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REDUCTION OF WATER TURBIDITY WITH BIO-FLOCCULENT: USE OF ALOE VERA GEL

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Abstract: Presence of turbidity in water reduces its quality and makes it unsuitable for different uses. Turbidity is a result of the presence of negatively-charged, fine particles in the water; causing it being polluted. It is removed by adding a coagulant/ flocculent to the polluted water to neutralize the negative charges on the suspended particles. This step is known as coagulation and is followed by a flocculation step when the uncharged particles form larger flocs capable of settling. Chemical coagulants proved to have many dangerous effects on human health and negative effects on the environment. Thus, the use of biomaterials has become an interesting alternative. The present study is set out to use Aloe Vera Gel (AVG) as an example of a natural coagulant for treating of turbid water. Experiments are conducted on a suspension of clay in water. The variables studied are: coagulant dose, clay concentration, mixing time, hydration of clay and particle size of clay. The highest percentage reduction in turbidity (97.73%) was achieved by clay suspensions of low concentration (20g/l), gel dose (2g/l) after 125 minutes. The recorded value for residual turbidity was 18.1 NTU. Also, clay suspension with 15 g/L concentration gives the lowest value of residual turbidity 21.9 NTU after 125 minutes using 2.4 g/L of gel concentration with percent reduction 97.08%. Hydration of clay particles resulted in a higher percentage reduction in turbidity (60.9% for the hydrated sample and 30.8% for the un-hydrated sample, after 5 minutes of settling). The combination of 10 minutes rapid mixing and 15 minutes of slow mixing gave the best results compared to other combinations tested. Thus, the results of the current research showed that AVG can serve as a promising bio-coagulant with high efficiency in removing turbidity from polluted water.

Keywords*:* Aloe Vera Gel (AVG), Bio-flocculent, Turbidity, Coagulation, Flocculation.

1. INTRODUCTION

Water is considered the backbone of life in all its elements, as it is urgent to pay attention to its quality in everything of its specifications. Among these aspects of water specifications is turbidity [1]. Particles that are like water in terms of density, such as bacteria and silt, remain suspended in the water and do not settle to the bottom until they are treated and transformed into large particles called flocs, and then they are removed by the sedimentation process [2].

Depending on the characteristics of the polluted water, physical, chemical and biological processes can be applied to remove these pollutants. The physical methods are: adsorption, ion exchange, membrane technologies, etc. [3]. Chemical treatment includes chemical reactions, coagulation, precipitation, advanced oxidation, neutralization, etc. Biological treatment systems include membrane bioreactors, biofilters, and activated sludge and others [4].

Although the previously mentioned processes efficiently remove pollutants from contaminated water, these processes, especially chemical processes, may have some disadvantages such as the use of chemicals in coagulation and flocculation technology [5].

Sustainable technologies based on the use of biomaterials have become a promising solution for removing pollutants.

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For example, natural biomaterials such as Aloe Vera, Moringa Olefira, etc., have been used to remove contaminants such as dyes, turbidity, metals, etc. in many processes (adsorption, coagulation, flocculation, degradation, etc.) [6].

Aloe Vera is biodegradable, safe, and abundant in many regions over the world, and it has been accepted for water treatment, and various polluted water quality parameters (TSS, TDS, turbidity, COD, BOD, heavy metals concentration, color, etc.) were evaluated to detect their efficiencies in removing pollutants through the use of coagulation and flocculation techniques.

Coagulation-flocculation is a common process used to remove various contaminants such as suspended solids, organic and inorganic materials.

In this process, a coagulating material is added to the contaminated water to destabilize colloidal materials allowing the suspended particles to agglomerate to form larger settleable flocs [7]. However, one of the disadvantages of this process is that traces of the coagulant remain in the treated water, which negatively affects human health and may cause neurotoxicity if a chemical reagent is used [8]. In addition, secondary reactions of these chemicals with other compounds present in the polluted water may produce new products with unknown health risks and many other diseases such as Alzheimer's disease, which has recently been reported to be linked to the use of alum [9, 10]. So, it is urgent to consider alternative flocculants/coagulants which should be available in low cost, biodegradable and eco-friendly without health risks.

