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Effect of Using Porcelanite on the Performance of Water and Wastewater Treatment

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Abstract

In this study the local materials (Porcelanite) was tested as coagulant aid with alum. Also, it was used the porcelanite material as a dual media with sand to determine the efficiency of this material. This was done by doing the experimental work, to improve the performance of the coagulation and filtration processes used in water treatment plants. The work required installing of a pilot plant system, the experimental work was included tests for both water and wastewater. the initial turbidity for experiments was between (10-200 NTU).The results indicated that the porcelanite material has more efficient in the removal of turbidity for all levels of turbidity and more efficient in removal of BOD_5 in the coagulation and filtration processes . The average of efficiency of turbidity removal with the initial turbidity of (10,50, and 100,150 ,200 NTU) were (72.8 ,84, and 91 %)respectively when adding alum only in the coagulation process. These percentage were increased to a value of (79,93,and95%) respectively when using alum with coagulant aid of porcelanite material. Also, the results of present study referred that when using the porcelanite material as a dual media with sand in the filtration process ,the percent of turbidity removal was about of (87%), while the removal efficiency by using single media was about of(74%)when using alum only in the coagulation process. The efficiency was increased to about (93%) and (80%) by using the dual media and single media respectively when using porcelanite material with alum in the coagulation process . The local alum was gave the removal efficiency of BOD_5 of about (46%) ,while when using porcelanite with alum the removal efficiency was increased to a value of about (61%).In the filtration process the removal efficiency of BOD_5 by using dual media was better than that by using single media by about of (18%) when using alum only in the coagulation process. When using the porcelanite material with alum, the removal efficiency by using dual media better than that by using single media also by about (25%).

Keyword : Coagulation , Filtration , Porcelanite material

الخلاصة

في هذه الدراسة تم اختيار مادة البورسلنايت كمادة مساعدة للتخثير مع الشب واستخدام مادة البورسلنايت كمرشح ثنـائي مع الرمل لمعرفة كفاءة هذه المادة لتحسين أداء عمليتي التخثير والترشيح في محطات معالجة الماء . ولقد تطلب العمـل إنـشاء منظومة معالجة مختبرية. العمل التجريبي تضمن فحوصات لكل من الماء وماء المجاري .العكورة الابتدائية لجميـع التجـارب تراوحت بين (10- 200 NTU) . وقد أظهرت النتائج بان مادة البورسلنايت أكثر كفاءة عند استخدامها مع الشب فـي إزالـة العكورة ولجميع مستويات الكدرة كذلك اكثر كفاءة في ازالة ال(BOD) في عمليتي التخثير والترشيح.فقد وجد ان كفاءة إزالـة العكورة عند مستوى عكورة ابتدائية (10،50و 100،150 200NTU) كانت بحدود (72.8 ، 84و 91 %) عند استخدام الشب فقط في عملية التخثير وهذه النسبة تزداد لتصبح(79،93 و95%) بعد إضافة الشب مع البورسلنايت. وقد بينت النتائج ايضا عنـد استعمال مادة البورسلنايت كمرشح ثنائي مع الرمل فان نسبة ازالة العكورة كانت بحدود (87%)بينما نـسبة الازالـة باسـتخدام مرشح الرمل كانت (74 %) عند استخدام الشب فقط في عملية التخثير.وكانت كفاءة الازالـة بحـدود (93 %)و(80 %) باستخدام المرشح الثنائي ومرشح الرمل على التوالي عند استخدام مادة البورسلنايت مع الشب في عملية التخثير. كذلك أعطـى الشب المحلي كفاءة إزالة (BOD)بحدود (46%) بينما عند استخدام الشب مع البورسلنايت فان كفاءة إزالـة (BOD) تـزداد لتصبح بحدود (61%) . في عمليةالترشيح وجد ان كفاءة ازالة ال BOD باستخدام المرشح الثنائي أفضل من اسـتخدام مرشـح الرمل بحدود(18 %) عند استخدام الشب فقط في عملية التخثير، بينما عند استخدام الشب مع البورسلنايت فان كفاءة إزالـة ال BODباستخدام المرشح الثنائي أفضل من مرشح الرمل بحدود(25 %).

