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Comparison of the Sludge Volume Index (SVI) between a natural coagulant and aluminum sulfate

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Abstract : This study evaluated the sedimentation behavior of the residual sludge produced in the raw water treatment using Aluminum Sulfate and saline extract of *Moringa Oleifera* seed at laboratory scale. The conventional parameter was measured to evaluate the sedimentability of sludge: The Sludge Volume Index (SVI). A completely randomized design with factorial structure was made, taking into account the factor 'Turbidity' of water. The results were analyzed using tables of varianceanalysis. For this study, raw water was collected from the Sinu River in the Mocari neighborhood from Monteria, Colombia, with turbidity levels of 150 NTU, 265 NTU, and 408 NTU. It was evidenced that the sedimentability of the sludge does not differ significantly when the *Moringa Oleifera* extract or the Aluminum Sulfate areapplied as coagulants. The greater turbidity in the water, the greater the index volume of sludge, regardless of the coagulant used. The coagulants show excellent sedimentation capacity, since the value of the SVI is in the characteristic range.
Key Words : Raw water, coagulants, SVI, sedimentability, residual sludge.

Introduction

One of the unit operations most used to remove suspended material produced in the potabilization of raw water is sedimentation. Once the coagulant is applied, formation of the floc begins, starting from the destabilization of colloids present in the water, which are then precipitated by gravity. The most economical way to obtain this separation is by removing suspended solids through sedimentation[1,2].

In order to analyze sedimentability, the Sludge Volume Index (SVI) developed by Mohlman, was used, based on the physical properties of Mixed Liquor Suspended Solids (MLSS)[3]. The SVI quantifies the volume of the sludgeexpressed in units of mL/g. This is measured as the height, expressed in mL of the solids interface after being sedimented for 30 minutes in a 1000 mL graduated cylinder divided by the mass of solids expressed in grams. The result represents the volume occupied by one gram of suspended solids. The test, standardized for greater reproducibility, has been used very frequently to describe the sedimentation behavior of sludge[4].

However, the general applicability of this measurement has been questioned due to the dependence on the solids concentration and the diameter of the cylinder used in the test. Nontheless, despite its deficiencies, SVI is the most widely used measure of compactibility of sludge by environmental researchers[3,5,6].

The flocculated sludge with a SVI of 150 mL/g is frequently considered as the dividing line between a voluminous sludge (values above) and non-voluminous one[7]. *Grady et al.*[8] consider that values below 80 mL/g are excellent and between 80 and 150 mL/g are moderate, while SVI values between 76 and 80 mL/g can be considered indicators of good sedimentability. A SVI between 100 and 150 mL/g indicates good sedimentation, and higher values are generally but not always associated with the phenomenon of sludge removal indicating poor sedimentation and low sedimentation velocity[4].

The purpose of this study was to compare sedimentation and the SVI between the residual sludge produced in the raw water treatment using Aluminum Sulfate and *Moringa Oleifera* seed extracts as coagulants.

Materials and Methods

Water samples were collected from the Sinú River in the Mocari neighborhood, Municipality ofMonteria, Colombia (see Figure 1) and then stored at room temperature in plastic bins. The turbidity of the samples was measured by the nephelometric method with a HACH 2001P Turbidimeter. All tests were performed according to the procedures established by the Standard Methods.

Figure 1. Location of the study area and the samples

Coagulation-flocculation jar tests were performed in an E & Q Flocculator[9] with two kinds of coagulants, *Moringa oleifera* and Aluminum Sulfate. 10 beakers were filled with 1000 mL each and the optimum dose of each coagulant was applied;immediately homogenizing the mixture. The coagulation-rapid mixing process was performed at 200 rpm for 1 minute and then flocculation-slow mixing at 40 rpm for 20 minutes[10]. The beakers mixture was deposited in 5 Imhoff cones and allowed to settle for 30 minutes, then the sediment sludge volume was read. In Figure 2, the assembly for the test is shown.

To test the suspended solids, the glass filter disc was inserted into the crucible, washed with distilled-deionized water, the crucible was brought to the stove (103 ° C-105 ° C) for two hours.