Scientists have used different parts (seeds, leaves, cuttings, roots, fruits, etc.) of plants as potential sources of flocculants-coagulants [6]. Interestingly, Aloe Vera Gel (AVG) has been reported to be a promising natural material to replace chemicals in the coagulation-flocculation treatment process [11, 12]. Figure (1) shows the chemical structure of AVG and table (1) shows its chemical composition. It is reported in previous researches that AVG was implemented in many stages, including mainly the material preparation and the optimization of the operating parameters (gel concentration, pH, mixing speed, hydration, concentration of pollutants, etc.). Essentially, dosage is an important parameter to be studied because the unsuitable concentration of gel could result in low performance of the coagulation-flocculation process [13, 14].

A study on Aloe Vera plant showed that it was effective in removing about 85.15% of turbidity from water [15-16]. It is also reported that when AVG is used to treat river water it reduced color by 15%, turbidity by 72% and suspended particles by 91% under selected influencing parameters [17]

In the present work, AVG is used in its raw form and clay is used in the tests as an example of the suspended pollutants in water. The turbidity value is tracked and is used as an indicator of the treatment efficiency. Various factors were studied, such as the concentration of pollutant (clay), the concentration of the coagulant (AVG), the speed of mixing, effect of clay hydration and particle size of clay.

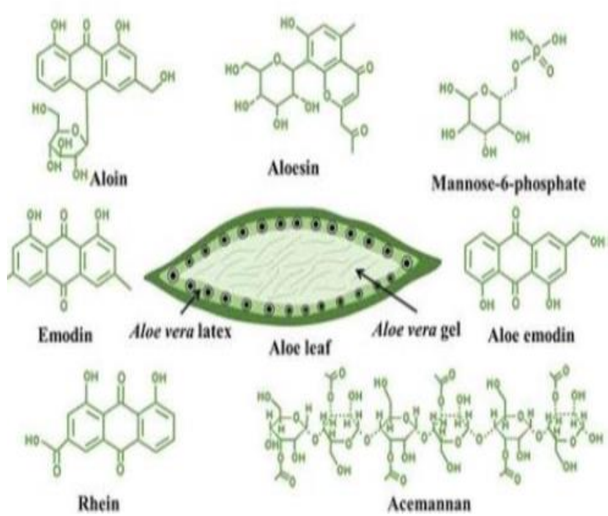

Figure 1: Chemical structure of AVG [13]

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Table 1: Chemical composition of AVG [14]

Compounds	Unit	Content
pH	%	4.0-4.5
Water	%	99.51
Fat	%	0.067
Carbohydrates	%	0.043
Protein	IU	0.038
Vitamin A	Mg	4.594
Vitamin C	Ppm	3.4
Calcium	Ppm	458
Phosphorus	Ppm	20.10
Fe	Ppm	1.18
Magnesium	Ppm	60.8
Manganese	Ppm	1.04
Potassium	Ppm	797.0
Sodium	ppm	84.4
Total dissolved solids (TDS)	%	0.490

2. MATERIALS AND METHOD

A. Materials:

i. Clay:

The polluted water sample are synthetically prepared in the laboratory using clay at the sides of River Nile, Egypt.

River Nile clay has brownish black color when wet but convert to brownish grey when dry and its moisture content is 7.55%. It mainly consists of hydrated aluminum silicates accompanied by comparatively large proportion of organic and inorganic matters, iron compounds and sand. Nile clay contains about 25% free iron oxides, 23% Ferrous ions and 50% ferric substitutional ions in octahedral and tetrahedral sites of the clay minerals [18, 19]. The batch of clay was subjected to screen analysis and the required particle size was used in the experimental work.

ii. Aloe Vera Gel

Aloe Vera Gel (AVG) is extracted from Aloe Vera plant and was used as a natural coagulant (Figure 2 (a, b)). The main functional groups are Phosphate, Ketone and Hydroxyl.

