



Influence of using Porcelanite as Coagulant Aids on the Floc Filtration and
Determination of the Optimum Percentage Removal turbidity

By

Amal Hamza Khalil

(Assistant Lecture)

Ruqaya khadum Mohammed

(Assistant Lecture)

Israa Sadi Abdul – Amir

(Assistant Lecture)

Influence of using Porcelanite as coagulant aids on the Floc Filtration and determination optimum percentage removal turbidity

Abstract

The implication of energy input (G value) and energy input time (T_f) as well as the GT_f value (Camp number) resulting from the orthokinetic particle aggregation as part of the adsorption coagulation with charge neutralization were investigated in the laboratory using a direct filtration tests carried out at a constant particle concentration. The water was flocculated with alum alone=44 mg/l, pH=7.6 (case NO.1) ; alum =30 mg/l and porcelanite dose =12 mg/l (as coagulant aids);pH=7.51; Temperature =31.4C° (case No.2) and alum =23 mg/l and porcelanite dose =18 mg/l (as coagulant aids); pH=7.6; Temperature =34.4C° (case No.3). In this research optimum removal of turbidity by means of this a direct filtration apparatus was achieved in the case No.2 at G values of around 25 sec^{-1} , $T_f =10$ min the percentage removal of turbidity obtained was about (90 %) , whereas in case No.1 , the optimum percentage obtained was about (84 %) at $G = 40 sec^{-1}$, $T_f = 20$ min and case No.3 , the optimum percentage obtained was about (86 %) at $G= 30 sec^{-1}$, $T_f = 20$ min.

الخلاصة

أن المعنى المتضمن لمعامل انحدار السرعة ($G sec^{-1}$ Energy input) وزمن المزج (T_f Energy input time) بالإضافة إلى $G T_f$ الذي هو رقم كامب (Camp Number) والنتائج من ميكانيكية تخثير العوالق بطريقة الامتصاص وتعادل الشحنات (adsorption coagulation with charge neutralization) والتي تم بحثها مختبريا باستخدام جهاز الترشيح المباشر (direct filtration tests) وعند مستوى كدرة (150 NTU) . يتم إضافة الشب مرة بمفرده بجرعة (٤٤ ملغم/لتر) وعند pH=7.6 (حالة الدراسة الأولى) ، والشب بجرعة (٣٠ ملغم/لتر) وجرعة بورسلنايت (١٢ ملغم/لتر) (كمادة مساعدة للتخثير) وعند pH=7.51 ودرجة حرارة (٣١.٤) (حالة الدراسة الثانية)، وجرعة الشب (٢٣ ملغم/لتر) وجرعة بورسلنايت (١٨ ملغم/لتر) وعند pH=7.5 ودرجة (٤٣.٤) (حالة الدراسة الثالثة) . في هذا البحث تحققت افضل ازالة للكدره بواسطة جهاز الترشيح المباشر عند الحالة الثانية عندما تكون قيمة معامل انحدار السرعة ($25 sec^{-1}$) وزمن المزج (10 min) حيث كانت الإزالة المتحققة هي (٩٠%) ، وأفضل إزالة متحققة في الحالة الأولى هي (٨٤%) عندما تكون قيمة معامل انحدار السرعة هي ($40 sec^{-1}$) وزمن المزج (20 min) ، وفي الحالة الثالثة كانت أفضل إزالة متحققة عند معامل الانحدار للسرعة ($30 sec^{-1}$) وزمن مزج (20min) حيث كانت بحدود (٨٦%).

Introduction

Colloidal particles that cause color and turbidity are difficult to separate from water because the particles will not settle by gravity and are so small that pass through the pores of most of the common filtration media. To be removed individual colloids must aggregate and grow in size. Aggregation is implicated not only by the small size of the particles but more importantly by the fact that physical and electrical forces keep the particles separated from each system and prevent the collision, these would be necessary for aggregation to occur. The process of destroying the stabilizing forces and causing aggregation of clay colloids is referred as “Chemical coagulation”.

The agglomeration of destabilized micro flocs, produced by transport and collisions, depends on the size of particles and on the frequency of the successful collisions of particles. Thus, it also depends on the energy input at this stage. For micro flocs of $> 1 \mu\text{m}$ agglomeration takes (16.8- 546 sec) and according determines the velocity of the entire flocculation process (Bernhardat and Schell, 1982).

Toleman (1942) showed that the best result were obtained with flash mixing of chemicals followed by a slower after mix for building up floc. The slower mix must provide a maximum number of collisions, but the velocity must not be high enough to break up the formed floc.

Hudson's compilation (1965) showed that the floc volume concentration varies directly with the alum, which is to be expected; and inversely with the velocity gradient used. This latter finding (if verified) is very important in that it indicates that for a particular coagulant dose the floc volume concentration may be varied over a wide range by the change in velocity gradient.

Owing to the fact that both the energy dissipation in the agglomeration basins (calculated as G values) and the retention time of water T_f , the GT_f values depend on the amount of water to be treated. However, there is an optimal GT_f range, where even with increasing throughput and thus with increasing filter velocities, the filter running time is sufficient and the quality of the filtration remains satisfactory (Harris et al., 1966).

Omelia (1969) stated there are two major differences between floc formed from hydrolyzed species of metal ions and synthetic organic polymers. Synthetic polymers usually form stronger floc. Which can undergo higher velocity gradients, however, their rate of formation is generally slower than that of inorganic coagulants, because extended segments of broken polymer bridges have a tendency to fold back and cover several reactions sites on the same particle rather than remain extended for floc reformation. As a result, higher velocity gradient in flocculator may be possible with a synthetic polymer; nevertheless, stirring for an excessive time period must be avoided.

Hudson (1973) reported that the result of jar test series for which the duration of flocculation was varied. In this series rapid mixing was at 165 rpm. No stators were used. The data show that results were impaired when time of agitation exceeded (40 min).

Bernhardat and Schell (1982) showed that the flocs formed are retained in the filter with varying efficiency, depending on the granulation size of filter material, as the energy input (G value) increases. A filter construction like that in the pilot plant and in the phosphorus elimination plant (PEP) at first produces flocs that are better retained in the filter when the G value is increased and when GT value is approximately 10000-20000. If the G value and the GT value are increased further, the floc are more and more difficult to

retain in the filter and finally break through the filter completely, as shown in figure (1)



Figure (1) Influence of increasing energy input in flocculation basins on floc filterability. (After Bernhardt and Schell, 1982)

The test did not follow the principle of commonly employed jar test apparatus (Tekippe and Ham, 1970,1971; Hudson, 1973; Bartby, 1981) which describes the characteristics of the generated flocs by their sedimentation behavior. Bratby (1981) discusses the applicability of a jar test for a solid liquid separation by sedimentation or filtration. In bench-scale tests, he discovered that addition of cationic polyelectrolytes used as primary coagulant to optimize flocculation conditions led to identical results for both sedimentation and filtration. Neither did Habibian and O'melia (1975), who used the same primary coagulant (polyelectrolytes) make out any discrepancy between the results of the jar test and those obtained from a large filtration pilot plant.

Brink et al. (1988) found out that with regard to low turbidity raw water (≤ 2 NTU), the conventional sedimentation jar test can not be used to determine the optimum flocculent dose for a direct filtration, since under these conditions there is no formation of clearly visible flocs to the extent required. The authors developed a jar test with separately arranged tests filters consisting of a single or double layer design (50.8 mm in diameter, filter bed depth 500 mm, sand layer 500 or 250 mm with a grain size of $d_{10}=0.5$ mm, anthracite layer 500 or 250 mm with a grain size $d_{10} =0.93$ mm). Over period of 3 min and at a rotation speed of 100 (rpm), the water was first flocculated in a square (2.8 L) tank and subsequently filtered. However, it is very likely that by pouring the floc suspension into filter aggregates will be modified. With aluminum sulfate as flocculent, Brink et al. (1988) obtained results in a conventional jar test, which deviated notably from those of a filtration jar test. By contrast, the results from the filtration tests were in good agreement with the data of a pilot plant, which was run in parallel.

