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EVALUATION OF FLOCCULATION PERFOTMANCE OF ALOE VERA WITH CLAY SUSPENSION

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***Abstract*:** Flocculation is one of the commonly used processes in the treatment of wastewater. It aims to eliminate colloidal particles that cannot be removed by other methods. Traditionally, aluminum or iron salts and synthetic polymer have been utilized. Remaining traces of these chemicals in water is a source of pollution hazards. Besides, it generates slowly biodegradable sludge. Thus, the recent trend is towards using biomaterials. Moreover biopolymers, have coagulation and flocculation properties, which can remove over 80-90% of water turbidity at almost no cost. Additionally, the use of natural polymers produces sludge-increased biodegradability. In the present study, Aloe Vera Gel (AVG) is used for enhancing turbidity removal of clay suspension of different concentrations. AVG is used in dosages of 2, 4, 6, and 8 ml/l of clay suspensions with concentrations 10 and 50 gm clay/l. Different particle sizes of clay are tested. Results indicated that increased particle size enhances turbidity removal. Higher values for percentage reduction in turbidity are satisfied by increasing AVG dose up to 6 ml/l. The lowest value for residual turbidity (40 NTU) and the highest percentage in turbidity reduction (89%) are satisfied when using a clay suspension 10 g/l, with particle size 600 µm, using AVG dose 6 ml/l. Best performance is obtained from AVG when using a ratio 6/100 for AVG dose/solid particles (for clay suspension 10 g/l). This ratio was 12/100 for clay suspension 50 g/l. Thus, AVG could be considered an environmentally – friendly option for treatment of turbid water with feasible results.

Keywords: Aloe Vera Gel (AVG), Clay, Coagulation, Turbidity.

1. INTRODUCTION

Industrial effluents are considered the primary source of water pollution and impurities due to their high chemical content and wide range of organic and inorganic contaminants [1-3]. These contaminants may be suspended and dissolved particles, organic and inorganic contaminants, toxic chemicals, non-biodegradable products and color, all of which are harmful to the environment and human health [4-6]. The discharge of raw industrial effluents might cause the following environmental problems: (a) Visible and irregular pigmentation of water surfaces. (b) Severe consequences on organisms/microorganisms affecting their organic activities. (c) Significant damage to the aquatic lifecycle due to the absorption of dissolved oxygen by pollutants [2, 7-12]. Various methods have commonly been known for wastewater treatment [13-18] and among these methods is flocculation [19-20].

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Flocculation is a water and wastewater treatment technology whereby the large aggregation of flocs in water can be formed and be later separated through sedimentation [21]. Numerous researchers have reported the significance of coagulation/flocculation process in industrial wastewater treatment due to its efficacy, convenience of use, and low cost [7, 22]. However, its full potential is restricted by some significant drawbacks. For instance: challenges concerning coagulant/ flocculent recyclability, the generation of large sludge volumes and the adverse effects associated with health issues [23, 24]. The coagulation/flocculation process is widely employed for industrial wastewater treatment to remove colloidal particles, dyes, heavy metals, and organic matter due to its ease of use, low cost, and upgradeability [25, 26]. This process involves the addition of coagulants/flocculants, which can be chemical or natural materials that destabilize and aggregate the suspended particles and colloids in the wastewater [27]. Coagulants, such as aluminum sulfate, ferric chloride, and polyaluminum chloride, work by neutralizing the charge on the particles, while flocculants, such as polyacrylamide and chitosan, bind the destabilized particles together to form larger, denser flocs that can be easily separated from the wastewater [28, 29]. Thus, chemical coagulants are generally inorganic salts that are added to the wastewater to neutralize the electrostatic charges on the particles, destabilize the suspended solids, and promote aggregation into larger particles that can be more easily removed. Common chemical coagulants include aluminum sulphate (alum), ferric sulphate, ferric chloride, and polyaluminum chloride (PAC) [30, 31]. Contrarily, chemical flocculants may be a type of organic polymers that are added to wastewater to make the particles larger and heavier so that they will settle or filter out more easily. These polymers possess a large molecular mass and a high concentration of electric charge, which allows them to adsorb onto the surfaces of the particles and create bridges between them [32]. Larger flocs are created as a result, which are easier to remove from the wastewater.

Generally, the performance of the coagulation/flocculation processes is affected by several operational factors, including pH, coagulant/flocculent dosage, mixing rate, mixing time, temperature, and the physical characteristics of the coagulant/flocculent material, including density and particle size [24, 28, 33-36].

Recently, natural materials from various sources have been investigated as a sustainable alternative to chemical coagulants/flocculants. Examples of natural-based coagulants/flocculants (NC/Fs) are plant seeds, tannin, and certain vegetables/fruit peels [37]. Natural coagulants are used in water with low to medium turbidity (50-500 NTU) and have similar performance to its chemical counterparts [38]. Flocculants derived from plants possess polyelectrolytes (mainly polysaccharides and protein compounds) that can affect the stability of ionic charges in aqueous solution [39]. Plants of the genus *Opuntia* sp (family Cactaceae) produce a hydrocolloid (or mucilage) with highly branched structures that can retain water [40]. According to Ref. [41] plant-based bioflocculant can act as co-coagulant with aluminum sulphate. Natural flocculants can also be derived from seeds of plantago, ovata, Moringa olifiera, etc. Some natural starches can be used as natural aid also. It also covers a comprehensive list of natural flocculants, namely chitosan, starch, microbial tannin, cellulose, and gelatin [21].

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In contrast to chemical substances, NC/Fs are nontoxic, sustainable and generally harmless. Moreover, natural extracts are often locally available, making them affordable alternate to chemical substances [42, 43]. They contain a wide range of active compounds, including soluble proteins, which have positive charges when it interacts with a solution. These proteins can bind to the negative ions in raw effluents, which cause turbidity [44, 45]. Karam *et al.* (2021) [37] examined the viability of applying coagulation/flocculation processes for real textile effluent decontamination. Dehghani *et al.* (2016) [38] also obtained considerable COD, turbidity, and TSS removals up to 38.6%, 63.7%, and 62.1%, respectively, after treating oil refinery effluent at 70 mg/l optimum of *Moringa oleifera* (MO) dose. In a study conducted by Jagaba *et al.* (2020) [39], it was found that an optimal dosage of 2000 mg/l of MO resulted in significant removal rates of turbidity, COD, TSS, color, and oil & grease from palm oil mill effluents. It was also observed that contaminant removal rates rise as the C/F dose increases until the optimal C/F dosage is reached [40]. An investigation into the effect of mixing rate on food industry wastewater treatment was conducted by Anteneh, 2014 [41]. In the present work Aloe Vera Gel (AVG) is used as a natural C/F for enhancing turbidity removal from a clay suspension. Factors affecting the flocculent performance are studied and the optimum conditions for securing high flocculation performance are outlined. The target is satisfying the highest level of contaminant removal thus, improving the quality of the treated water, reducing the environmental impact of industrial effluents, and reducing the overall costs of wastewater treatment and ensuring that the effluent meets the required regulatory standards.

2. MATERIALS AND METHOD

I. Material:

The materials used in the study are: Bentonite clay: used for preparing clay suspension with different concentrations, Aloe Vera Gel (AVG); used as natural coagulant/ flocculent and distilled water is used in the preparation of clay suspension.

II. Method:

A. Preparation of Aloe Vera Gel (AVG)

Aloe Vera leaves are washed then peeled. The leaves are cut into halves and the AV gel is extracted. The AVG is mixed in a blender to bring it to a liquid-like gel (Fig. 1). Gel could be kept in a refrigerator for up to 7 days for daily use. The dose required is taken by volume.