(a) (b)

Fig. 2: Aloe Vera plant (a) and Aloe Vera gel (b)

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iii. Method:

Experimental work was conducted at a laboratory scale by blending Aloe vera gel and using it, with specified ratios, to treat clay suspension at different operating parameters such as clay concentration (5, 10, 15 and 20 g/l), gel dosage 0.4, 0.8, 1.2, 1.6, 2.0 and 2.4 g/l), time of rapid and slow mixing (5, 10, 15 and 20 min) and hydration. The turbidity of mixture was evaluated using Turbidity Meter (Model no: TU-2016).
Synthetically prepared clay suspension is prepared in different concentrations; using specified weights of clay in water.
The flocculent is added to clay suspension in a predetermined concentration, rapid and slow mixing are affected and the sample is allowed to settle. During the settling process, samples were taken from turbid water and its turbidity was measured periodically till constant value of residual turbidity when the settling process ends.

3. RESULTS AND DISCUSSION

A. Effect of hydration of clay:

To study this effect two experiments were run under the same operating conditions except that one sample of clay suspension is freshly prepared while the other was left for one day to affect hydration of the clay particles before it is being tested. The experimental values of this test are represented graphically in figure (3).
Examination of the results revealed that a slight improvement in turbidity removal is observed when the clay particles are left to hydrate before being tested. This improvement was more clear in the early period of the clarification process. In addition, longer time was needed to reach a constant value for residual turbidity for the un-hydrated sample (100 minutes for the un-hydrated sample compared to 75 minutes for the hydrated sample). Thus, hydration of clay particles had a limited effect on reducing the values of residual turbidity and of settling time.

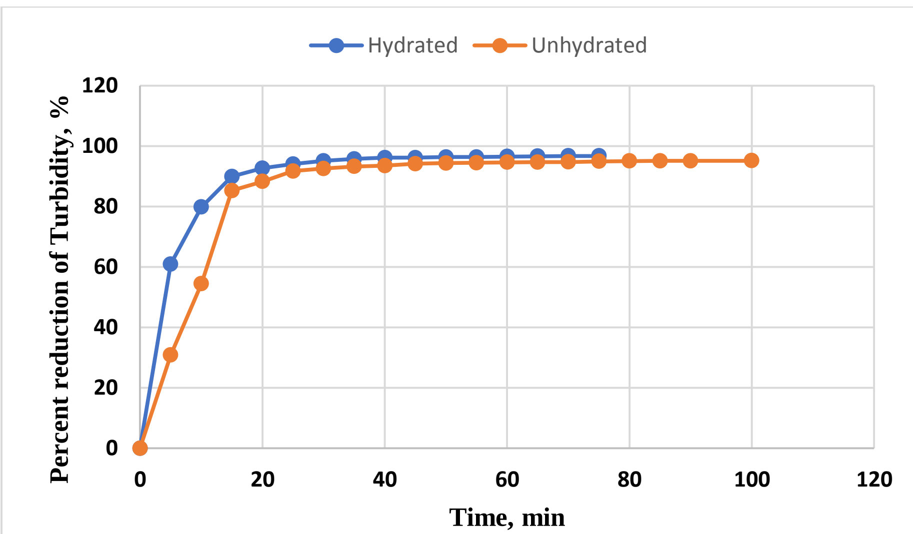

Figure 3: Effect of clay hydration on percentage reduction of turbidity

B. Effect of mixing time:

The length of the slow and rapid mixing stages is changed to determine the optimum value for each. The experimental values of this test are given in table (2) and are plotted in figure (4). Five combinations of rapid and slow mixing speeds are tested e.g., (5, 15), (10, 15), (15, 15); (10, 10) and (10, 20) minutes, respectively. A maximum percentage reduction in turbidity of 96.73% is obtained when stirring for 10 minutes at high speed followed by 15 minutes at low speed.
The enhancing effect of mixing time is most evident in the early stage of coagulation. Therefore, mixing time plays an important role in reducing turbidity, thus sedimentation time is reduced while having high performance.