Using a test apparatus with two successive stirred reactors and a directly connected sedimentation or filtration step, Kulte (1990) was able to show that it takes a G value of ($30-60 \text{ sec}^{-1}$) to produce filterable flocs, whereas a formation of settable flocs required much higher G values $60-80\text{sec}^{-1}$. The test further demonstrated that the sedimentation behavior of the flocs does not give an insight into their filtration behavior.

Speedy et al. (1969) concluded that alum as coagulant seemed moderately effective for algal removal, but using lime as coagulant or as coagulant aid seemed much more efficient, entrapped the cell up on settling.

Bratby (1981) used standard jar test for optimizing coagulant and flocculent aids for settling. Optimizing was based on settling water quality. If primary coagulant is applied alone, the researchers suggested that the optimizing should be based on an economical analysis relating chemical cost and sedimentation basin cost, and if the primary coagulant used with flocculent aids, optimizing should be based on minimizing the clogging of down stream filter surface.

Object of the Study

- 1- Studying the different influence of two factors experimentally such as: mixing (slow and rapid) intensity and time of mixing , in order to determine the optimal percentage of removal turbidity.
- 2- Studying the influence of using wetting agents (porcelanite) with alum on the percentage of removal turbidity, mixing intensity and time of mixing.
- 3- Determination of G , T_f and $G T_f$ (Camp Number) that gives optimum percentage removal of turbidity with and without adding weighting agents (porcelanite) for initial turbidity of 150 (NTU) .

Experimental

Test Procedure: -

The tests discussed in this paper were carried out with the floc filtration test apparatus as shown in figure (2). Its technical data are summarized in table (1).

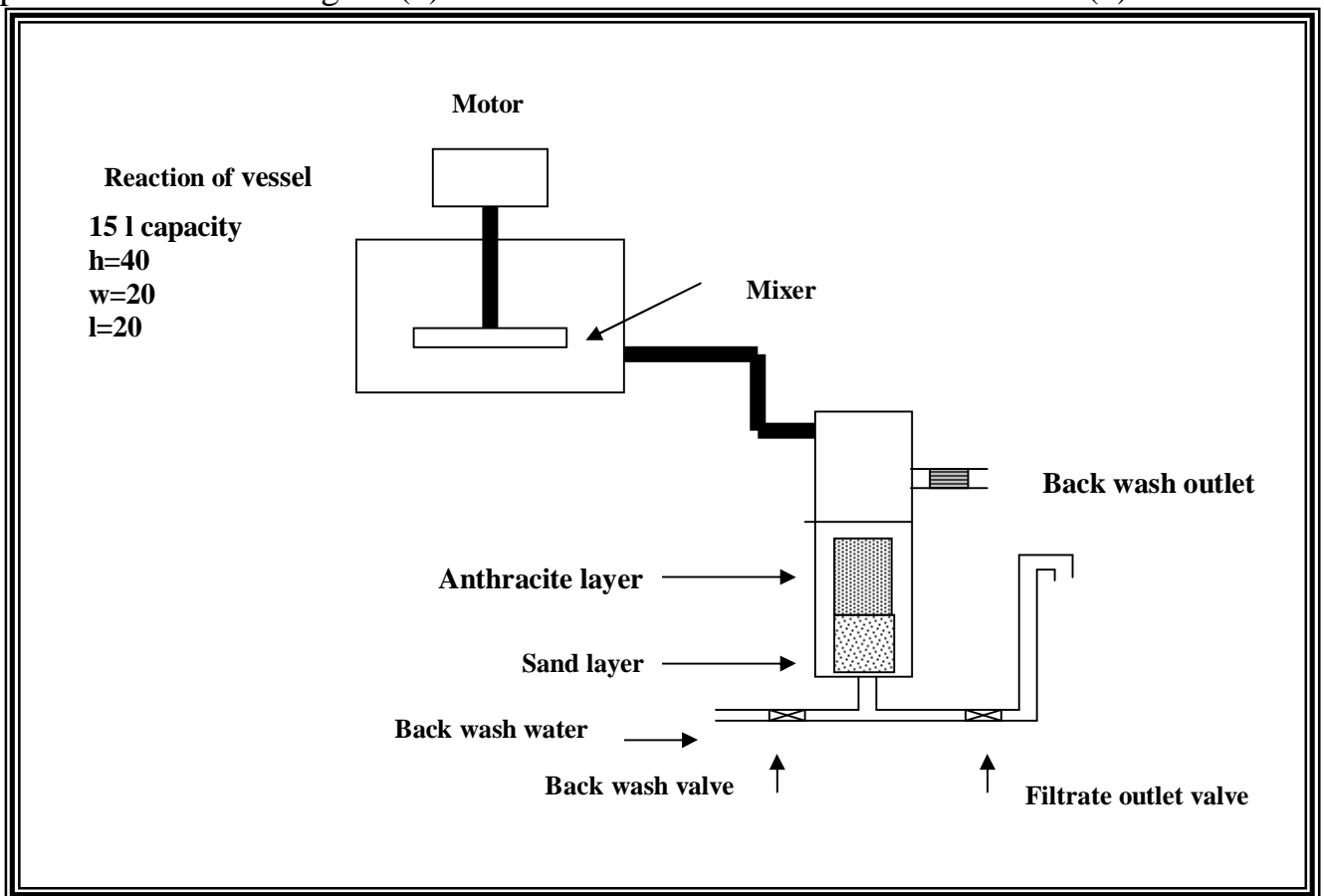


Figure (2) Schematic illustration of laboratory direct test apparatus.

Table (1) technical data and design of the floc filtration test apparatus

Operation	Discontinuous, i.e. batch procedure.		
Destabilization	Over (4 min) at a rotation of approximately (1600) r.p.m.		
Aggregation	By different G and T_f values.		
Filtration	Filter	diameter	7.5 cm
		Surface area	44.2 cm
		Bed depth	40 cm
		Filtration rate	10 ml /sec
		Sand layer	20 cm
		Anthracite layer	20 cm

The water used in the investigations were koalnite mixed with tap water in laboratory. Particle size distribution of this clay was determined by hydrometer test, result of this test is presented in figure (3).

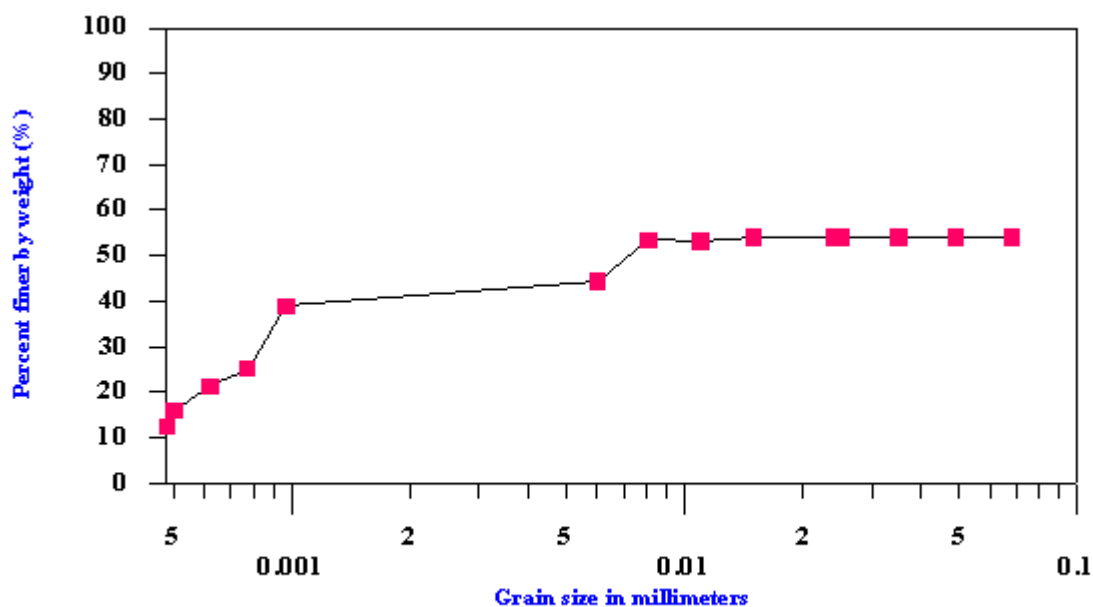


Figure (3) Particle size diameter & percentage finer for clay used in the study

Each test run was performed at initial turbidity of 150 (NTU). In case No.1 (44 mg/l) of alum as coagulant alone, while in case No. 2 (30 mg/l) of alum and 12 (mg / l) porcelainte dose at pH= 7.51 , Temperature = 31.4c°, in case No.3 (23 mg/l) of alum and (18 mg/l) porcelainte dose at pH= 7.6 , Temperature=34.4c° Destabilization(coagulation) and aggregation (flocculation) took place in the reaction vessel of the test apparatus. At this pH value for any case the poly nuclear Al^+ hydroxo complexes in the water are

positively charged (Bernhardt et al. 1989) and destabilize the fine disperse system by charge neutralization.