Fig. 1: The scheme of Aloe Vera gel preparation

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B. Preparation of clay suspension

1- Clay is dried in a drying oven at 105^{O}C till constant weight and its water content is recorded.
2- Clay powder is subjected to a screen analysis test and classified into different sizes.
3- At time of experiment, the required weight of clay is added to distilled water and the volume is completed to 1 letter and shacked well for homogenization and the resulting suspension is used in the experiments; either alone (for use as a reference test) or after the addition of the required dose of AVG.

C. Characterization of AVG

AVG has different components as shown in Table 1.

Table 1: Chemical composition of AVG

Component	Quantity
Carbopol 940	1 g
Glycerin	5 g
EDTA	0.10 g
Propylene Glycol	2.7 g
Methylparaben	0.20 g
Triethanolamine	1.15 g
Glycolic extract	10 ml
Water	100 g

D. Characterization of clay

Clay deposits are generally found in many geological regions located in the Nile Valley and Delta of Egypt. The major contents of the clay sample are: CaO (15.5%), silica (21.25%) and alumina (7.52%). While the percent of other components is Fe_2O_3 (1.95), TiO_2 (0.23), MgO (0.80), and MnO (0.03). In addition, high values of SO_3 (4.83%) and P_2O_5 (4.54%) appeared owing to the existence of gypsum and apatite. While the loss on ignition (LOI) of the clay sample was 42.90%.

3. RESULTS AND DISCUSSION

The experimental results obtained from the present study are presented and discussed herein.

I. Improvement in turbidity reduction due to the use of Aloe Vera Gel (AVG) as a flocculent:

This test is run on clay suspension with concentration 10gm/l for 4 different dosages of AVG; 2, 4, 6 and 8 ml/l of suspension. The test is repeated for particle sizes 200, 400, and 600 µm. The results of this test are given in figures 2- 6 for different concentrations of AVG and compared with the reference test (no AVG is used).

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A. Using AV dose of 2ml/l:

Compared to the reference experiments (with no AVG used), values of residual turbidity were lower for all particle sizes (PS) used. Values of residual turbidity were 91, 79 and 68 NTU for particle sizes 200, 400 and 600, respectively. However, percentage reduction in turbidity was 79, 78 and 81% for particle sizes 200, 400 and 600 µm, respectively; compared to 76, 76 and ٧7% when no AVG was used. Thus, a noticeable improvement in percentage reduction in turbidity is obtained due to the use of AVG. Much improvement is noticed for relatively larger particle sizes. This also means that particles size is an important factor for turbidity reduction in the presence of AVG as a flocculent.

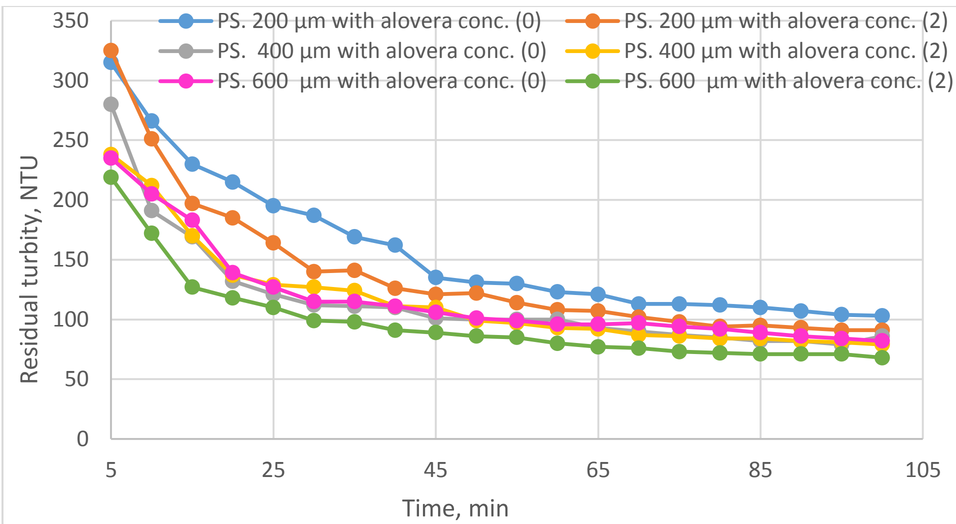

Fig. 2: Improvement of turbidity removal due to the use of AVG
(2 ml AVG/l of suspension, clay concentration = 10 g/l, PS 200, 400, 600 µm)

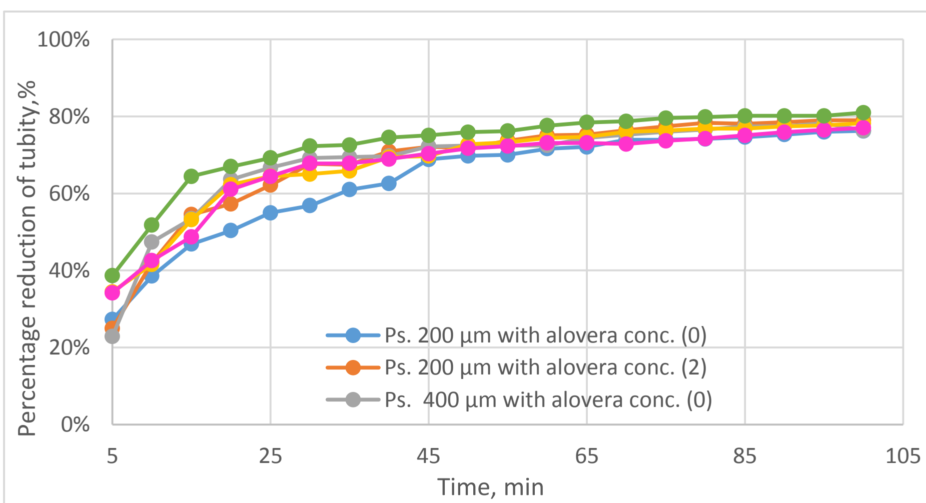

Fig. 3: Percentage reduction in residual turbidity due to the use of AVG
(AVG concentration 2ml/l)

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B. Using AV dose of 4ml/l:

Compared to the reference experiment (with no AVG used), values of remaining turbidity were lower for all particle sizes used. However, percentage reduction in turbidity was 83%, 84% and 86% for particle sizes 200, 400 and 600 µm, respectively; compared to 76%, 76% and ٧7% when no AVG was used. Thus, a noticeable improvement in percentage reduction in turbidity is obtained due to the use of AVG dose 4 ml/l of suspension. It is also noticed that higher percentage reduction in turbidity is satisfied as the dose of AVG is higher (79, 78 and 81% for 2 ml AVG as compared to 83, 84 and 86 for AVG 4ml/l).