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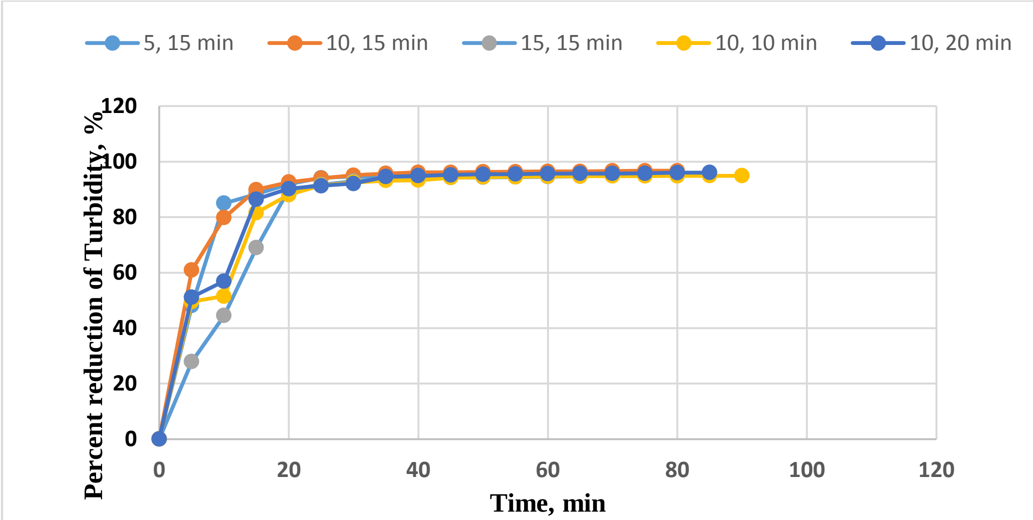

Figure 4: Change of percentage reduction in turbidity with mixing time

Table 2: Change of percentage reduction in turbidity with mixing time

Time	Percentage reduction in turbidity, %				
	5, 15 min	10, 15 min	15, 15 min	10, 10 min	10, 20 min
0	0	0	0	0	0
5	48.1	60.9	27.92	49.54	51.17
10	85.04	79.81	44.5	51.53	56.93
15	88.28	89.9	69	81.62	86.48
20	91.9	92.64	89.9	88.1	90.27
25	94.17	94.01	91.72	91.5	91.31
30	94.62	95.09	92.95	92.5	92.1
35	94.92	95.72	94.05	93.2	94.59
40	95.27	96.12	94.31	93.33	94.96
45	95.27	96.16	94.31	94.27	95.2
50	95.28	96.34	94.37	94.48	95.48
55	95.96	96.37	94.46	94.52	95.53
60	95.73	96.52	94.59	94.68	95.67
65	95.87	96.52	94.79	94.77	95.72
70	95.93	96.64	94.95	94.81	95.76
75	96.03	96.73	95	94.84	95.8
80	96.09	96.73	95.03	94.86	96.01
85				94.91	96.09
90				94.93	

C. Effect of gel concentration:

i. (Using 5 g/L clay suspension):

The experimental values for this test are given in table (3) and are plotted as shown in figure (5). The maximum percentage reduction in turbidity (96.73%) was achieved when using 0.8 g/L gel with 5 g/L clay suspension. However, when using a gel concentration of 1.6 g/L a reduction of 93% was given, after the same period of 75 minutes, which is less than the previous percentage. These values are compared to the 84.32% turbidity reduction of the reference sample (no gel is added) after the same period of 75 minutes. Thus, gel concentration of 1.6 g/L although not performing well for turbidity removal, resulted in enhanced turbidity removal by about 9% compared to the reference sample.

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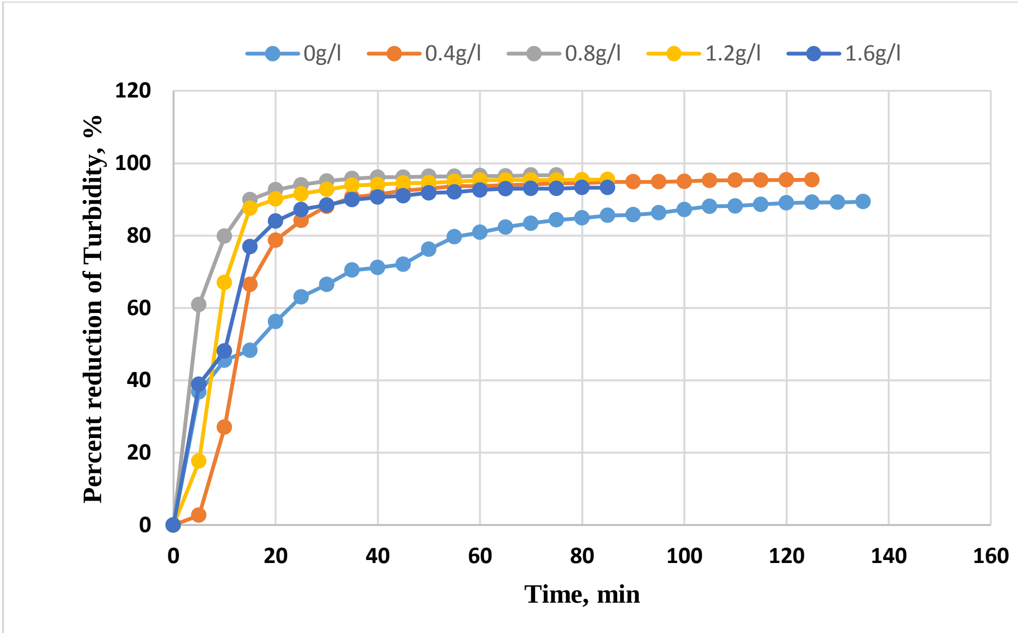

