation formed with alum as primary coagulant



Graph 3. Floc Sedimentation formed with aloe blend as primary coagulant



Graph 4. Floc Sedimentation formed with aloe blend as coagulant aid

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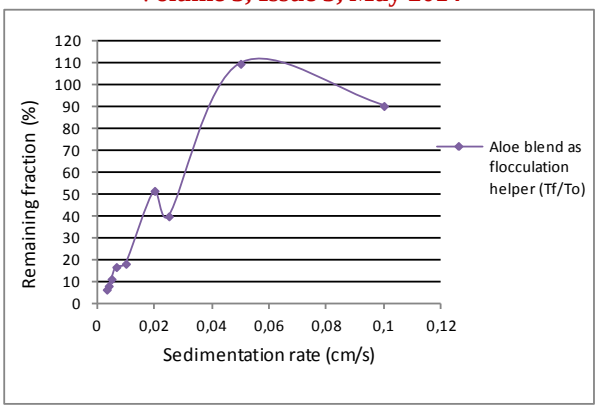
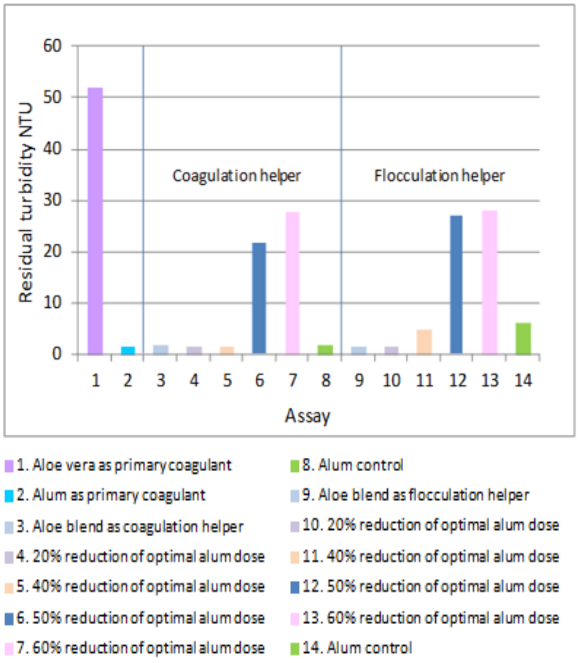


Graph 5 Floc Sedimentation formed with aloe blend as flocculation aid



Graph 6. Assays overview with blend of Aloe Vera in high turbidity water.

Table 1. Initial conditions of raw water

PARAMETERS	VALUES
Turbidity(NTU)	45.5
Apparent color (UPC)	320
Alkalinity(mg./l)	70
pH	7.78

Table 2. Optimal values for aluminum sulfate as a primary coagulant in medium turbidity water.

PARAMETERS		RESULTS
Optimal Dose		70 mg/l
Optimal Concentration		5%
Speed Gradient	Rapid mix	150 rpm for 35 s.
	Slow mix	30 rpm for 25 min.

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Table 3. Optimal dose and concentration for the aloe blend used as primary coagulant

Parameters	Results	Residual Turbidity (NTU)	Residual Color (UPC)
Optimal Dose	140 mg/l	32,8	210
Optimal concentration	10 %	31.6	250

Table 4. Aloe Vera blend as coagulation aid with simultaneous reduction in the optimal dose.

Aluminum sulphate dose (mg/l)	Optimal dose of aloe blend (mg/l)	Residual Turbidity (NTU)	Turbidity removal %
70 (primary coagulant)	-----	6.25	86.3
------	140 (primary coagulant)	32.8	27.9
70 (100%optimal dose)	5	1.87	95.9
56 (*20% optimal dose)	5	1.59	96.5
42 (*40% optimal dose)	5	2.7	94.1
35 (*50% optimal dose)	7	3.93	91.4
28 (*60% optimal dose)	6	4.22	90.7

* Reduction in percentages on the alum optimal dose

Table 5. Trials overview with Alum and Aloe Vera as flocculation aids in medium turbidity water samples

Doses of aluminum sulfate (mg/l)	Dose of Aloe Vera blend (mg/l)	Residual turbidity (NTU)	Turbidity removal %
70 (primary coagulant)	-----	3.61	92
------	140 (primary coagulant)	32.8	27.9
70 (100% optimal dose)	12	1.69	96.3
56 (*20% optimal dose)	10	1.72	96.2
42 (*40% optimal dose)	12	3.87	91.5
35 (*50% ooptimal dose)	12	3.16	93.1
28 (*60% optimal dose)	11	5.57	87.8

* Reduction in percentages on the alum optimal dose

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Table 6. Optimal time of sedimentation and the respective residual turbidity

Method	Optimal time [min.]	Final residual turbidity [NTU]
Alum as primary coagulant	25	3,11
Aloe blend as primary coagulant	25	31,5
Aloe blend as coagulant helper	30	1,34
Aloe blend as flocculation helper	30	2,82

Table 7 Initial conditions of raw water

PARAMETERS	VALUES
Residual turbidity (NTU)	101
Apparent color (UPC)	550
Alkalinity (mg./l)	65
pH	7.1

Table 8.Optimal parameters of aluminum sulfate as primary coagulant

PARAMETERS		RESULTS
Optimal dose		40 mg/l
Optimal concentration		5%
Speed gradient	Rapid mix	150 rpm during 35 s.
	Slow mix	30 rpm during 25 min.

Table 9. Optimal parameters using Aloe Vera as primary coagulant blend.

Parameters	Results	Residual Turbidity (NTU)	Color (UPC)
Optimal dose	130 mg/l	52.1	350
Optimal concentration	10%	55.5	360

Table 10. The Aloe Vera as coagulation helper in high turbidity water sample

Aluminum Sulfate dose (mg/l)	Aloe Vera dose (mg/l)	Residual turbidity (NTU)	Turbidityr emoval %
40 (primarycoagulant)	-----	1.89	98.1
------	130 (primarycoagulant)	52.1	48.4
40 (100% optimaldose)	10	1.89	98.1
32 (*20% optimaldose)	**13**	**1.33**	**98.7**
24 (*40% optimaldose)	**14**	**1.55**	**98.5**
20 (*50% optimaldose)	17	21.8	78.4
16 (*60% optimaldose)	8	27.7	72.6

* Reduction in percentages on the alum optimal dose

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Table 11. Alum and Aloe Vera as flocculation helper in high turbidity water sample.

Doses of aluminum sulfate (mg/l)	Aloe Vera dose (mg/l)	Residual turbidity (NTU)	Turbidity removal %
70 (primary coagulant)	-----	3.61	92
------	140 (primary coagulant)	32.8	27.9
70 (100% optimal dose)	12	1.69	96.3
56 (*20% optimal dose)	10	1.72	96.2
42 (*40% optimal dose)	12	3.87	91.5
35 (*50% optimal dose)	12	3.16	93.1
28 (*60% optimal dose)	11	5.57	87.8

* Reduction in percentages on the alum optimal dose

Table 12. Optimal timing of sedimentation and respective residual turbidity

METHOD	Optimal time [min.]	Final residual turbidity [NTU]
Alum as primary coagulant	30	2.28
Aloe Solution as primary coagulant	10	85,1
Aloe solution as coagulant helper	25	6,47
Aloe solution as flocculation helper	30	2,64