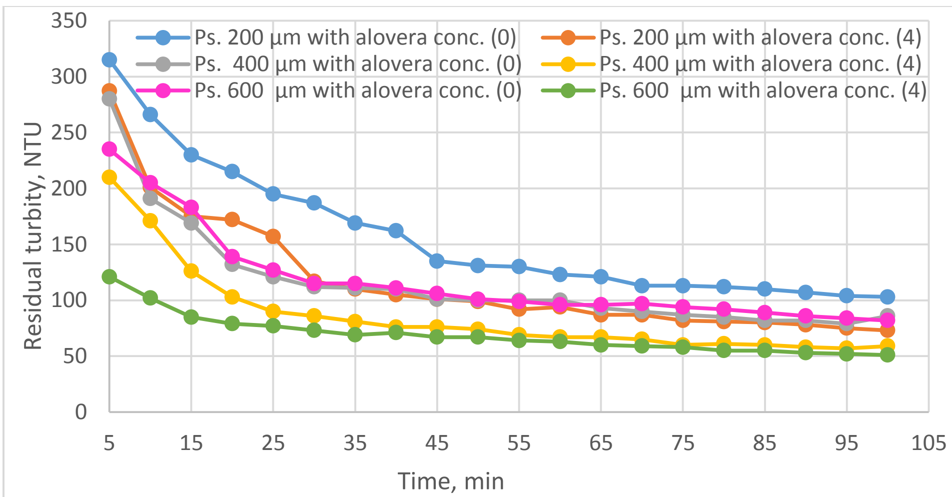

Fig. 4: Improvement of turbidity removal due to the use of AVG
(4 ml AVG/l of suspension, clay concentration = 10 g/l, PS 200, 400, 600 µm)

C. Using AV dose of 6ml/l:

Results of this test are given in Fig. 6. Values of residual turbidity by the end of experiment (after 100 minutes of settling) were ٥٥, 49 and ٤٠ for particle sizes 200, 400 and 600 µm, respectively. These values correspond to 73, 59 and 51 NTU when AVG dose of 4ml/l is used. Thus, an enhancement in the performance of AVG as a flocculent is noticed when its dose is increased from 4 to 6 ml/l of suspension. The percentage reduction in turbidity was ٨7, ٨7 and ٨9% for particle sizes 200, 400 and 600 µm, respectively; compared to 83, 84 and 86% when AVG was used in concentration 4 ml/l. Thus, a noticeable improvement in percentage reduction in turbidity is obtained due to the use of AVG in concentration 6 ml/l of suspension.

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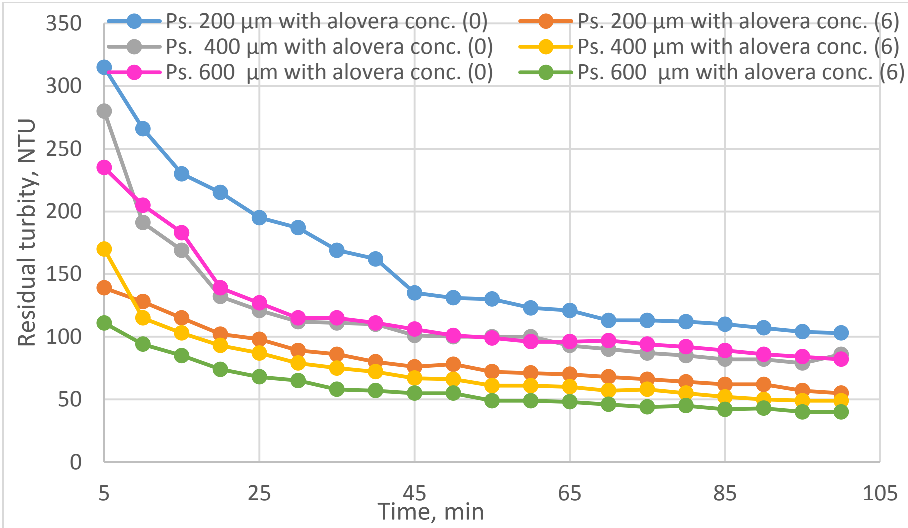

Fig. 5: Improvement of turbidity removal due to the use of AVG
(6 ml AVG/l of suspension, clay concentration = 10 g/l, PS 200, 400, 600 µm)

D. Using AV dose of 8ml/l:

The results of this test are represented in figure 6. Examination of Fig. 6 clarifies that values of residual turbidity are 85, 57 and 51for particle sizes 200, 400 and 600 µm, respectively (higher than the test of 6 ml AVG/l). This corresponds to percentage reduction in turbidity of 80, 84 and 86% for particle sizes 200, 400 and 600 µm, respectively (lower than the values of the test of 6 mlAV/l). Thus, increasing AVG dose beyond 6 ml/l is not recommended.

The results of this test are summarized as given in Table 2. Examination of Table 2 indicates that

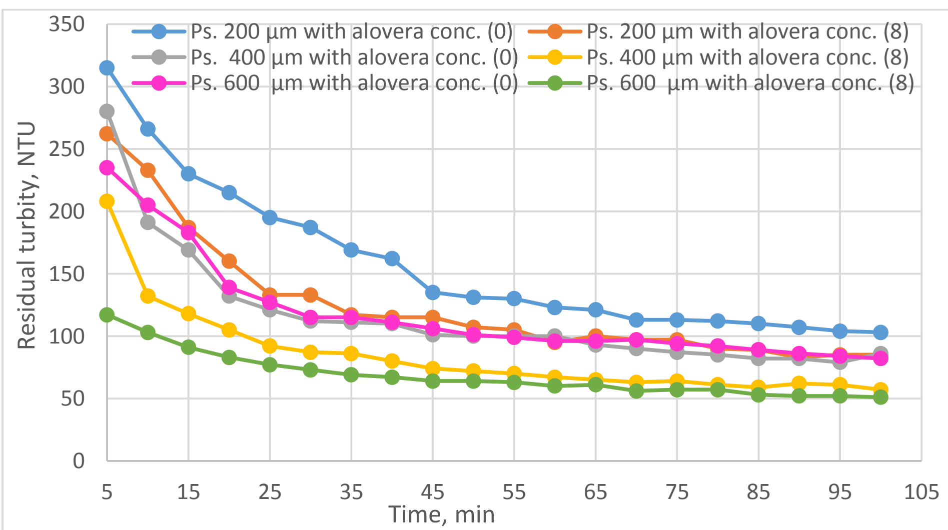

Fig. 6: Improvement on turbidity removal due to the use of AVG
(8 ml AVG/l of suspension, clay concentration = 10 g/l)

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the lower level of remaining turbidity is 40 NTU and it is satisfied by a suspension of 10 g/l made with particle sizes 600 µm. Besides, the highest percentage reduction in turbidity is 89% and it is satisfied by the same suspension.

Table 2: Improvement in turbidity removal due to the use of AVG
(2, 4, 6, 8 ml AVG/l of suspension, clay concentration = 10 g/l, particle sizes 200, 400, 600µm)

Dose of AVG., ml/l	0	2	4	6	8
PS 200 µm					
Residual Turbity, NTU	103	91	73	55	85
Reduction of turbidity, %	76	79	83	87	80
Improvement in turbidity removal due to use of AVG, %.	0	12	29	47	17
PS 400 µm					
Residual Turbidity, NTU	86	79	59	49	57
Reduction of turbidity, %	76	78	84	87	84
Improvement in turbidity removal due to use of AVG, %	0	8	31	43	34
PS 600 µm					
Residual Turbidity, NTU	82	68	51	**40**	51
Reduction of turbidity, %	77%	81%	86%	**89%**	86%
Improvement in turbidity removal due to use of AVG, %	**0%**	**17%**	**38%**	**51%**	**38%**

II. Effect of particle size of clay on turbidity removal:

A. (No Aloe Vera, AV, is used):

This test is run on clay suspensions of 10 g/l concentration, without the use of a flocculent. The particle sizes tested are: 200, 400 and 600 µm. The results of this test are given in Fig. 7. Examination of Fig. 7 shows that the sedimentation behavior of clay suspension of 600 µm particle size is better than that of clay suspension with particle sizes 200 and 400 µm. Suspension with particle size 200 µm shows lower rate of turbidity removal in the early period; up to about 40 minutes (compared with suspension with 400 and 600 µm particle size). After that both suspensions had the same attitude with almost the same rate of sedimentation. For suspensions with particle sizes 200, 400 and 600 µm, the final turbidity values (after 100 minutes) were 103, ٨٦ and 82 NTU, respectively. This represents a percentage reduction of turbidity of 76, 76 and 77%, respectively. Thus, the highest value for percentage turbidity reduction (77%) and the lowest value for absolute residual turbidity (82 NTU) was shown by clay suspension of particle size 600 µm.