Introduction

Treatment of raw water loaded with suspended matters, such as most surface waters in Iraq, requires principally the separation of the solid and colloids particles that cause turbidity from the raw water. Production of portable water, that is free from turbidity and diseases causing organisms, and production of wastewater with less organic matter is the major objective of conventional water and wastewater treatment.

The purpose of coagulation is thus to make particles of bigger size by adding certain chemicals known as the "coagulants" to the water. The coagulants react with the impurities in water and convert them in settleable size.

Filtration is another ancient and widely used technology that removes particles and at least some microbes from water. The effectiveness of these filtration methods in reducing microbes also varies widely, depending on the type of microbe and the type and quality of the filtration medium or system.

(Al-Anbari,(1997) selected suitable and durable locally filter media. He tested lightweight materials like [porcelanite rocks (PR) and burnt kaolinite (BK)], and a heavy weight media like [geothite rocks (GR)]. For single media filter, porcelanite (PR) and kaolinite (BK) gave better results in turbidity removal efficiency (TRE %) and net water product (NWP) value (m^3/run) than sand medium. This was because of their higher porosity and angular grain surface textures. The performance of the mixed media filter gave better results than the conventional single media, and sometimes superior to that of dual media.

(Al-Ansary ,1998), evaluated the performance of locally porcelanite rocks as a filter media in the treatment of water supplies. He studied the performance of dual media filter composed of porcelanite and sand. The results showed that the PR filter is more effective in turbidity removal, more length in filter run, and less head loss during filtration nearly by (40%).

(Al-Marshidi ,2000) stated that the porcelanite as well as bentonite are effective in removing turbidity of raw water with turbidity level of (50 NTU) and less. Furthermore, he found that porcelanite or bentonite must be added to water and should be dispersed throughout the water body for at least (45 seconds) before the addition of the primary coagulant (alum).

(Abed-Ohn, 2003) ***Arabic*** showed that the high efficiency of porcelanite to extract ions of heavy metals (Fe, Zn, Cr, Cu, Ni, Co, Cd, Pb, Mn) from water as coagulant, and lowering their concentrations to less than the environmental limits. This was achieved when using porcelanite of granular size (0.15 to 0.25 mm). The adsorption capacity of porcelanite is due to the large surface area within the composition of cristobalite and tridymite.

(Al-Auraji, 2003) made a research to improve the performance of the filters of Al-Daura water treatment plant by using locally materials such as porcelanite rocks (PR) and burnt kaolinite (BK) as well as anthracite. The results showed that dual media filter gave better water quality, lower head losses, and longer filter run time than single sand filters.

(Batool- Mohammed,2005) tested the dual filter to improve the performance of the filtration process in water treatment plants. She used porcelanite rocks to get dual media with sand in her experimental work. She showed that the dual media had no significant effects on the pH, conductivity and TDS of the treated water like sand, but was efficient in turbidity and bacterial removal. The removal bacterial efficiency of the treated water was 16 % more than in sand filters.

Adsorption capacity for porcelanite made it important for getting rid the environment from the different pollution .(Al-Wetaify ;2005).

Objectives of the study:

The main objectives of this study are:

1. Evaluating the performance of local material (porcelanite) as coagulant aid with alum to treat water and wastewater by using a pilot plant system consist of coagulation, flocculation, sedimentation and filtration.

2. Comparison between the efficiency of porcelanite material as coagulant aid with alum and alum only in removing the turbidity from water and removing organic matter from wastewater.

3. Evaluating the performance of porcelanite material as a dual filter media with sand.

4. Comparison between many types of coagulants.

5. Developing a statistical model which describes the treatment process.

Experimental Work

A pilot plant as shown in Fig.(1) was constructed to conduct the experimental work. The purpose of the pilot plant is to perform the processes of coagulation, flocculation, sedimentation and filtration. Two hundreds experiments were conducted during this study. The experimental work was conducted in the Laboratory of Al-Muamera Wastewater Treatment Plant of Hilla City.

The pilot plant used consisting of coagulation, flocculation, sedimentation and filtration processes. Fig.(2) shows a schematic diagram of the pilot plant used.