Compared to the usual jar test condition, destabilization was not induced by rapid mixing at 350 (r.p.m) over (1 min), a high speed stirrer was used over (4 min) at a rotation speed of (1600 r.p.m) to destabilize the suspension. The reasons for this approach can be best explained by the results obtained in tests geared to optimize the rapid mixing phase. Aggregation took place at different energy input levels(G values) and energy input times (T_f).Shown in the table (2).

Table (2) G and T_f values applied in the tests

G (sec ⁻¹)	T _f (min)	G T _f
15	5- 50	4500-45000
25	5- 50	7500-75000
30	5- 50	9000-90000
40	5- 50	12000-120000
50	5- 50	15000-150000
75	5- 20	22500-90000

The energy per unit mass and time was dissipated at various rotation speeds and determined with a rotation viscometer³ by measuring the torque at the stirrer shank according to the following equation (klute et al.1978).

$$X = \frac{w \times D}{r \times n} \quad (\text{cm}^2 / \text{sec}^3) \quad \dots\dots\dots(1)$$

Where :

- W : the circular frequency (1/ sec).
- D : the torque (g.cm² / sec²).
- V : the reactor volume (cm³).
- R : the density (g / cm³).

From the dissipated energy X measured as indicated above, the mean G value can now be computed as postulated by Camp and Stein (1943).

$$G = \left(\frac{X}{V} \right)^{1/2} \quad (\text{1/ sec}) \quad \dots\dots\dots(2)$$

Where :

V: denotes the kinematics' viscosity (cm²/ sec).

After destabilization of colloids in the reaction vessel of the test apparatus, raw water transport to the second stage its flocculation, in this stage formation of bigger flocs by agglomeration of small ones is made. The reaction of vessel of the test apparatus is plexi- glass, having (25*25*35 cm) dimensions and the height of water is (25 cm). A mechanical propeller was rotating on vertical shaft in the basin. The mixing motor was fitted with electrical speed variation device through which rotating frequency (N) could be

arranged from (0- 200) r.p.m . It was possible to keep the G value of flocculation at suitable range (15- 75) sec⁻¹, the G-N relationship was calculated as $G= 0.043 N^{3/2}$. Figure (4) shows the relationship between G and N values used in the research.

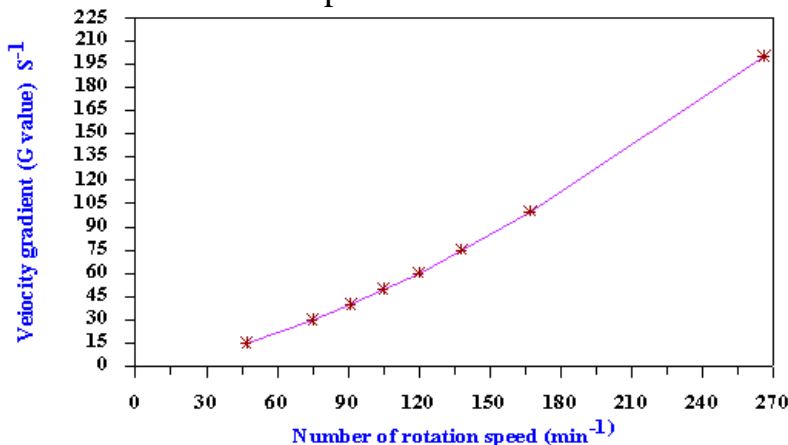


Figure (4) energy input (G value) as function of the rotation speed (floc filtration test apparatus)

After generated flocs enter the filter below (figure 2) and passed through at a filtration rate of 10 (ml/ min). The filter layer consisted of (20 cm) of sand layer and (20 cm) of Anthracite layer. In preliminary tests, this layer depth had proved to be optimum. Since the test could only be carried out with a floc suspension, the filter bed depth had to be such that within the given time it would be possible to determine the implications of the various influencing factors on the effluent quality (turbidity). If the filter layer had been too thick, the available filtration time of approximately (22 min) would have been insufficient to analysis the filtration behaviors of flocs which is largely dependent on the influence factors such as the energy input and energy input times.

Investigated Parameters

The implications of the investigated factors for both the aggregation and filtration process were determined by a continuous measuring of the residual turbidity in the filtrate, by using turbidity meter for measuring the residual turbidity in water filter, at intervals of (1 min). by plotting the turbidity of filtrate against the filtration time as shown in figures (5,11,17) we again insight in to the filtration procedure. In these figures, the first 3 min (case No.1 ; alum dose adding alone) , 2 min (case No.2; alum = 30 mg/l , porcelanite dose =12 mg/l) , 2.5 min (case No.3 ; alum =23 mg/l , porcelanite dose = 18 mg/l) , we gain insight into filtration procedure. In this diagram, the first (3,2,2.5) min represent the ripening period of the filter. The actual filtration phase then follows. Thereafter, flocs gradually begin to break through. After a filter run of (20,22,27) min for the three cases the water volume has completely penetrated the filter. Turbidity values measured after this time are of no practical value and can thus be ignored.

Blank or " Zero tests" for reference purposes were carried out without adjusting a velocity gradient during the aggregation phase (destabilization and no aggregation phase; G and $T_f=0$) .these " zero tests " always showed the same filtration curves.

The percentage removal turbidity which served to characterize the filtration properties of the flocs was calculated by follow eq.

$$E = \left(\frac{C_o - C}{C_o} \right) * 100\% \dots\dots\dots(3)$$

Where :

E : % removal of turbidity matter.

C_o : initial turbidity (NTU).

C: residual turbidity in the filtrate (NTU).

Results and discussion:

Laboratory results obtained using floc filtration test apparatus is analyzed and discussed in the following three case.

Case Study No.1 (alum dose= 44mg/l alone):

Figure 5, represents the residual turbidity versus filter run time, for $G = 15 \text{ sec}^{-1}$. In this figure, the decreased residual turbidity was obtained with increase in T_f from 5-20 min. It was stated that floc particle size is of basic importance to the filtration process. Thus, the larger floc particles can be removed by simple straining at the filter bed. Therefore, the lowering residual turbidity was obtained (48 NTU) at $T_f = 20 \text{ min}$ with respect of $G = 15 \text{ sec}^{-1}$.