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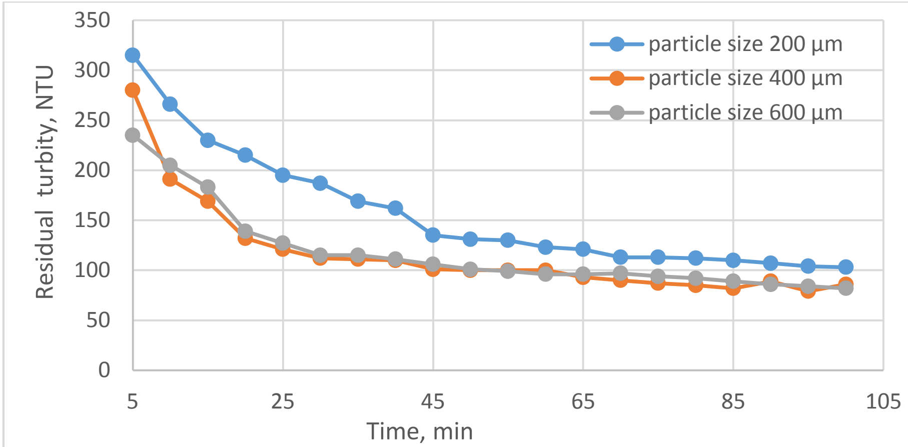

Fig. 7: Effect of particle size of clay on turbidity removal

B. *Effect of particle size on turbidity removal using AVG:*

This test is run on clay suspension with concentration 10 g/l; using three different particle sizes; 200, 400 and 600 µm in presence of AVG with concentrations 2, 4, 6 or 8 ml/l of suspension. The results of this test are shown in Figures 8 – 11.

C. *Using different particle sizes with AVG dose 2 ml/l*

Examination of Fig. 8, for the results of using AVG concentration 2 ml/l, shows that lower residual turbidity levels are observed when treating a suspension with clay particle size of 600 µm than with 400 and 200 µm particle size (eg. 68, 79 and 91 NTU for 600, 400 and 200 µm particle sizes, respectively (using 2 ml AVG/l)). It is noticed that this sequence is the same as the values of initial turbidity; where initial turbidity values of 357, 363 and 433 NTU are recorded for suspensions made with particle sizes 600, 400 and 200 µm, respectively.Thus, in this test suspensions with higher values for initial turbidity result in supernatant with higher values of remaining turbidity. However, the percentage reduction in turbidity was lower for suspensions with 400 µm PS compared to those with 600 and 200 µm PS suspensions; 78% for 400 µm and 81% and 79% for particle sizes 600 and 200 µm, respectively.

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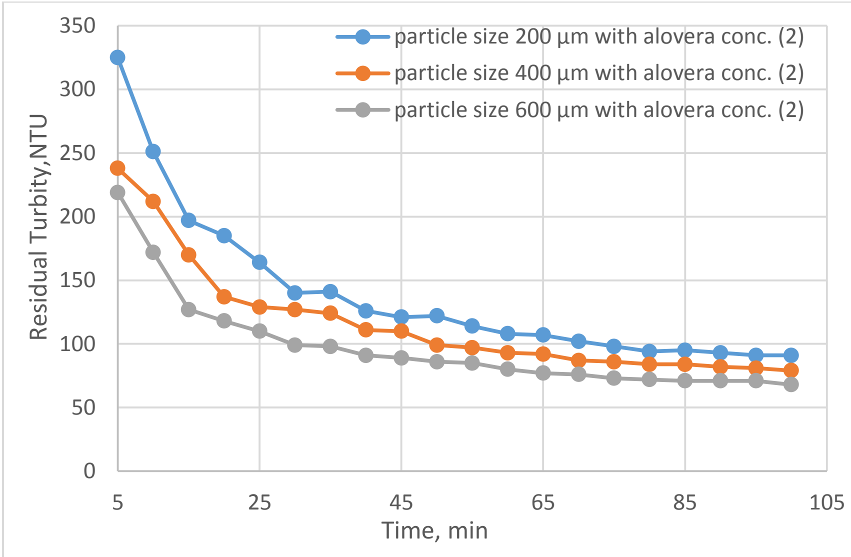

Fig. 8: Effect of particle size on turbidity removal using AVG
(AVG dose 2ml/l & particle sizes 200, 400 and 600 µm)

D. Using different particle sizes with AVG dose 4 ml/l:

The same experiments for the tests run, using AVG dose of 2 ml/l, are repeated except that the AVG dosage used is 4 ml/l. Results of this test are represented in Fig. 9 for suspensions made with clay with different particle sizes; 200, 400 and 600 µm. Figure 9 reveals that the curves showing change of turbidity with time have the same trend as in the previous section, i.e., lower values for remaining turbidity are noticed with suspension of larger particle sizes. A percentage reduction in turbidity of 86, 84 and 83% was satisfied for suspensions with particle sizes 600, 400 and 200 µm, respectively. These values are to be compared with 81, 78 and 79% when using AVG dosage of 2 ml/l as given in the previous test. Thus, an improvement resulted when increasing AVG dose from 2 to 4 ml/l.

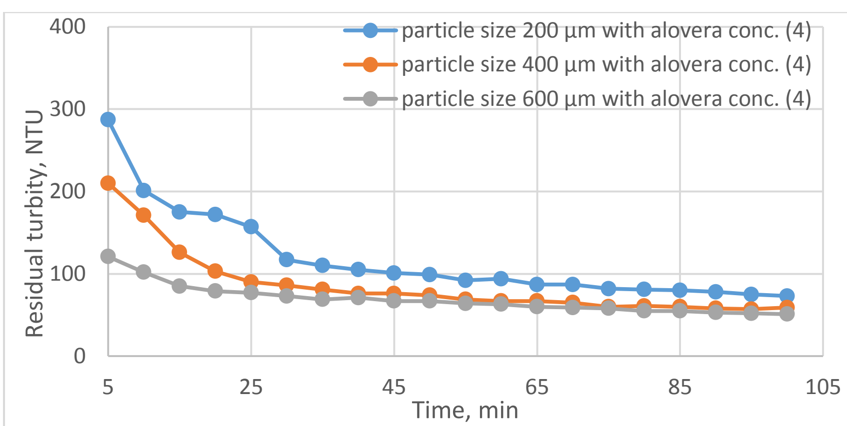

Fig. 9: Effect of particle size on turbidity removal using AVG
(AVG dose 4ml/l & particle sizes 200, 400 and 600 µm)

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E. Using different particle sizes with AVG dose 6 ml/l

The results of this test are given in figure 10. Figure 10 shows that the residual turbidity by the end of experiment was 40, 49 and 55 NTU for suspensions made with particle sizes 600, 400 and 200 µm, respectively. The percentage reduction in turbidity was 89, 87 and 87% for particle sizes 600, 400 and 200 µm, respectively. This is to be compared with 81, 78, 79% and 86, 84 and 83% for the same sequence when using AVG dosage 2 and 4 ml/l, respectively. Thus, a noticeable reduction in residual turbidity and increase of percentage reduction in turbidity is shown by the suspension made with particle size 600 µm as the AVG dosage is increased (an increase in % reduction of turbidity from 81 to 86 to 89 % as AVG concentration is increased from 2 to 4 to 6 ml/l)