Figure 5: Effect of gel concentration on 5 g/L clay suspension
(Hydrated sample, Particle size = 125- 200 µm, Clay concentration = 5g/L, Time of rapid mixing = 10 min, Time of slow mixing =15 min)

Table 3: Effect of gel concentration on % reduction of turbidity
(Hydrated sample, Particle size = 125- 200 µm, Clay concentration = 5g/L, Time of rapid mixing = 10 min, Time of slow mixing =15 min)

Time	0.0 g/l	0.4 g/l	0.8 g/l	1.2 g/l	1.6 g/l
0	0	0	0	0	0
5	36.75	2.7	60.9	17.65	38.91
10	45.58	27.02	79.81	67.02	48.1
15	48.28	66.48	89.9	87.56	76.93
20	56.21	78.73	92.64	90.09	83.96
25	63.06	84.14	94.01	91.53	87.2
30	66.48	88.1	95.09	92.72	88.46
35	70.45	90.63	95.72	93.89	89.9
40	71.17	91.36	96.12	94.1	90.63
45	72.07	92.46	96.16	94.52	90.99
50	76.21	92.95	96.34	94.59	91.8
55	79.63	93.65	96.37	94.93	92.04
60	80.9	93.67	96.52	95.31	92.59
65	82.34	93.92	96.46	95.33	92.97
70	83.42	94.1	96.73	95.34	93.009
75	84.32	94.45	96.73	95.35	93.009
80	84.86	94.46		95.45	93.26
85	85.58	94.84		95.49	93.26

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ii. (Using 10 g/L clay suspension):

The experimental values of this test are plotted as given in figure (6). Results indicated that the highest percentage reduction in turbidity of 98.36% is satisfied when using 1.6 g/l gel concentration. The lowest performance was given when using 2g/l gel concentration. In previous tests, when using a 5 g/L clay suspension, the best results were obtained when using gel concentration of 0.8 g/L. Thus, higher gel concentration is required for higher clay concentrations.

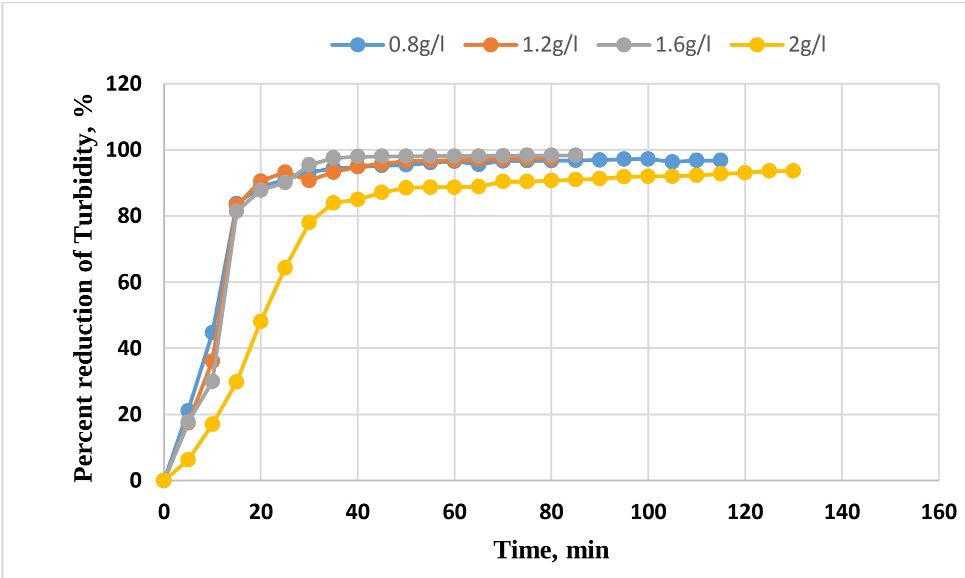

Figure 6: Change of percent reduction of turbidity with gel dose (10g/L clay suspension)