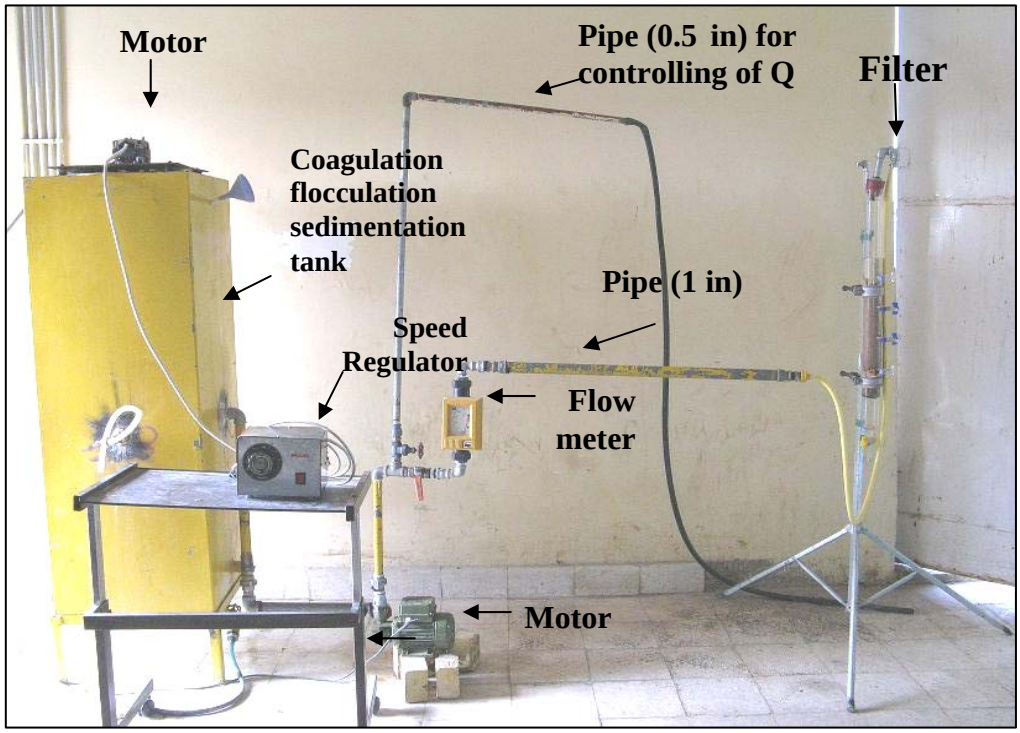

Fig. (1): The Pilot Plant Used

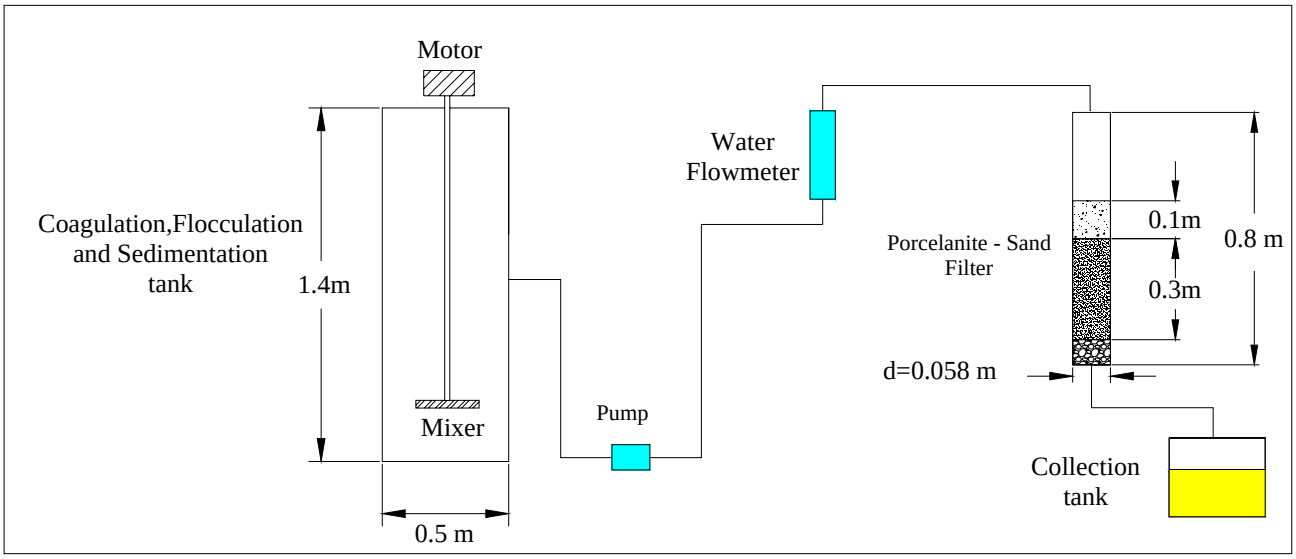

Fig. (2): Schematic Diagram of Pilot Plant

The tank used in this study has a capacity of (350 L), and it has dimension of (1.4m x 0.5m x 0.5m). A stainless steel paddle mixer was connected to the tank for two purposes: firstly for preparing synthetic raw water and secondly to mix the coagulants with water .The mixer was driven by a motor , which was connected to a speed regulator . The mixing of water and wastewater was done continuously. Three processes (coagulation, flocculation and sedimentation) were conducted in this tank. The destabilization of colloids was achieved by using different types of coagulants and electrically driven stirring propeller, to disperse these coagulants. The stirrer has a constant rotation speed equal to (250 r.p.m) with mixing time of (1min).Flocculation process is the formation of bigger flocs by agglomeration of small ones. This process obtained after a destabilization of colloids occurred in rapid mixing process.The value of G was kept constant at a value of $20s^{-1}$ and also ,the value of speed was maintend constant at a value of (60 r.p.m).The mixing time was equal to a value of (15-20 min).