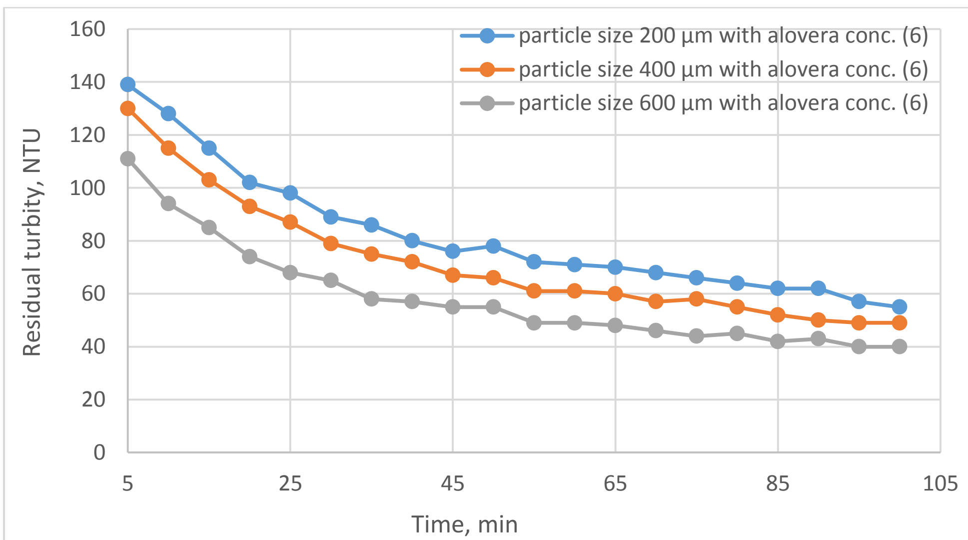

Fig. 10: Effect of particle size on turbidity removal using AVG
(AVG dose 6ml/l & particle sizes 200, 400 and 600 µm)

F. Using different particle sizes with AVG dose 8 ml/l

The results of this test are shown in figure 11. Examination of Fig. 11 declares that the remaining turbidity was 85, 57 and 51 NTU for suspensions with particle sizes 200, 400 and 600 µm, respectively. Besides, the percentage reduction in turbidity at the end of experiment was 86, 84 and 80% for suspensions made with particle sizes 600, 400 and 200 µm, respectively. These values do not seem to be better than the values obtained when using AVG of dosage 6 ml/l. Thus, no gain has resulted by increasing AVG dose and hence, no higher concentrations were examined.

Summarizing the results of the present test shows that the highest percentage reduction in turbidity is satisfied when using AVG dose of 6 ml/l. This percentage falls in the range 87 to 89% (according to particle size) which means that the most that can be satisfied with the use of AVG is 89% reduction in turbidity with a remaining turbidity value of 40 NTU.

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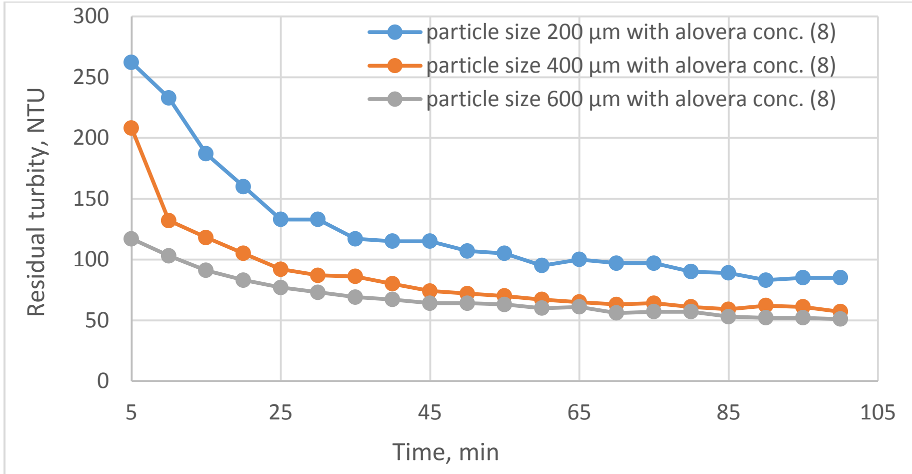

Fig. 11: Effect of particle size on turbidity removal using AVG
(AVG dose 8ml/l & particle sizes 200, 400 and 600 µm)

III. Effect of AV dosage

This test is run on clay suspensions of 10 g/l concentration, using AV dosages of 0, 2, 4, 6 and 8 ml/l of suspension. The test is repeated for clay particle sizes of 200, 400 and 600 µm and the percentage reduction in turbidity is calculated as well. The results of this test are given in Figs. ١2 – 14.

A. Using particle size 200 µm:

The results of this test are given in Fig. ١2 for suspension with particle size 200 µm using different concentrations of AVG. Examination of Fig. 12 shows that values of residual turbidity were 103, 91, 73, 55 and 85 NTU when using AVG dosage of 0, 2, 4, 6 or 8 ml/l, respectively. Thus, the minimum value of residual turbidity (55 NTU) is obtained when using AVG dose of 6 ml/l. The corresponding percentage reduction in turbidity is 76, 79, 83, 87 and 80% for AVG doses 0, 2, 4, 6 and 8 ml/l, respectively.

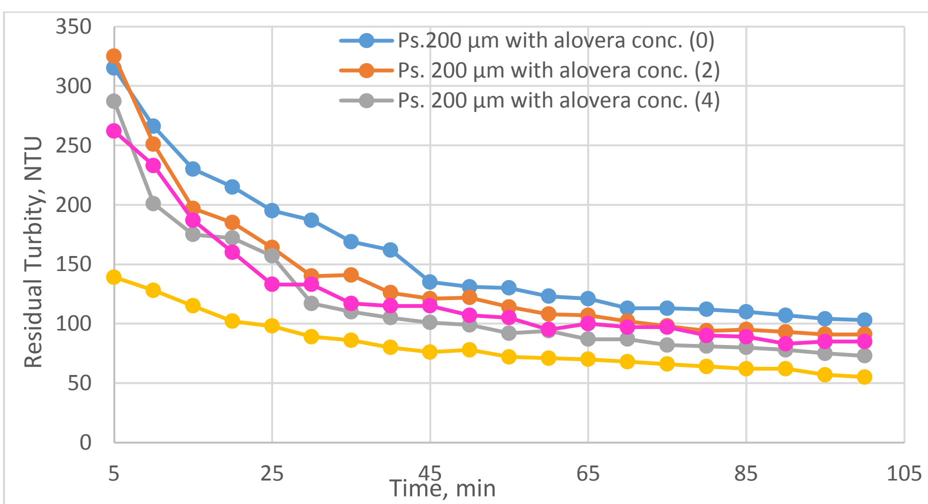

Fig. 12: Effect of AV dose on turbidity removal
(Particle size 200 µm & AVG doses 0, 2, 4, 6 and 8 ml/l of suspension)

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B. Using particle size 400 µm:

The results of the test run on suspension with PS 400 µm are presented in Fig. ۱3. Examination of Fig. ۱3 reveals that residual turbidity by the end of experiment was 86, 79, 59, 49 and 57 NTU when using AVG doses of 0, 2, 4, 6 and 8 ml/l of clay suspension. Thus, the minimum residual turbidity is accomplished when using AVG dose 6 ml/l of suspension. This also corresponds to the maximum value for percentage reduction of turbidity (percentage reduction of turbidity 76, 78, 84, 87 and 84% for AVG doses 0, 2, 4, 6 and 8 ml/l, respectively).