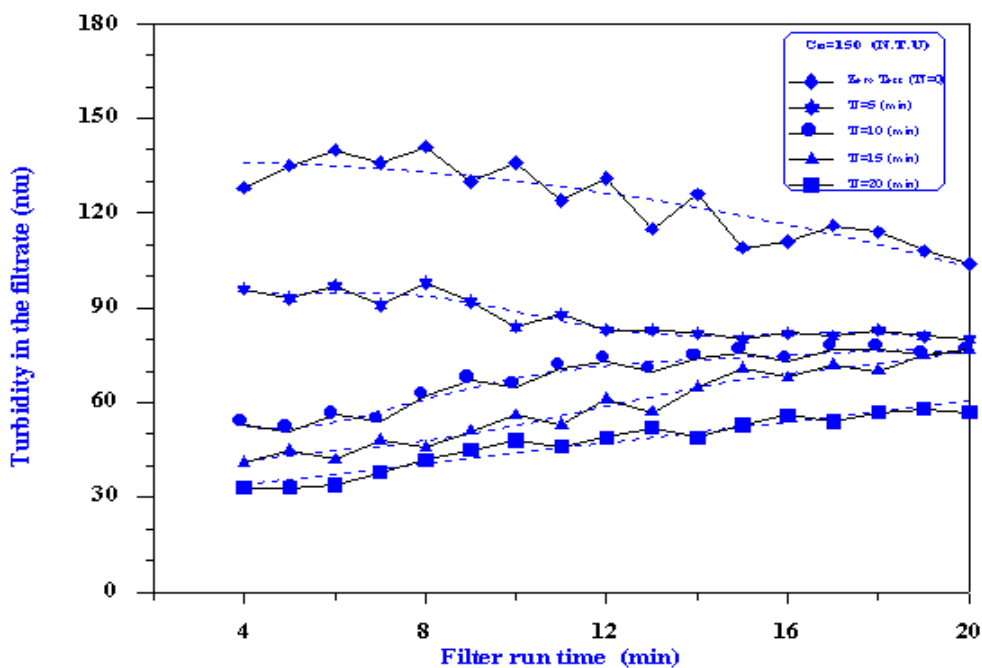


Figure (5) relation between filter run time and residual turbidity in filtrate at $G= 15\text{sec}^{-1}$ for various T_f time

Figure 6, shows the relation between residual turbidity, and filter run time, within fraction of filter run time of (9-15) min. It was found, the lowering residual turbidity attained (30 NTU) at $T_f = 20 \text{ min}$, for $G = 30 \text{ sec}^{-1}$. Thus, increases the flocculation rate with increases T_f because of the increases in the inter particle collision rate. As the flocculation rate increases, larger flocs are formed resulting in higher filtration rates, thus lower residual turbidity.

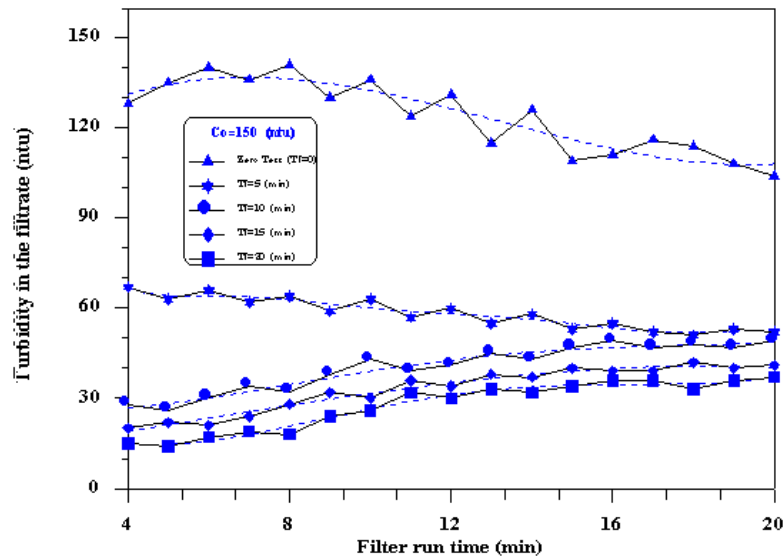


Figure (6) relation between filter run time and residual turbidity in filtrate at $G= 30 \text{ sec}^{-1}$ for various T_f time

Figure 7, shows the filter run time versus residual turbidity for experimental result for the filtration curve of $G = 40 \text{ sec}^{-1}$. From this figure, the lowering residual turbidity of 24 (NTU) was obtained with $T_f = 20$ minute, when it was compared with $G = 30 \text{ sec}^{-1}$.

Figure 8, represents a filtration process at $G= 50 \text{ sec}^{-1}$. The lowering residual turbidity of 27 (NTU) is obtained at $T_f = 15$ min, while at $T_f = 20$ min attained increasing residual turbidity is 33 (NTU). It was observed that increasing G from 15 - 50 sec^{-1} , through T_f from 5-15 min led to decrease residual turbidity in the filtrate (at $T_f = 15$ min and G is 15,30,40 and 50 the residual turbidity in the filtrate as follows: 60, 36, 29 and 27).

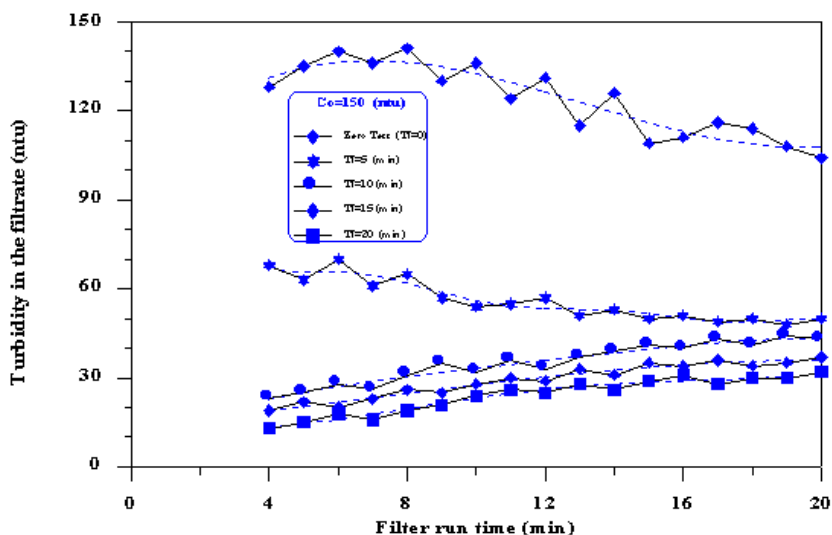


Figure (7) relation between filter run time and residual turbidity in filtrate at $G= 40 \text{ sec}^{-1}$ for various T_f time

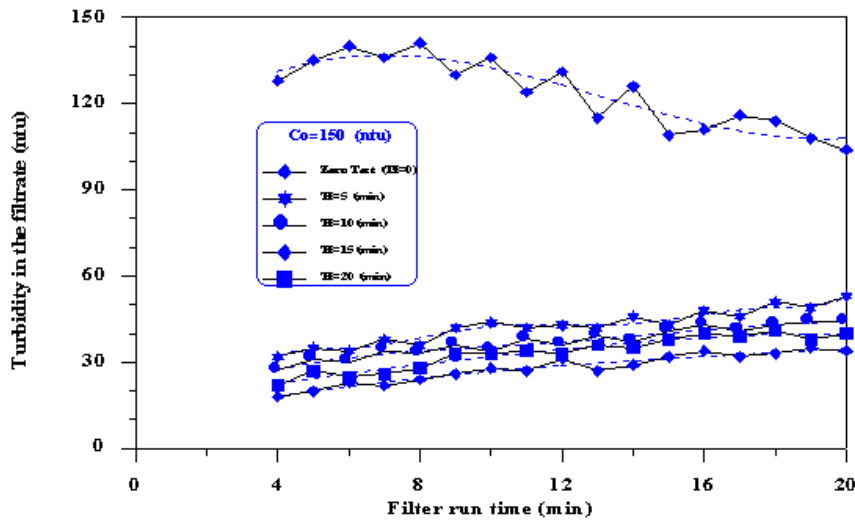


Figure (8) relation between filter run time and residual turbidity in filtrate at $G= 50 \text{ sec}^{-1}$ for various T_f time

Figures 9 , shows that when higher G values of 75 was used, increase of residual Turbidity, within a fraction of filtration (9-15) minute is attained in shorter T_f . In contrast with $G = 40 \text{ sec}^{-1}$ and Gt (Camp number) of 48000, where the floc are retained in the filter depth of sand media. Conversely, with $G = 75 \text{ sec}^{-1}$. Flocs a pass with relative small retaining when it was compared with low G range ($30\text{-}50 \text{ sec}^{-1}$), so flocculation energy using G higher (75 sec^{-1}) is not preferable because of strong shear forces developed, that causes breakage of flocs aggregates. As a result the residual turbidity increases in the filtrate.