In this study a vertical Pyrex glass filter column was used. It has a dimension of (5.8 cm diameter) and length of (80 cm length).There are two types of filters were used. The first filter has sand bed of(single media) of height of 40 cm, while the type of second filter is of a dual media of sand bed of 30 cm in height and 10 cm of porcelanite height.

The suspension materials used in the experimental work are fine in it's name and is from kaolinite clay (which passed through sieve No 200).The kaolinite clay has a particle size distribution as shown in Fig.(3).

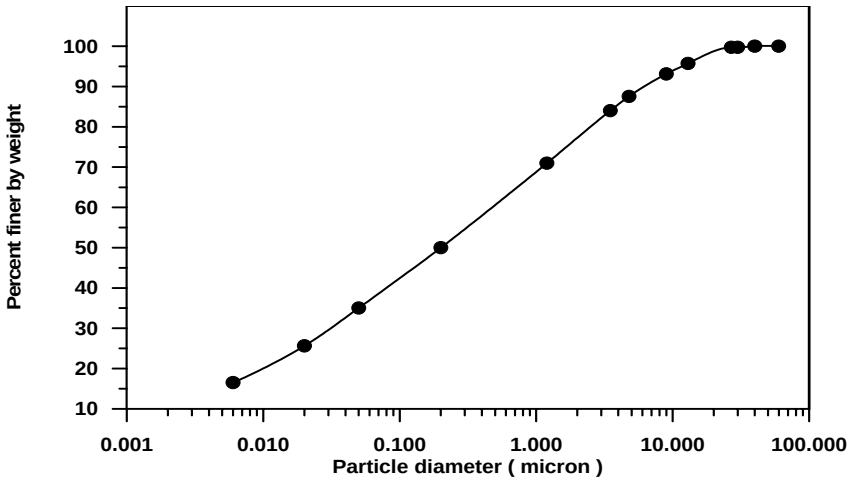

Fig. (3): Particle Size Distribution of Kaolinite Clay

Local material of porcelanite was used as coagulant aid .The powder size is between (0.07 – 0.1) mm, with effective size of (0.085 mm) and the value of uniformity coefficient was (3.18).The porcelanite was supplied from the General Establishment for Geological Survey and Mineralogy-Ministry of Industry and Minerals (GEGSM) . The chemical and physical analysis of the porcelanite is shown in Table (1).The particle size distribution is shown in Fig. (4)**.**

The effective size of porcelanite particles used in the filter as a filter media is 0.9 mm , while the uniformity coefficient is of a value equal to 1.67.After sieving process the porcelanite was washed with tap water for several times to remove dust and fine particles. The porcelanite media has a particle size distribution as shown in Fig. (5).