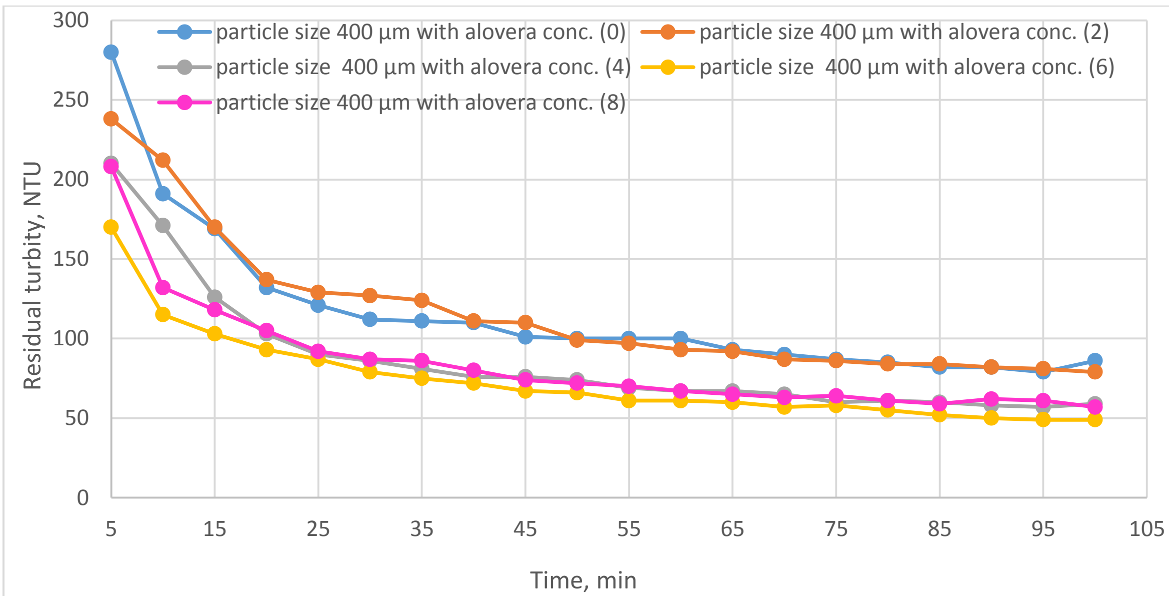

Fig. 13: Effect of AV dose on turbidity removal
(Particle size 400 µm & AVG doses 2, 4, 6 and 8 ml/l of suspension)

C. Using particle size 600 µm:

This test is run on clay suspensions made with particle size 600 µm; using different concentrations of AVG to investigate the effect of AVG dose on turbidity removal. The results are represented as in Fig. ۱4. Examination of Fig. ۱4 clarifies that the minimum level of residual turbidity (40 NTU) is obtained when using AVG dose of 6 ml/l of suspension. The highest residual turbidity (68 NTU) is achieved when using AVG dose of 2 ml/l of suspension. The highest percentage reduction in turbidity (89%) is noticed when AVG dose was 6 ml/l of suspension, and the lowest percentage reduction in turbidity was 81%; when AVG dose was 2 ml/l of suspension.

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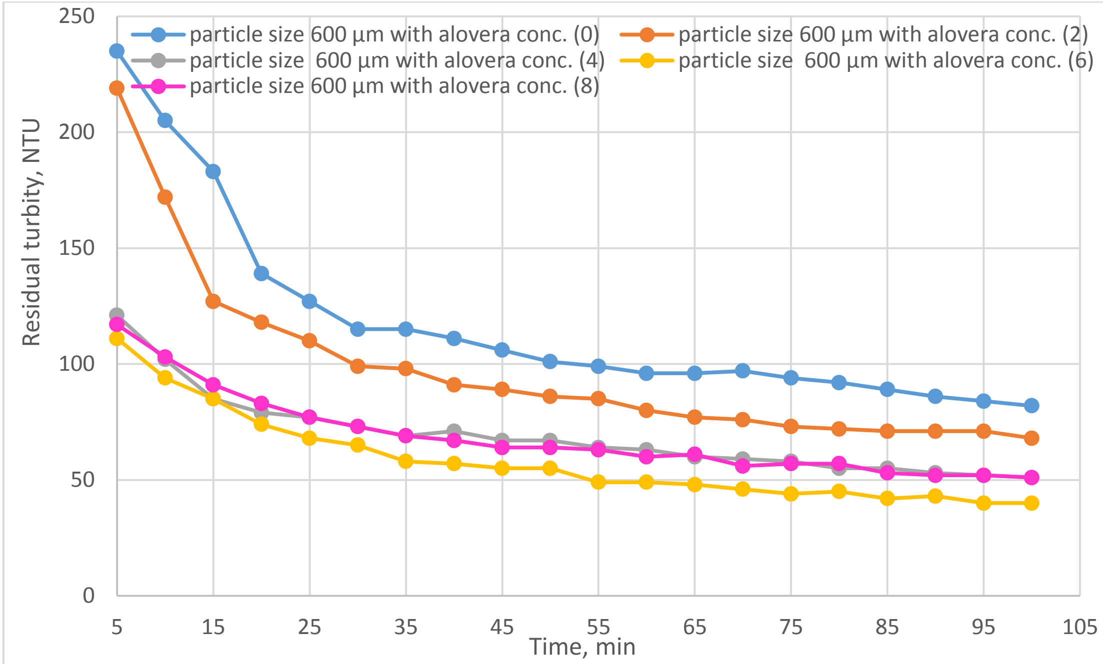

Fig. 14: Effect of AV dose on turbidity removal
(Particle size 600 µm & AVG doses 0, 2, 4, 6 and 8 ml/l of suspension)

IV. Effect of clay concentration on turbidity removal

Tests are run to investigate the effect of clay particles concentration, in the suspension under test, on turbidity removal. Clay concentrations tested are 10 and 50 g/l and the test is repeated with AV concentrations 0, 2, 4 and 6 ml /l of suspension for particle sizes 200 and 600 µm.

A. Effect of clay concentration when no AVG is used:

The results of this test are given in table 3 and Fig. 15.Examination of table 3 declares that the lowest level of residual turbidity (82 NTU) is obtained from a 10g/l suspension made with clay of particle size 600 µm. This is followed by 86 and 103 NTU for particle sizes 400 and 200 µm, respectively. Thus in absence of a flocculent the value of residual turbidity is inversely proportional with clay particle size. Fig. 15 shows the change of turbidity with time along the test time. Comparing the results of the two clay suspensions used shows that clay suspension with lower concentration (10 g/l), for the 3 particle sizes tested, resulted in a supernatant with lower values for residual turbidity, e.g., 103, 86 & 82 NTU for 10 g/l suspensions with particle sizes 200, 400 and 600 as compared to 460, 353 and 296 NTU for 50 g/l suspension with the same sequence of particle sizes, respectively.