Figure 2. Assembly of sedimentation test

It was then allowed to cool in the desiccator and the filter paper was weighed on the analytical balance. The drying and cooling process was repeated until constant weight. The homogenized samples were filtered and baked again for two hours, then cooled in the desiccator for half an hour and the filter paper was weighed on the analytical balance[11].

Finally, the sludge volume index was calculated with the data of the volume of the sludge compacted at 30 min in the cone Imhoff, and the initial concentration of the total suspended solids in each of the samples[12], using the following equation:

$$\mathrm{SVI}\left(\frac{\mathrm{mL}}{\mathrm{g}}\right) = \frac{\mathrm{Sed.sol\ 30'}\left(\frac{\mathrm{mL}}{\mathrm{l}}\right)}{\mathrm{TSS}\left(\frac{\mathrm{g}}{\mathrm{l}}\right)} \qquad (1)$$

Where:
SVI = Sludge Volume Index
Sed.Sol30´ = Sediment solids in 30 minutes
SST = Total Suspended Solids

Results and Discussion

Tables 1 and 2 show the SVI results of the water samples treated with coagulants of *Moringa oleifera* seed extract and Aluminum Sulfate, respectively.

The statistical tool that was implemented for data analysis corresponds to an analysis of variance (ANOVA), using the statistical software R.

Table 1. Results of the Sludge VolumeIndex (SVI) for *Moringa oleifera*.

Raw Water Turbidity	Jar 1	Jar 2	Jar 3	Jar 4
150	0.328	0.174	0.185	0.521
265	6.767	7.887	4.976	6.171
408	1.858	2.890	1.795	1.442

Source: Authors

Table 2. Results of the Sludge Volume Index (SVI) for Aluminum Sulfate.

Raw Water Turbidity	Jar 1	Jar 2	Jar 3	Jar 4
150	8.403	2.054	0.847	0.705
265	2.058	2.648	0.660	3.334
408	1.858	2.890	1.795	1.917

Source: Authors

To verify the assumptions of this analysis, it is necessary to comply with three hypotheses[13]:

- That the residual data be independent to ensure that the compared samples were randomly extracted. In this case, the level of significance allows to accept or reject independence between variables. If this level is greater than 0.05, the hypothesis of independence between variables is accepted[14].
- That the data were normal. To ensure compliance with this criterion, the p-value must be greater than 0.05. In this case the null hypothesis was not rejected, therefore the assumption of normality is fulfilled[15].
- •That the data had the same homogeneity of variance. To ensure compliance with this criterion, it was established that the p-value was greater than 0.05 and it was concluded that the assumption of homogeneity was fulfilled[15]. Table 3 shows the results of the independence hypothesis for the coagulant SVI data.

Table 3. Independence of residuals

Durbin–Watson Test		
Coagulant	Statistical	Criteria
M. oleifera	DW: 2.4223	*p* value: 0.5591
Aluminum S.	DW: 1.394	*p* value: 0.2918

Source: Authors

According to the p-value from Table 3, it can be affirmed that the assumption of independence is satisfied in both models since the p-value (0.5591) and (0.2918) are greater than 0.05.Table 4 shows the results of the normality hypothesis for the coagulant SVI data.

Table 4. Normality of residuals

Normality Test Shapiro- Wilk		
Coagulant	Statistical	Criteria
M. oleifera	SW: 0.93232	*p* value: 0.4053
Aluminum S.	SW: 0.83288	*p* value: 0.02271

Source: Authors

The assumption of normality of the residuals in the model is fulfilled when using the *Moringa oleifera* coagulant.

Table 5 shows the results of the variance homogeneity hypothesis for the coagulant SVI data. Likewise, the assumption of homogeneity of variances for the two coagulants was fulfilled.