Table (1) :Chemical and Physical Analysis of Porcelanite Used in this Study

Chemical Composition %	**SiO_3**	**Al_2O_3**	**Fe_2O_3**	**TiO_2**	**P_2O_5**	**CaO**	**MgO**	**Na_2O**	**K_2O**	**L.O.I**
	83.57	**0.62**	**4.45**	**0.01**	**1.82**	**1.46**	**0.5**	**0.16**	**0.22**	**5.9**
Specific gravity (SG)		**Range for 5 Sample**			**Average (SG)**			**Recommendation**		
		1.5-1.61			**1.554**			**Ok**		
Porosity		**0.52**								

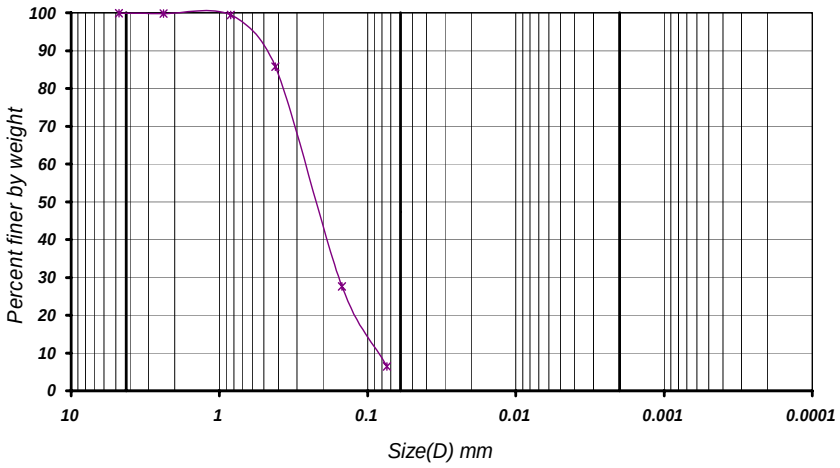

Fig. (4): Particle Size Distribution of Powder Porcelanite Used

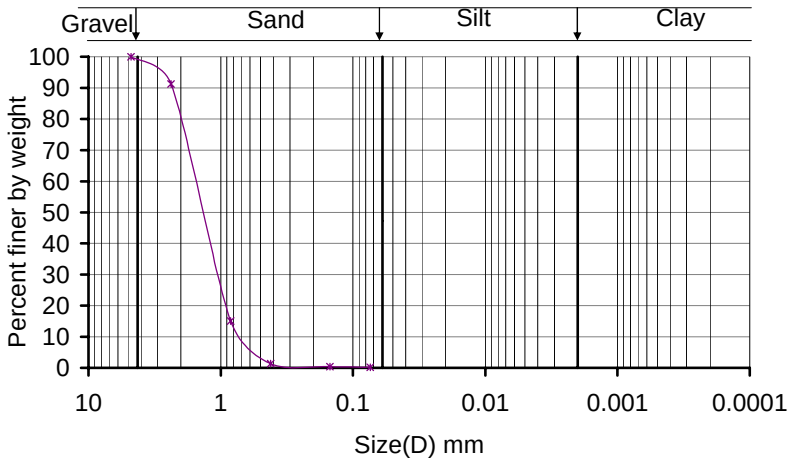

Fig . (5): Particle Size Distribution of Porcelanite Rocks Sample Used as a Filter Media in this Study

In this study The effective size of sand particles is of 0.45 mm , while the uniformity coefficient is of a value equal to 1.71 .Fig. (6) shows the particle size distribution of sand material.