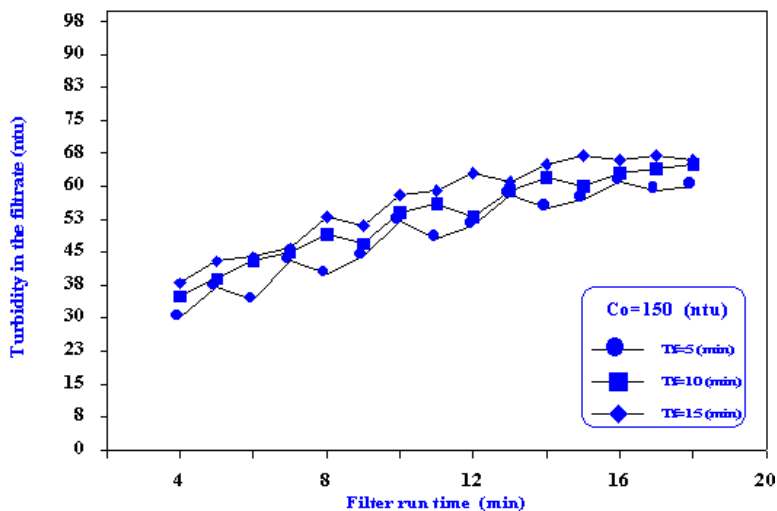


Figure (9) relation between filter run time and residual turbidity in filtrate at $G= 75 \text{ sec}^{-1}$ for various T_f time

Figure 10, shows the relation between percentage removal of turbid matter, and energy input time, for velocity gradient within range from $15\text{-}100 \text{ sec}^{-1}$. It was found that slow mixing speed ($G = 30 \text{ sec}^{-1}$) is the required mixing speed for 15-60 minute of T_f to get a good percentage removal of turbid matter within range from (76%-82%). The same figure, shows that the optimum slow mixing speed was found to be $G = 40 \text{ sec}^{-1}$, which resulted in maximum percentage removal of turbid matter of (84%), at $T_f = 20$ minute. On

the other hand, with increased G up to 50 sec^{-1} , it was found that there is an increase in percentage removal with the increase in T_f within range 5-15 minute, thereafter, it led to decrease in percentage removal of turbid matter.

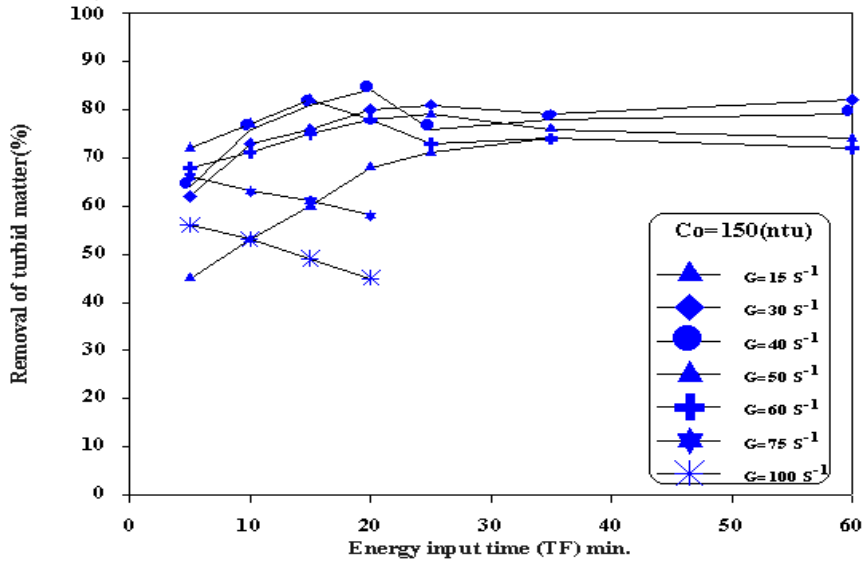


Figure (10) Removal of turbid matter (%) as function of the energy input time (T_f) for different G values .

Table 3, gives a summary of the optimum slow mixing speed as G , and T_f . The table shows that $G = 40 \text{ sec}^{-1}$, and $T_f = 20$ minute give better turbidity removal compared with the other low G .

Table (3) Optimum percentage removal through G from ($30\text{-}50 \text{ sec}^{-1}$) and different T_f .

$G = 30 \text{ sec}^{-1}$		$G = 40 \text{ sec}^{-1}$		$G = 50 \text{ sec}^{-1}$	
T_f (min)	Percentage removal of turbidity %	T_f (min)	Percentage removal of turbidity %	T_f (min)	Percentage removal of turbidity %
15	76	10	76	5	72
20	80	15	81	10	77
25	81	20	84	15	82
35	79	-	-	-	-
60	82	-	-	-	-

Case No.2(alum=30 mg/l, porcelanite dose= 12 mg/l) :

Figure 11, shows the relation between residual turbidity and filter run time, for different T_f and at $G = 15 \text{ sec}^{-1}$. It was notable that any increase in T_f lead to a decrease in the residual turbidity in the filtrate. For the same figure, the filtration curves of T_f of zero "zero test" indicates the water containing the destabilized particles taken directly to a granular filter, where small relative contact flocculation take place as part of the filtration process. Therefore, it shows different results between $T_f = 0$ and $T_f > 5$ (min). At this point

the fine particles are not entrapped in the floc, the filter will be unable to remove them, leads to increase residual turbidity in the filtrate, while at $T_f=5$ (min) enough collision occurred so that the floc particles grew to a size that will filtrate rapidly, it was found at that $T_f=20$ (min) it could attain a reduce in the residual turbidity (31 NTU).

Figure 12, shows the relation of filter run time versus residual turbidity. Ten minute is found to be optimum period of mixing at $G=25 \text{ sec}^{-1}$ and using porcelanite dose as coagulant aid, could attain minimum residual turbidity (15 NTU). Within filtration fraction of filter run time (8- 15) min, whereas an increase of $T_f >15$ (min) led to relative increase in residual turbidity. In conclusion it can be stated that at high turbidity. Longer T_f may tend to increase in the breakage flocs resulting poor filtration characteristics. On other hand, shorter mixing time will not allow complete formation of the flocs, while at using flocculants aid a good results may be attain as shown in figure 12 .

Figure 13, shows a filtration process at $G=30 \text{ sec}^{-1}$. The minimum residual turbidity of (27 NTU) is at $T_f=20$ (min). Thereafter, an increase of T_f lead to a relatively increase of residual turbidity. It can be stated that the rate of agglomeration of destabilized particles to form visible floc is dependent on G and T_f .

Figures 14, 15 , which explains the relation of filter run time versus residual turbidity in filtration at $G=40, 50 (\text{sec}^{-1})$ and by using porcelanite as coagulant dose. It was found at $T_f=10, 15$ (min) respectively, could attain minimum residual turbidity (30,30) NTU, respectively. It can be stated that increasing G , Within adding porcelanite, larger than $G=30 \text{ sec}^{-1}$ led to relative increase of residual turbidity in filtrate, because of increasing in the breakage generated flocs during flocculation stage.

Figure 16, shows relation between the removal percentage of turbid matter, T_f and G . In this figure, inverse correlation between G and T_f is illustrated. It is notable that the percentage of removal turbidity increase with increase value of G from (15- 25) sec^{-1} with using porcelanite as coagulant aid, and T_f from (10-20) min, whereas the percentage of removal turbidity decreases relatively when increase is between (30 -75) sec^{-1} and T_f (10-50)min. The corresponding T_f range from (10-20) min is dependent on the selection of G and dose of coagulant aids for using with alum. Within certain limitations, it is possible to offset a small G value by a high T_f and vice versa without causing adverse effects to the floc formation process and the filterability of the flocs.

Case No.3 (alum=23 mg/l, porcelanite dose=18 mg/l):

Figure 17, 18 shows the relation between residual turbidity and filter run time with adding porcelanite dose=18 mg/l as coagulant aid, and with respect $G=15,25 \text{ sec}^{-1}$. It was found that on increasing T_f , residual turbidity was decreased in the filtrate. While figure 19, shows that the residual turbidity decrease as T_f increase from (5- 20) min , therefore, it was found that the minimum residual turbidity of (21 NTU) could be obtained with $T_f=20$ min when $G=30 \text{ sec}^{-1}$. whereas increase $G >40 \text{ sec}^{-1}$ lead to increase the residual turbidity in the filtrate.