Table 5. Homogeneity of variance

Levene's Test of Homogeneity of Variance		
Coagulant	Statistical	Criteria
M. oleifera	F: 2.5477	*p* value: 0.1328
Aluminum S.	F: 1.1356	*p* value: 0.3633

Source: Authors

After verifying the general compliance of the three hypotheses of independence, normality and homogeneity of the data, it was possible to perform the analysis of variance between the coagulants *Moringa oleifera* and Aluminum Sulfate, which allowed to determine if their respective sedimentabilities are significantly the same or different.

Table 6 shows the results of the ANOVA performed when comparing the SVI between the coagulants and the SVI according to the variation of the turbidity.

Table 6.Results of ANOVA of the SVI between the *Moringa oleifera* (MO) and Aluminum Sulfate (SA) coagulants as a function of the different turbidities

SV	DF	AS	MS	CF	*p* value:
Turbidity (MO)	2	80.68	40.34	64.14	0.0000047
Turbidity (AS)	2	1.97	0.983	0.198	0.824

Source: Authors

From the analysis of variance of the SVI versus coagulants, it was obtained that using *Moringa oleifera*, the level of turbidity has a highly significant influence on the level of sludge sedimentation. Whereas using Aluminum Sulfate, turbidity levels do not influence the SVI indicator. In addition, nonparametric tests were used to validate the hypothesis of the model, whose results are shown in Table 7.

Tabla 7. Nonparametic validation results

Kruskal-Wallisn Test		
Coagulant	**Statistical**	Criteria
M. oleifera	**KW: 9.8462**	*p* value: 0.0073
Aluminium S.	**KW: 0.2692**	*p* value: 0.8741

In agreement with the results of the parametric tests, significant differences of the SVI were also found when applying to the samples of raw water extracts of *Moringa oleifera* as coagulant. However, when comparing the statistical probability densities of the SVI of the coagulants used, both fall in the region of equality confidence; that is, according to the non-parametric test used, the SVI does not differ according to the type of coagulant used nor the level of turbidity of the raw water in a significant way (Figure 3).

In Figure 4, the results of the separate comparison of the statistical distributions of the SVI are shown.

The bold line represents the average of the distributions of each coagulant. The averages of the distributions were similar in magnitude, however the dispersion of the SVIs was different according to the coagulant that was used.

Finally, Figure 5 shows all the factors studied. It was noticed that the SVIs were more homogeneous when Aluminum Sulfate was used as a coagulant than when the *Moringa oleifera* extracts were used.