iii. Using 15 g/L clay suspension:

The experimental values of this test are plotted as given in figure (7). The highest percentage reduction in turbidity of 97.8% is satisfied when using 2.4 g/l gel concentration. The lowest performance is given when using 1.6 g/l gel concentration.

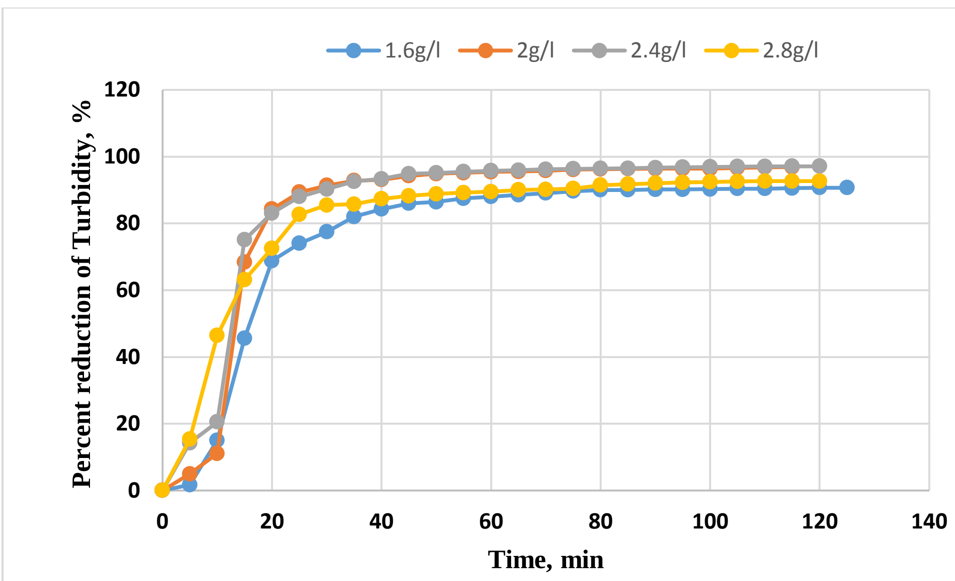

Figure 7: Change of percent reduction of turbidity with gel dose (15g/L clay suspension)

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iv. Using 20 g/L clay suspension:

The experimental values of this test are plotted as given in figure (8). The highest percentage reduction in turbidity of 97.73% is satisfied when using 2 g/l gel concentration. The lowest performance is given when using 1.2 g/l gel concentration.