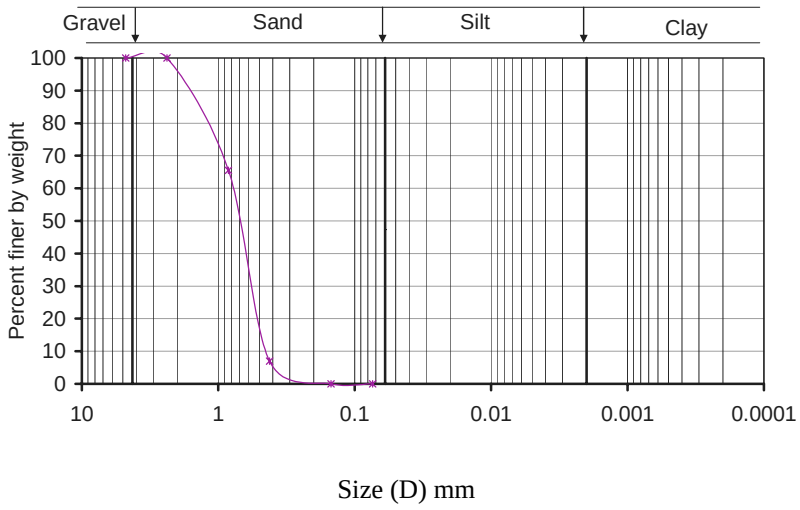

Fig. (6): Particle Size Distribution of Sand material

Results and Discussions

The following discussion deals with the performance of the pilot plant used according to the tests performed on the influent and effluent of the water flow system. Results obtained, using alum with locally material such as(porcelanite) , were used in evaluating the effect of this material on the residual turbidity and organic matter concentration of water and wastewater in coagulation and filtration processes . Three groups of experiments were conducted in this study , in group No.1 different ratios of alum to porcelanite (A/P) were tested while groups No.2 ,No.3 consist of all the experiments on the water and wastewater respectively.

Experimental Group No. 1:-

In this study alum and porcelanite were used as coagulant and coagulant aid respectively. In this group the selecting of the best percentage of (A/P)was occur ,where A is mean alum and P is mean porcelanite. Initially different ratio of A/P were done and discussed, and then minimum residual turbidity ratio was indicated and selected as the best ratio and used for all experiments.

Table (2) presents four sets of run; each set contains five different dosages of alum with different dosage of porcelanite in order to obtain the optimal dosages of alum and porcelanite.

Fig. (7) shows the relationship between the dosages of coagulants (alum, alum +porcelanite) and the efficiency of turbidity removal, with a different percentage of alum and porcelanite. The results indicated that the percentage of 75% of alum and 25% of porcelanite can be considered as the best percentage to obtain minimum turbidity.

Table (2) Summery of Experiments of Experimental Group No.1

Set No.	Dosage of coagulant mg/L	Percentage of alum %	Dosage of alum mg/L	Percentage of Porcelanite %	Dosage of porcelanite mg/L
1	10	100	10	0	0
	20	=	20	=	0
	30	=	30	=	0
	40	=	40	=	0
	50	=	50	=	0
2	10	50	5	50	5
	20	=	10	=	10
	30	=	15	=	15
	40	=	20	=	20
	50	=	25	=	25
3	10	60	6	40	4
	20	=	12	=	8
	30	=	18	=	12
	40	=	24	=	16
	50	=	30	=	20
4	10	75	7.5	25	2.5
	20	=	15	=	5
	30	=	23	=	7
	40	=	30	=	10
	50	=	38	=	12

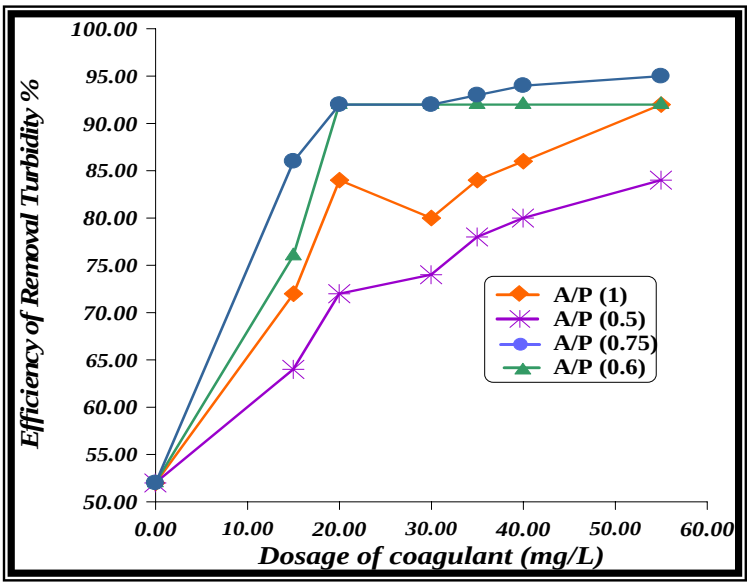

Fig. (7) :Variation of Efficiency of Removal Turbidity and Dosage of Coagulant with Different Dosages of Porcelanite

Experimental Group No. (2):-

This group includes all the experimental work in coagulation and filtration processes of the water .In the coagulation process five different initial values of water turbidity namely 10, 50, 100, 150, and 200 NTU were tested. It can be concluded that the best values of removal efficiency for all experiments in the coagulation process are obtained by adding dosages of alum with coagulant aid porcelanite .these values are better than those obtain by adding alum only. Fig.(8 to 12)explain the variation of dosage of alum and alum with porcelanite and the efficiency of turbidity removal under initial value of turbidity of(10,50,100,150 and 200 NTU).