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Table 3: Effect of clay concentration on turbidity removal
(No AVG is used)

Time, min	PS 200 µm		PS 400 µm		PS 600 µm	
	10gm/l	50gm/l	10gm/l	50gm/l	10gm/l	50gm/l
0	433	856	363	788	357	750
5	315	800	280	768	235	491
10	266	786	191	663	205	455
15	230	776	169	652	183	400
20	215	745	132	611	139	375
25	195	705	121	573	127	350
30	187	657	112	541	115	341
35	169	630	111	540	115	323
40	162	604	110	503	111	340
45	135	596	101	501	106	332
50	131	595	100	490	101	319
55	130	574	100	468	99	317
60	123	562	100	452	96	311
65	121	509	93	442	96	298
70	113	502	90	415	97	308
75	113	498	87	421	94	307
80	112	491	85	406	92	310
85	110	482	82	397	89	312
90	107	466	82	383	86	306
95	104	463	79	374	84	307
100	**103**	460	**86**	353	**82**	296

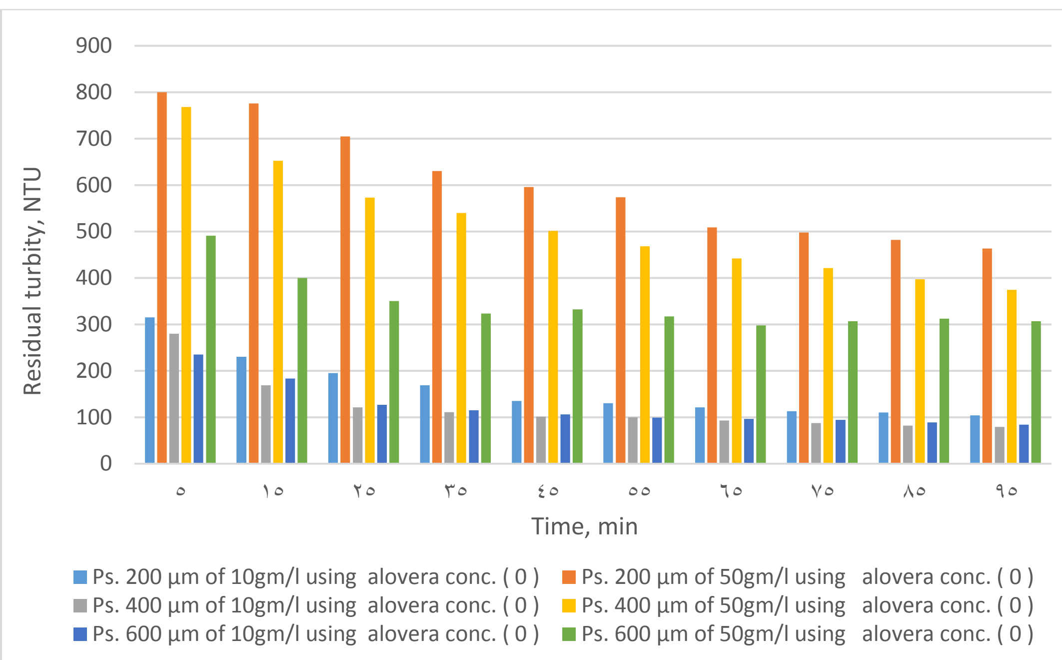

Fig. 15: Effect of clay concentration on turbidity removal
(No flocculent is added)

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B. Effect of clay concentration when AVG is used as a flocculent:

This test is run on clay suspensions with concentrations 10 and 50 g/l; using AVG dosages 2, 4 and 6 ml/l of suspension for 2 particle sizes 200 and 600 µm. The results for particle size 600 µm are presented in Table 4 and represented graphically in Fig. 16.
Examination of Table 4 reveals that the lowest level of residual turbidity (40 NTU) is accomplished by clay suspension with concentration 10 g/l, particle size 600 µm and AVG dose 6 ml/l. This is followed by 51 and 68 NTU for the same clay suspensions when using AVG dose 4 and 2 ml/l, respectively. The corresponding percentage reduction in turbidity is 89, 86 and 81% for AVG dosages of 6, 4 and 2 ml/l, respectively. Examination of the figures in table 4 clarifies that the performance of 50 g/l clay suspension of 600 µm particle size is not as high as that for clay suspension with 10g/l. This is the same trend shown in section 3.4.1 when no AVG is used. Thus increasing concentration of clay suspension acts negatively with respect to turbidity removal. The corresponding results for particle size 200 um are presented in Fig. 18 for AVG doses 0 and 2 ml/l of suspension. For 10 g/l clay suspension, the residual turbidity was 104 and 91 NTU for AVG doses 0 and 2 ml/l, respectively (compared to 463 and 267 NTU for a suspension of 50 g/l concentration. The percentage reduction in turbidity is 76 and 46% for suspensions 10 and 50 g/l, respectively (at 0 AVG dose) and it is 79 and 70% for clay suspensions 50 g/l (using AVG dose 2 ml/l). Thus, higher values for residual turbidity and lower values for percentage reduction in turbidity are obtained from suspensions with higher clay concentration. This is the same trend shown by a suspension made with 600 um particle size as given before. Thus, clay suspensions with higher concentration result in supernatant with higher values for residual turbidity for the two tested particle sizes of solids in the suspension (10 and 50 g/l).

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Table 4: Effect of clay concentration on turbidity removal
(Clay concentration 10, 50 g/l, AVGD 0, 2, 4, 6 ml/l, PS 600 µm)

Time	AVG. Conc.(0)		AVG. Conc.(2)		AVG. Conc.(4)		AVG. Conc.(6)	
	10gm/l	50gm/l	10gm/l	50gm/l	10gm/l	50gm/l	10gm/l	50gm/l
0	357	750	357	750	357	750	357	750
5	235	491	219	266	121	219	111	254
10	205	455	172	223	102	124	94	174
15	183	400	127	212	85	116	85	125
20	139	375	118	210	79	107	74	102
25	127	350	110	203	77	103	68	102
30	115	341	99	199	73	107	65	101
35	115	323	98	198	69	106	58	99
40	111	340	91	188	71	104	57	99
45	106	332	89	184	67	105	55	98
50	101	319	86	180	67	107	55	97
55	99	317	85	180	64	102	49	94
60	96	311	80	178	63	98	49	94
65	96	298	77	175	60	99	48	93
70	97	308	76	175	59	97	46	91
75	94	307	73	171	58	96	44	90
80	92	310	72	173	55	95	45	89
85	89	312	71	173	55	95	42	88
90	86	306	71	173	53	95	43	88
95	84	307	71	172	52	94	40	87
100	82	296	68	165	51	94	40	87

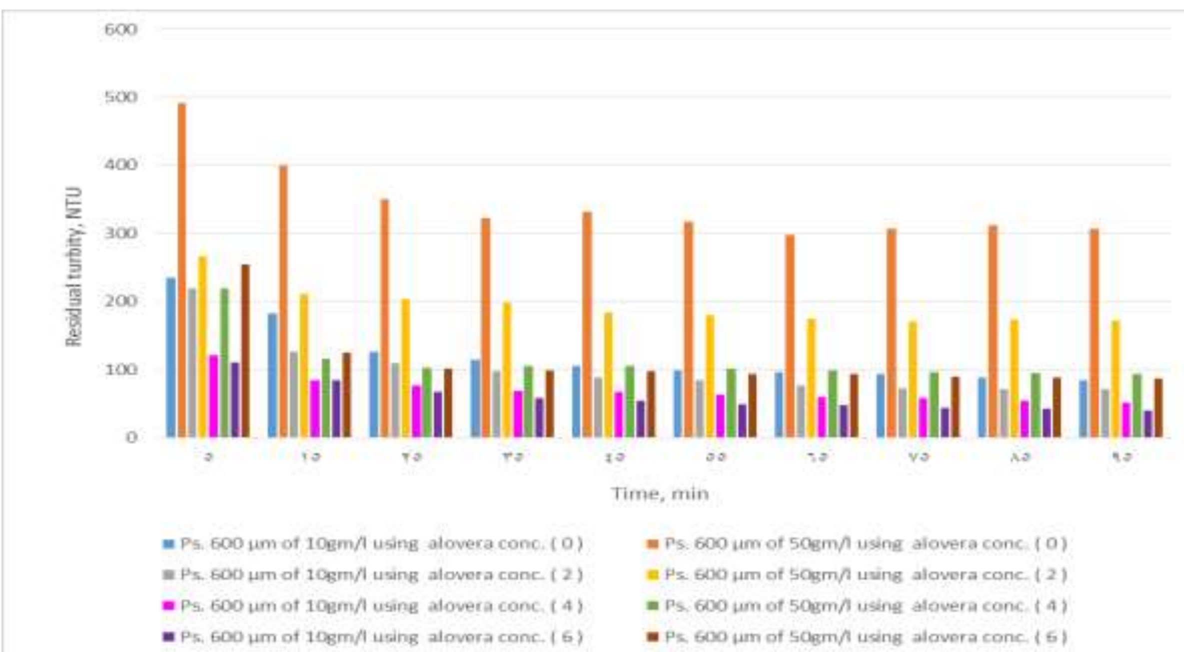

Fig. 16: Effect of clay concentration on turbidity removal
(Particle size 600 um, AVG dose 0, 2, 4, 6)