Table (4) summarizes the optimum slow- mixing speeds represented as velocity gradient ($G \text{ sec}^{-1}$) for porcelanite used as coagulant aids. With the same velocity gradients and energy input time, the table shows that porcelanite as coagulant aid produces low residual turbidity with(12 mg/l)compared with residual turbidity obtained with (18 mg/l) and with 44(mg/l) alum alone.

Table (4) optimum velocity gradient and energy input time for porcelanite as coagulant aids.

Raw water turbidity 150 NTU	Alum (mg/l)	G (sec ⁻¹)	T _f (min)	Porcelanite dose (mg/l)	Residual turbidity (NTU)
	30	25	10	12	15
	23	30	20	18	21
	44	40	20	-	25.5

Figure 20, represents the relation between percentage removal of turbid matter and T_f for different G values. From this figure, it becomes apparent through G (15 – 30) sec⁻¹ with use porcelanite dose =18 mg/l and T_f= (5- 25) min lead to the improvement in the filterability of generated flocs. However, at G= 30 sec⁻¹ gave maximum percentage removal of turbidity matter of (86%) at T_f=20 min. Thereafter, the percentage removal would decrease with increase T_f>(25- 50) min, whereas for G=40 sec⁻¹ could give improvement of grow floc through T_f from (10- 20) min, thus, was obtained percentage removal of turbid matter of (83 %) at T_f = 15 min.

In this figure, shows that the higher G= 75 sec⁻¹ was noted that low T_f =5 min could attain acceptable percentage of removal turbidity matter about (70 %). But, when T_f is increased >(5 -15) min, it cause the decrease in the percentage of removal turbidity. Thus increase in G performance leads to greater influence of aggregation phenomenon rather than break up. At increases beyond the T_f = 10 min break up assumes a greater role.

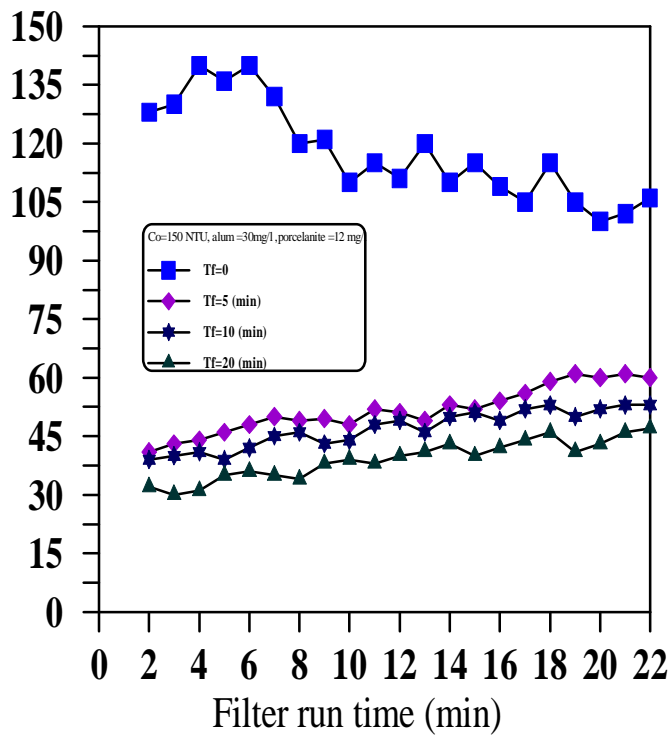


Figure (11) relation between filter run time and residual turbidity in filtrate at $G=15 \text{ sec}^{-1}$ for various T_f time.

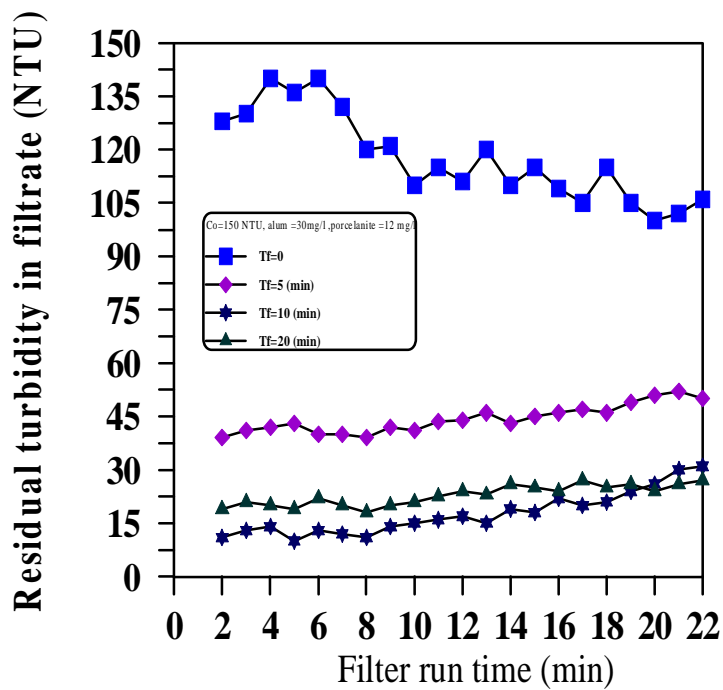


Figure (12) relation between filter run time and residual turbidity in filtrate at $G=25 \text{ sec}^{-1}$ for various T_f time

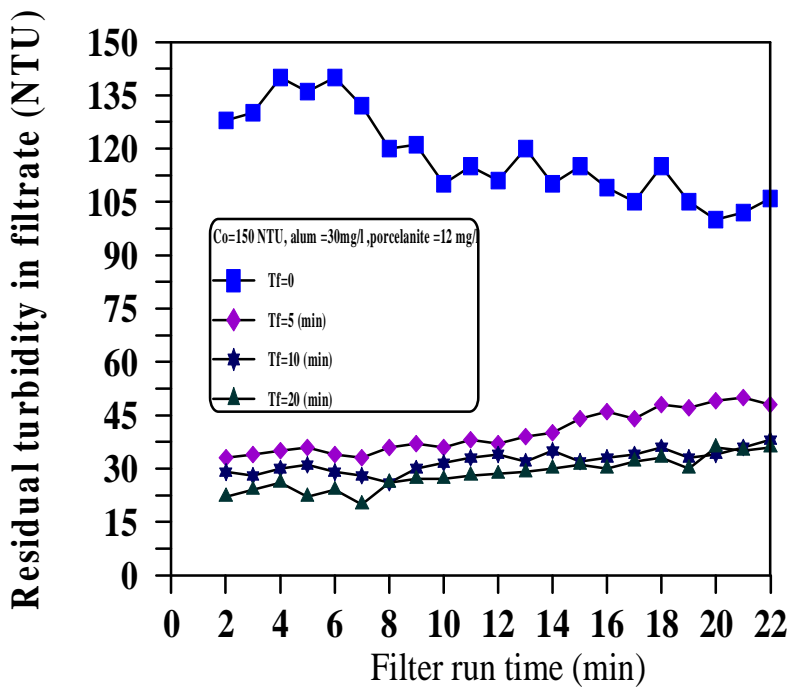


Figure (13) relation between filter run time and residual turbidity in filtrate at $G= 30\text{sec}^{-1}$ for various T_f time