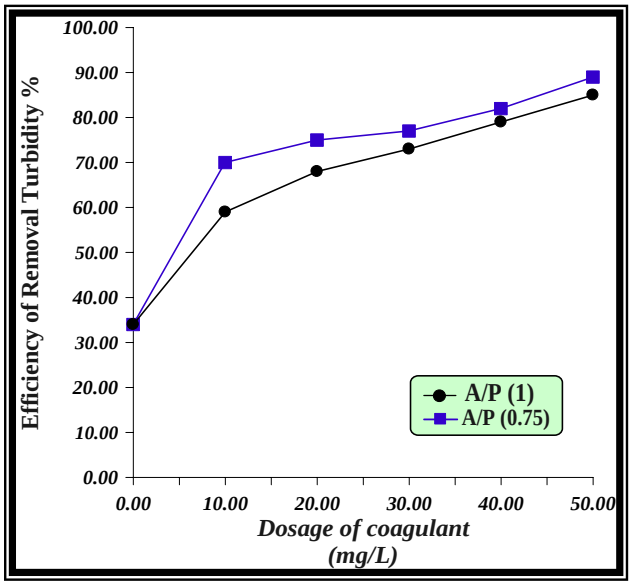

Fig. (8) : Turbidity Removal Versus Different Dosage of A/P under Initial Turbidity of (10 NTU)

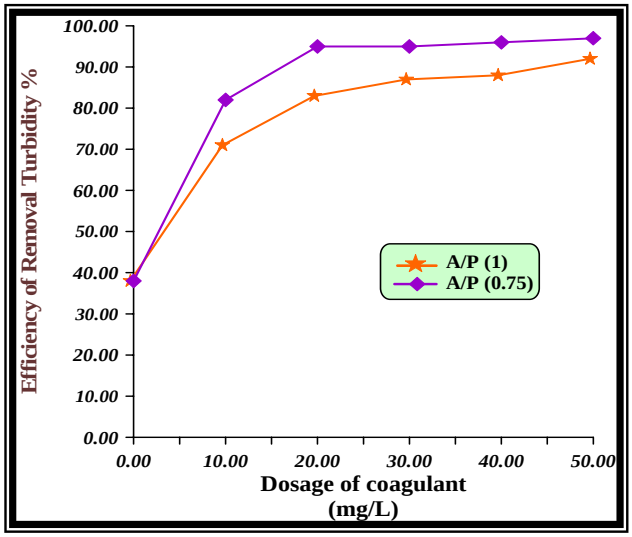

Fig. (9) : Turbidity Removal Versus Different Dosage of A/P under Initial Turbidity of (50 NTU)

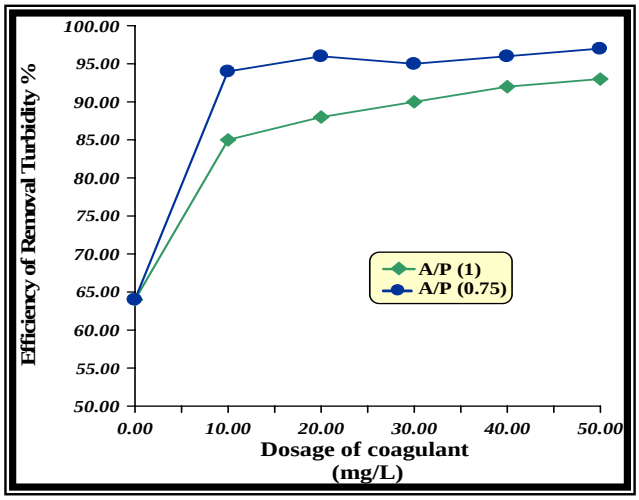

Fig.(10) : Turbidity Removal Versus Different Dosage of A/P under Initial Turbidity of (100 NTU)