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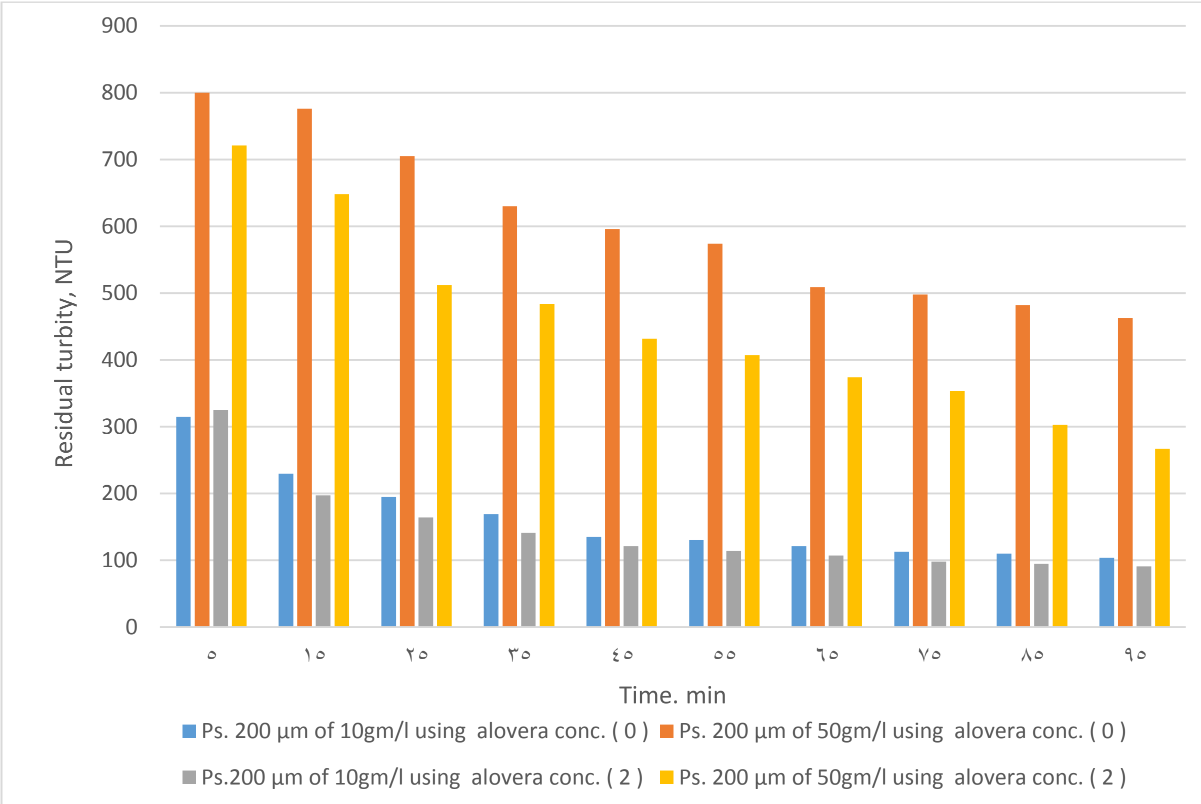

Fig. 17: Effect of clay concentration on turbidity removal
(Particle size 200 um, AVG dose 0, 2 ml/l)

V. Effect of Ratio of AV/Solid particles on turbidity removal

This test is expected to be interesting for the object of predicting the AVG dose required to satisfy the minimum residual turbidity or the maximum percentage reduction of turbidity from a suspension of known concentration.

The ratios of AVG/solid particles are calculated from the results of previous tests on clay suspensions with different concentrations; using different dosages of AVG.

The results of this test are summarized in Table 5; which displays the ratio of AVG dose/mass of clay particles (AVGD/C), initial turbidity, final turbidity and percentage reduction in turbidity at the end of experiment (after 100 minutes of settling). Examination of the figures of Table 5 clarifies that the minimum value of residual turbidity (40 NTU) and the maximum value for percentage reduction in turbidity (89%) is accomplished when using the ratio of AVGD/C of 6/10 (i.e. 60/100). That ratio satisfies the minimum level of residual turbidity for the three particle sizes tested (200, 400 and 600 µm); according to previous tests. These results are for clay suspension with 10 g clay/l of suspension.

The results for suspensions made with 50 g clay/l show that the best results (lowest residual turbidity of 87 NTU and highest percentage reduction in turbidity 88%) are obtained when using AVGD of 6 ml/l of suspension, i.e., AVGD/C = 6/50 (12/100);

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which is much less than the value (60/100) for best results when using clay suspension with concentration 10g/l. Thus, lower ratios of AVGD/C are needed in case of more concentrated clay suspensions. This may be due to the drag force between particles in suspension which enhances the settling of particles; leading to more clear supernatant.
Thus for 10 g/l clay suspension a ratio of 60/100 for AVGD/C is used and for 50 g/l clay suspension a ratio of 12/100 is used, both for 600 µm particle size.

Table 5: Effect of Ratio of AVGD/C on turbidity removal for PS 600 µm

AVGD, ml	AVGD (2ml)		AVGD (4ml)		AVGD (6ml)	
Clay Concentration, gm/l	10	50	10	50	10	50
Ratio (AVG/Soild particle)	0.2	0.04	0.40	0.08	0.60	0.12
Initial Turbidity (time = 0), NTU	357	750	357	750	357	750
Residual Turbidity (time =100), NTU	68	165	51	94	40	87
Percentage Reduction, %	81%	78%	86%	87%	89%	88%

4. CONCLUSION:

Experiments are run for turbidity reduction of clay suspensions prepared with different particle sizes and different concentrations, using different doses of AVG and the followings are concluded from the present work:

- A noticeable improvement in % reduction in turbidity is obtained due to the use of AVG as a natural flocculent.
- Experiments run on the reference sample (witout the use of AVG) indicated that increasing particle size of clay in suspension had a positive effect on turbidity removal.
- Higher values for % reduction in turbidity are obtained when increasing AVGD up to 6 ml/l of suspension.
- Lower values for residual turbidity (40 NTU) and higher values for % reduction in turbidity (89%) is obtained from a clay suspension 10 g/l, with particle size 600 um, using AVG dose 6 ml/l.
- Clay suspension with lower concentration resulted in a supernatant with lower values for residual turbidity.
- Best performance is obtained from AVG when using a ratio 6/10 for AVGD/Solid particles in suspension (for clay concentration 10 g/l). This ratio was found to be 12/100 for clay suspension with concentration 50 g/l.

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