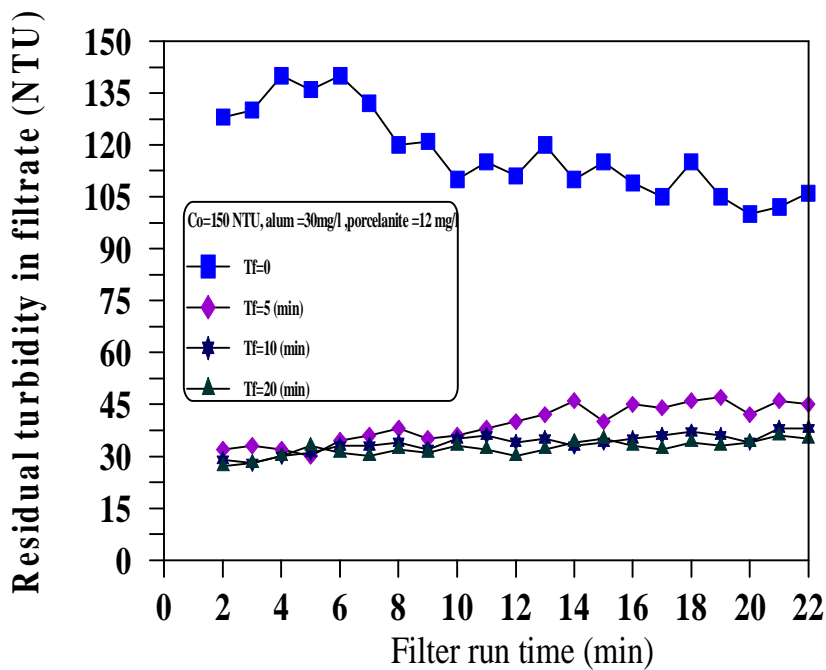


Figure (14) relation between filter run time and residual turbidity in filtrate at $G= 40\text{sec}^{-1}$ for various T_f time

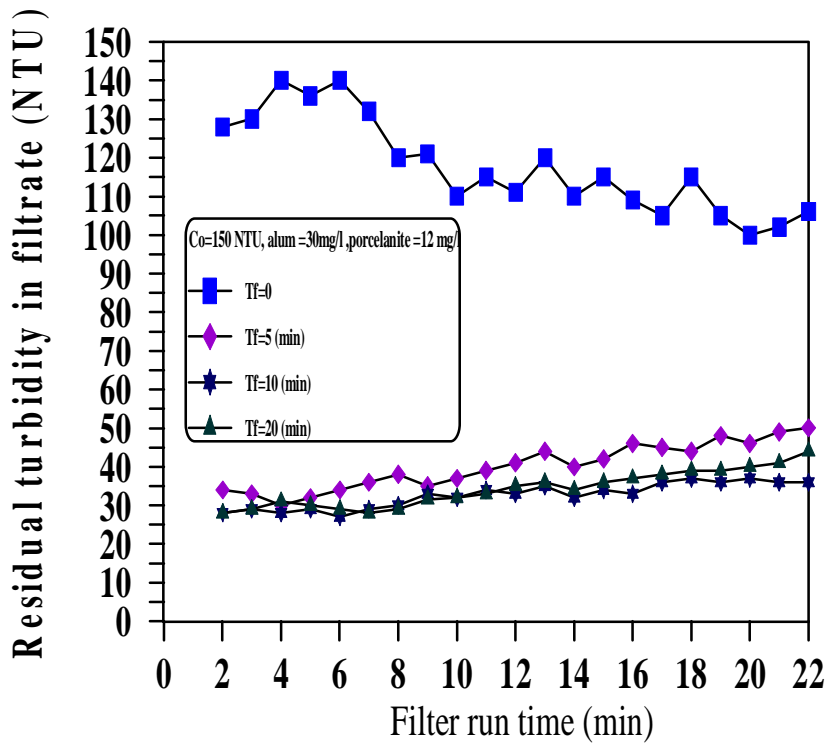


Figure (15) relation between filter run time and residual turbidity in filtrate at $G= 50\text{sec}^{-1}$ for various T_f time

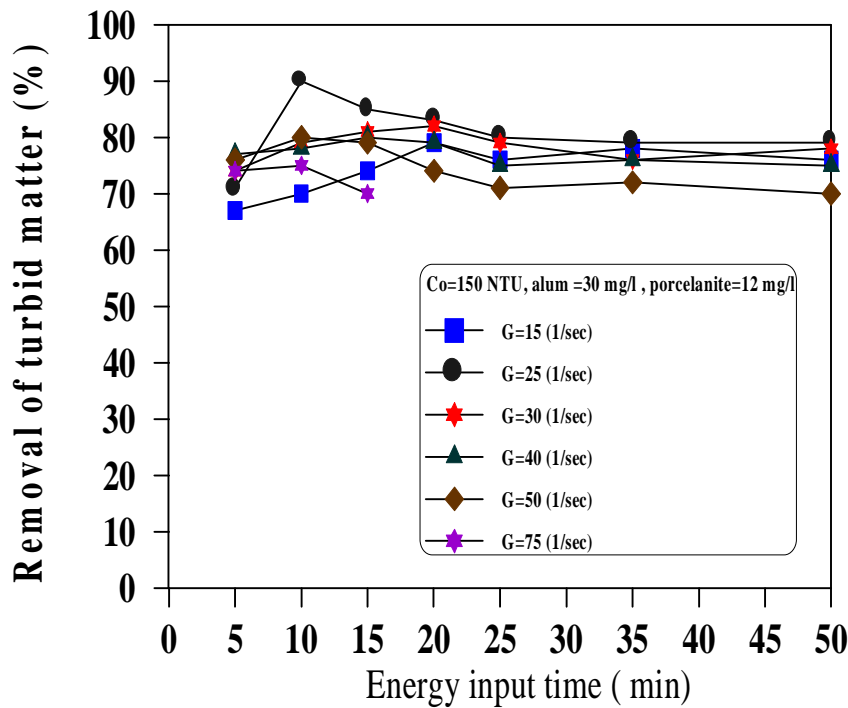


Figure (16) Removal of turbid matter (%) as function of the energy input time (T_f) for different G values .

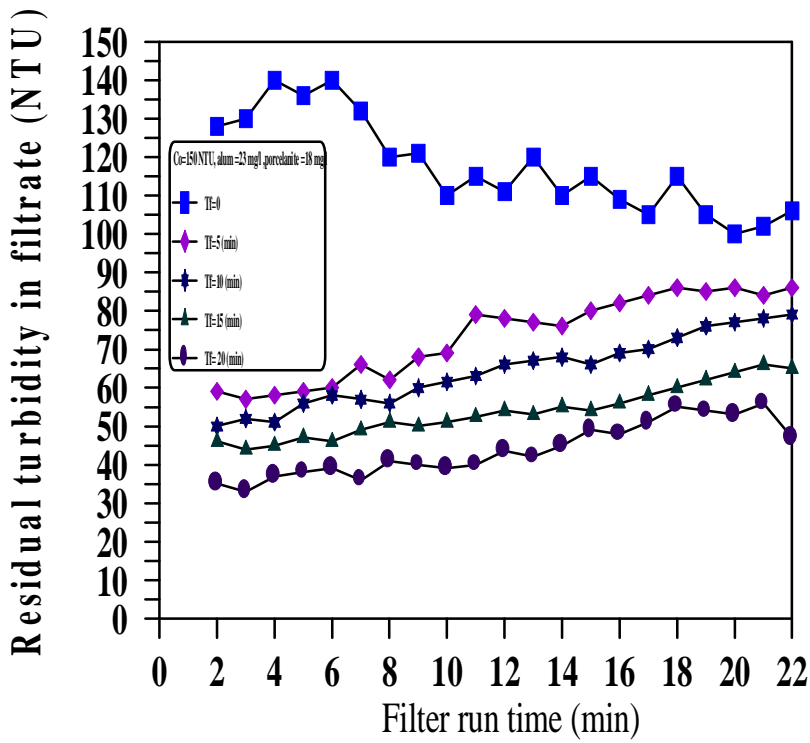


Figure (17) relation between filter run time and residual turbidity in filtrate at $G = 15 \text{ sec}^{-1}$ for various T_f time