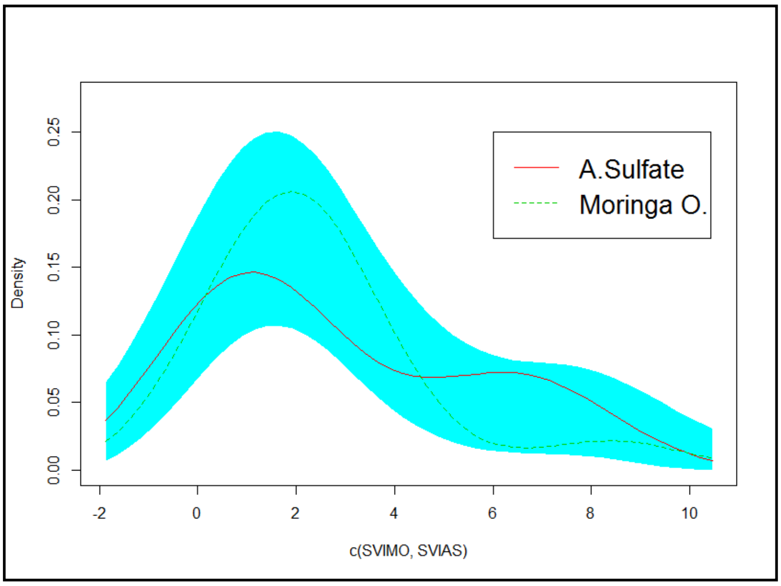

Figure 3. Comparison of probability densities

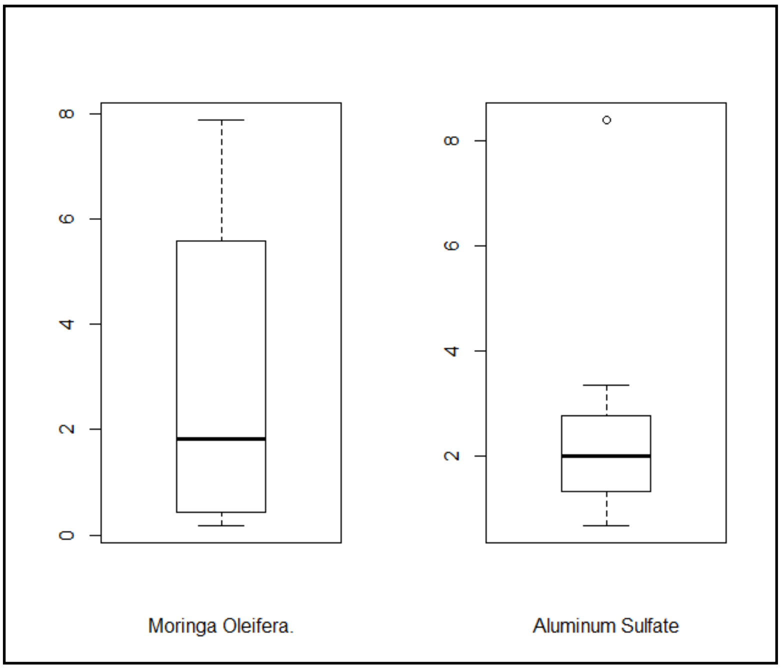

Figure 4.Comparisons of distributions of SVI

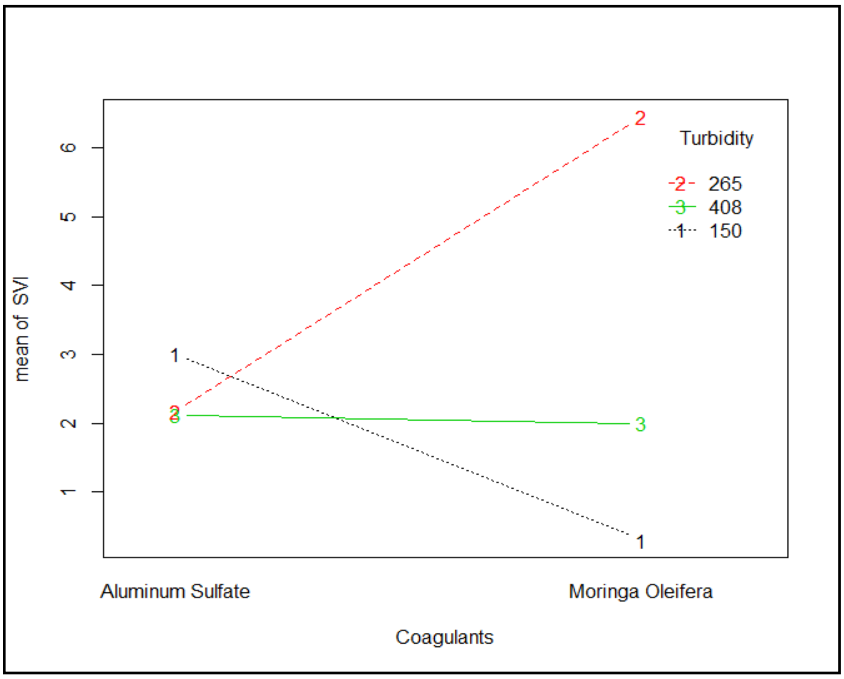

Figure 5. Profiles Graphic

Conclusions

The analysis of variance ANOVA, showed that the measurements of the SVI are more stable when applied to samples of raw water Aluminum Sulfate (as coagulant) than when *Moringa oleifera* oil extracts wereapplied. It was shown that the levels of turbidity of the raw water do not influence the values of the SVI found. On the other hand, the SVI was very variable in the ranges of significant differences of the coagulants used. This is reflected in the differences in probability of occurrence at certain levels of turbidity, so it is necessary to perform response surface curves to find regions of local or global optimization.

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