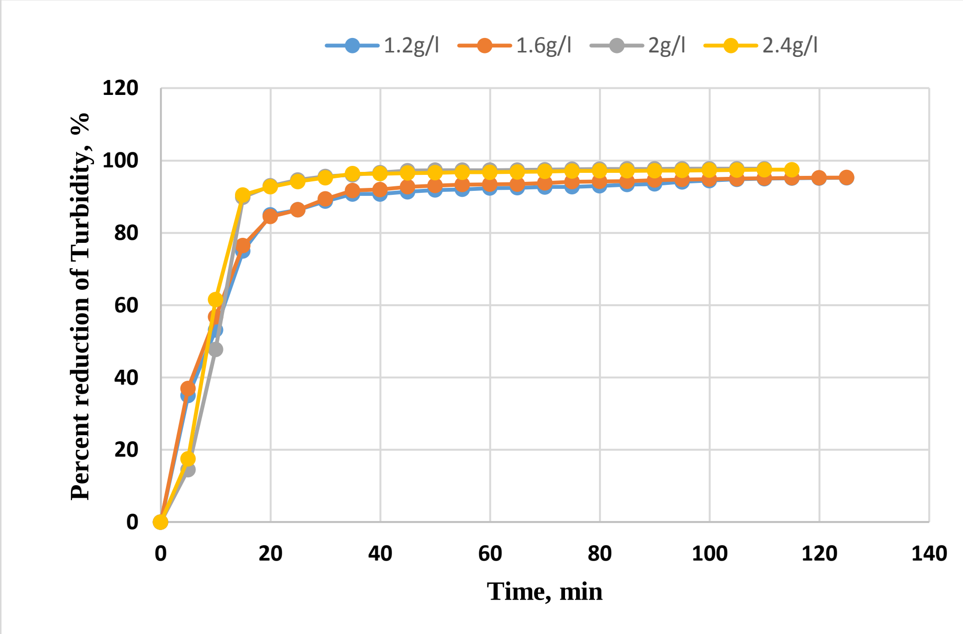

Figure 8: Change of percent reduction of turbidity with gel dose (20g/L clay suspension)

v. Effect of particle size:

The experimental values of this test are plotted as shown in figure (9). Examination of results shows that particle size affects the value of residual turbidity. The reduction in residual turbidity is higher for suspension with larger particles in the early period of settling. However, this suspension (with larger particles) takes longer time to reach an almost stable value for residual turbidity. Thus, suspension with small particles needed 65 minutes to reach the minimum value of residual turbidity of 17.9 NTU. This is to be compared with 10.7 NTU for suspension with big particles after 125 minutes.

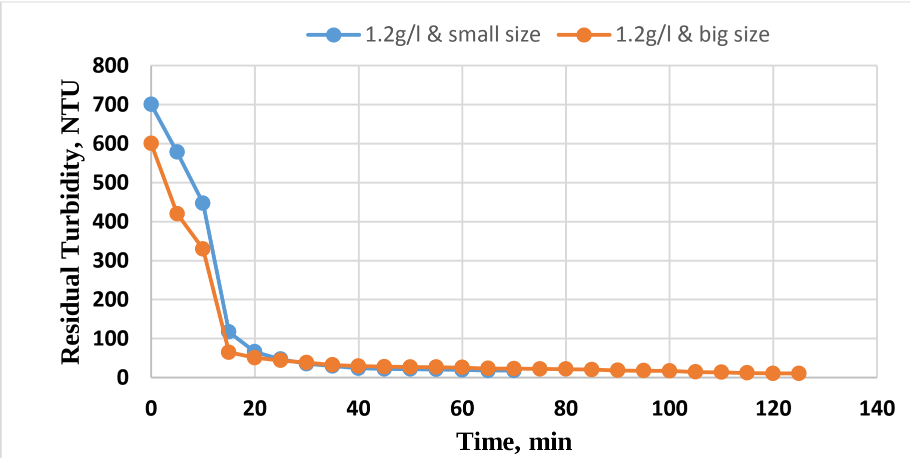

Figure 9: Effect of particle size on turbidity reduction
(Hydrated sample, Clay concentration = 10g/L, Gel concentration =1.2g/L, Time of rapid mixing = 10 min, Time of slow mixing =15 min)

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vi. Change of initial turbidity with clay concentration:

The experimental values of this test are given in table (4) and are represented in figure (10). Examination of these results indicates that the initial turbidity of clay suspension increases linearly with its concentration (solid content). Thus, a calibration curve could be established for a specified sample of clay such that the concentration of its suspension could be determined by measuring its turbidity.