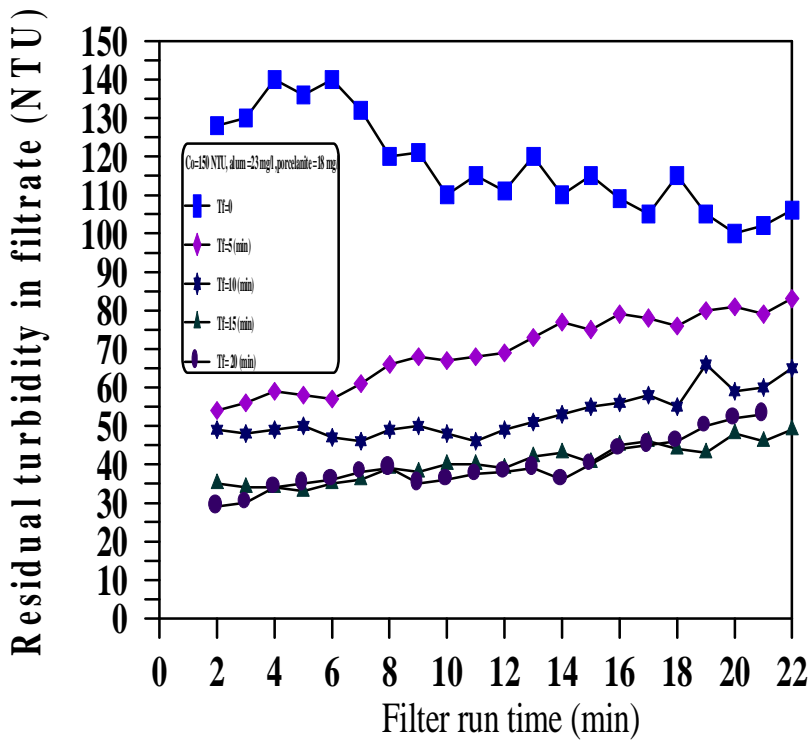


Figure (18) relation between filter run time and residual turbidity in filtrate at $G = 25 \text{ sec}^{-1}$ for various T_f values.

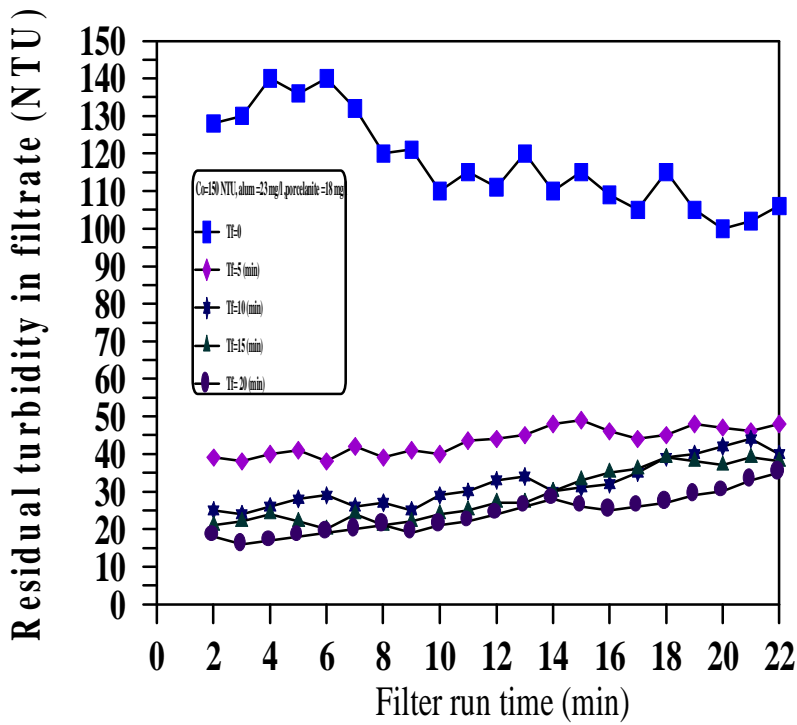


Figure (19) relation between filter run time and residual turbidity in filtrate at $G= 30\text{sec}^{-1}$ for various T_f time

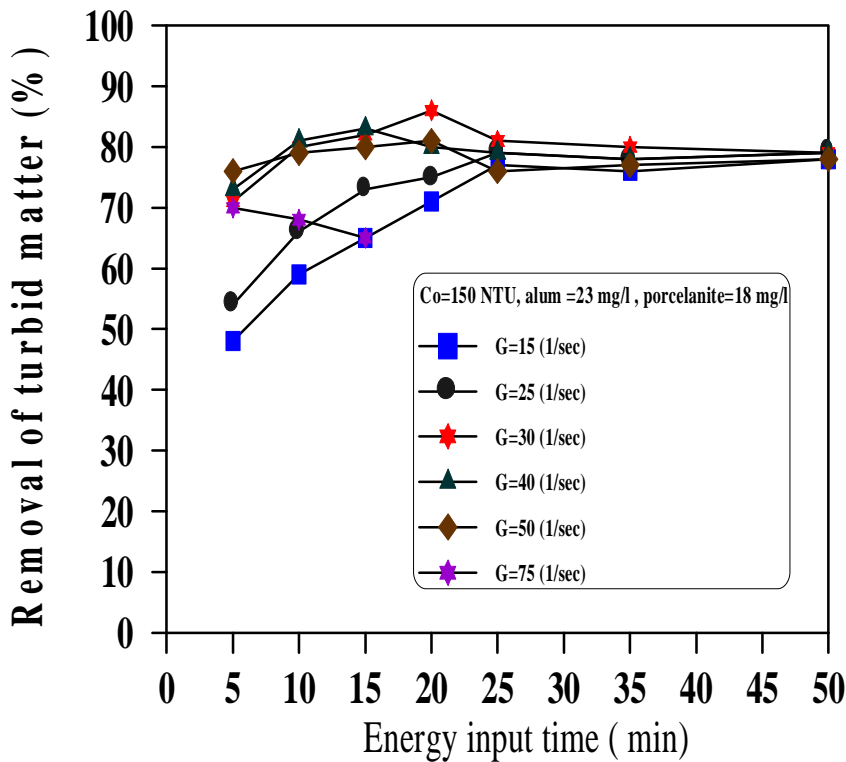


Figure (20) Removal of turbid matter (%) as function of the energy input time (T_f) for different G values .

Conclusions

- 1) For using alum alone, it was found experimentally that optimum percentage removal attain when $G= 40 \text{ sec}^{-1}$ and $T_f=20 \text{ min}$.
- 2) It was found that optimum doses of porcelanite used as coagulant aids is 18 (mg/l) which gave maximum percentage removal of turbidity at $G= 25 \text{ sec}^{-1}$ and $T_f =10 \text{ min}$.

References

- 1- Bernhardt,H.,and Schell,H.(1982)." Energy input controlled direct filtration to control progressive eutrophication ", J.AWWA,vol.74,No.6,P.261.
- 2- Tolman,S.L(1942).Water conditioningfor flocculationJ.AWWA,vol.34,No.3,P.404.
- 3- Hudson,H.E.(1965). " Physical aspects of flocculation ", J.AWWA,Vol.57,No.7,P.885.
- 4- Harris,H.S; Koafman , W.J;Korne,R.B(1966)."Orthkinetic flocculation in water purification.", J.ASCE,Vol.92,No.SA6.P.95.
- 5- Omelia,C.R.(1969)."A Review of the coagulation process" ,Public works, Vol.87.
- 6- Hudson,H.E.(1973) ."Evaluation of plant operation and jar test data ", J.AWWA,Vol.65, No.4, P.368.
- 7- Tekippe ,R.J; and Hamm.R.K.(1970)."Coagulation testing : A comparison of techniques – part I and II",J.AWWA ,Vol.62,No.9, P.594and 620.
- 8- Tekippe,R.J;and Ham, R.K(1971)." Velocity gradient path in coagulation " J.AwwA,Vol.63,P.439.
- 9- Bratby,J.R.(1981)." Interpreting laboratory results for the design of rapid mixing on flocculation system" J.AWWA,Vol.73,No.6,P.318.
- 10- Habibian,M.T ,and Omelia ,C.R.(1975). "Particales , polymers and performance in filtration." J.Env.Eng.Div.ASCE, Vol.101,P.567.
- 11- Brink.D.R.,Suing-JII choi,Al-Ani, M., and Hendricks,D.W.(1988)." Bench-scale evaluation of coagulation for low turbidity water" J.AWWA,Vol.80,P.199.
- 12- Klute,R.(1990)." Destabilization and aggregation in turbulent pipe flow" J.Water.Sci.Tech., Vol.21,P.435.