Table 4: Change of initial turbidity with clay concentration

Clay concentration (g/l)	Initial Turbidity (NTU)
5	555
10	700
15	750
20	800

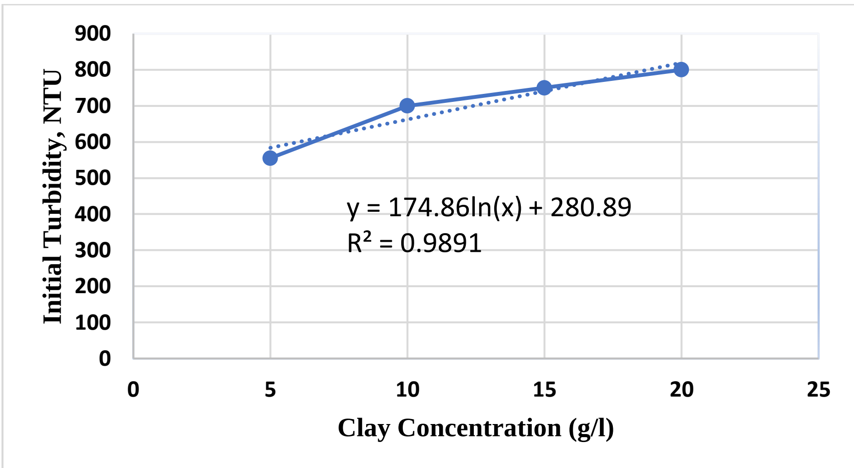

Figure 10: Change of initial turbidity with clay concentration

vii. Effect of clay concentration on the required gel dose:

The experimental values of this test which are given in table (5) and represented in figure (11) indicated that a more concentrated clay suspension needs higher dose of AVG to affect its settling. Thus a 5 g/l clay suspension required 0.8 g gel/l to affect a maximum reduction in turbidity of 96.74% while a 15 g /l clay suspension required a gel dose of 2.4 g/l to cause a percentage reduction in turbidity of 97.08%. This result helps in predetermining the optimum dose of gel required to affect settling of a clay suspension with a specified concentration.

Table 5: Effect of clay concentration on the required gel dose

Clay concentration (g/l)	Optimum gel dose (g/l)
5	0.8
10	1.6
15	2.4
20	2

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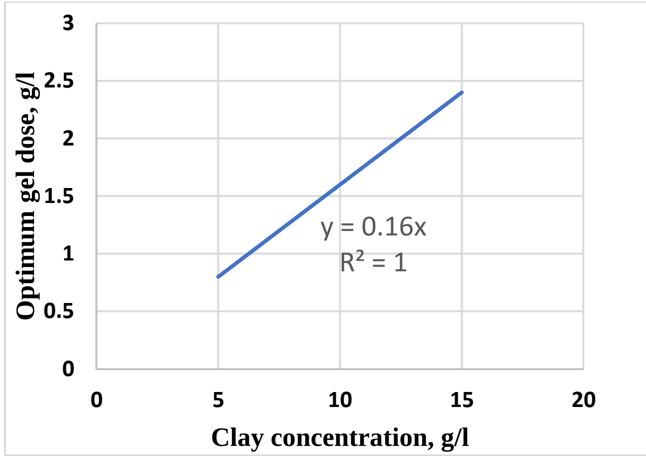

Figure 11: Effect of clay concentration on the required gel dose

4. CONCLUSION

Through this research, the following conclusions are obtained:

- A significant improvement in the percentage of turbidity reduction is obtained when using Aloe Vera gel as a natural flocculent.
- Clay suspension with low concentration (5 g/L) gives the lowest value of residual turbidity (18.1 NTU) after 75 minutes using 0.8g/L of gel concentration. This corresponds to 96.7% reduction in turbidity; compared with 84.32% reduction in turbidity for the reference sample.
- Hydration of clay particles resulted in a higher percentage reduction in turbidity (60.9% for the hydrated sample and 30.8% for the un-hydrated sample, after 5 minutes of settling).
- The combination of 10 minutes rapid mixing and 15 minutes of slow mixing gave the best results compared to other combinations tested (5/10, 5/15, 10/10 and 10/20).
- Clay concentration of 10 g/L gives the lowest value of residual turbidity (11.51 NTU) after 85 minutes using 1.6 g/L of AVG; resulting in turbidity reduction of 98.35%.
- Clay suspension with 15 g/L concentration gives the lowest value of residual turbidity (21.9 NTU) after 125 minutes using 2.4 g/L of AVG; leading to 97.08% reduction in turbidity.
- Clay suspension with 20 g/L concentration gives the lowest value of residual turbidity (18.1 NTU) after 125 minutes; using 2 g/L of AVG with percent reduction of 97.73 %.
- As the concentration of clay in suspension is higher, higher doses of AVG are required.
- Studying the effect of particle size showed that larger particles settle faster in the early stage of settling but it take longer time to reach unchanging values; compared to smaller particles. The final residual turbidity was lower for suspensions with larger particles.

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