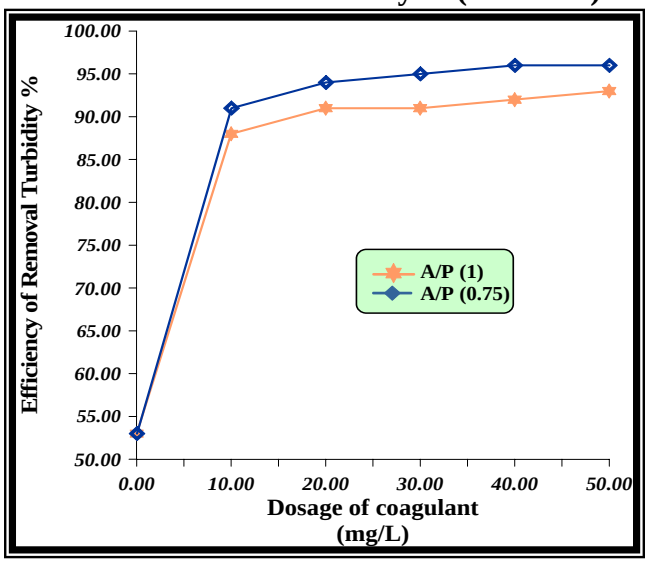

Fig. (11) : Turbidity Removal Versus Different Dosage of A/P under Initial Turbidity of (150 NTU)

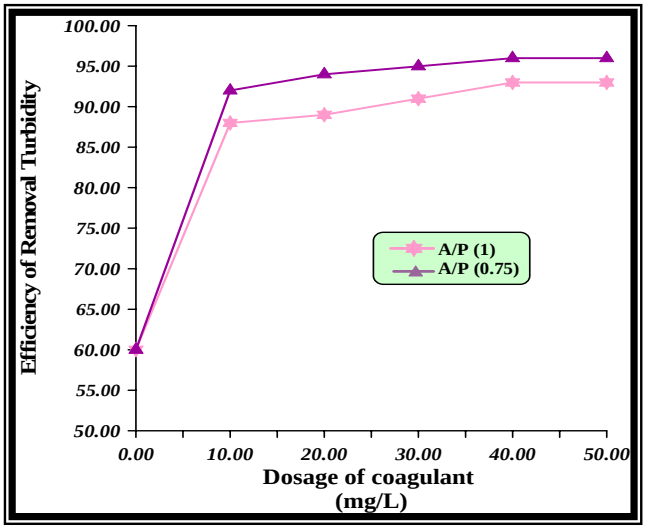

Fig. (12) : Turbidity Removal Versus Different Dosage of A/P under Initial Turbidity of (200 NTU

One can be seen that any increase in the coagulant dosage leads to increase of the removal efficiency of water for five dosages of values between (10-50) mg/L.

In the filtration process many experiments were tested by using alum and alum with porcelanite material in the coagulation process and by using two types of filter in the filtration process. These experiments were tested with different levels of initial turbidity namely of (10,50,100,150,and200 NTU).

Table (3) presents the relation between dosage of coagulants (alum, alum with porcelanite) for two types of filter media (single media , and dual media) with initial turbidity of 200 NTU.

Fig. (13 and 14) show the efficiency of filter of turbidity removal with initial value of 200 NTU after adding alum ,alum with porcelanite respectively. It can be concluded that the using of dual media was better than of using single media by about of 13%.

Table (3): Residual Turbidity Before and After Filtration Process of the Initial Turbidity of (200 NTU)

Run No.	Coagulant type	Dose mg/L	Filter type	Residual Turbidity		Eff. %
				Before filtration	After filtration	
1	Alum	10	Single media	25	6.2	75
2		20		20	4.52	77
3		30		16.22	4.32	73
4		40		14.5	3.66	75
5		50		12.7	2.75	78
6	Alum	10	Dual media	24.2	3.8	84
7		20		21.5	2.35	89
8		30		18.25	1.85	90
9		40		14.33	1.65	88
10		50		13.02	0.98	92
11	Alum+Porcelanite	10	Single media	15.5	3.55	77
12		20		13.5	2.66	80
13		30		11	1.95	82
14		40		9.05	1.66	82
15		50		8.2	1.2	85
16	Alum+Porcelanite	10	Dual media	16.8	2.05	88
17		20		12.25	0.66	95
18		30		10.4	0.4	96
19		40		9	0.5	94
20		50		8.5	0.22	97

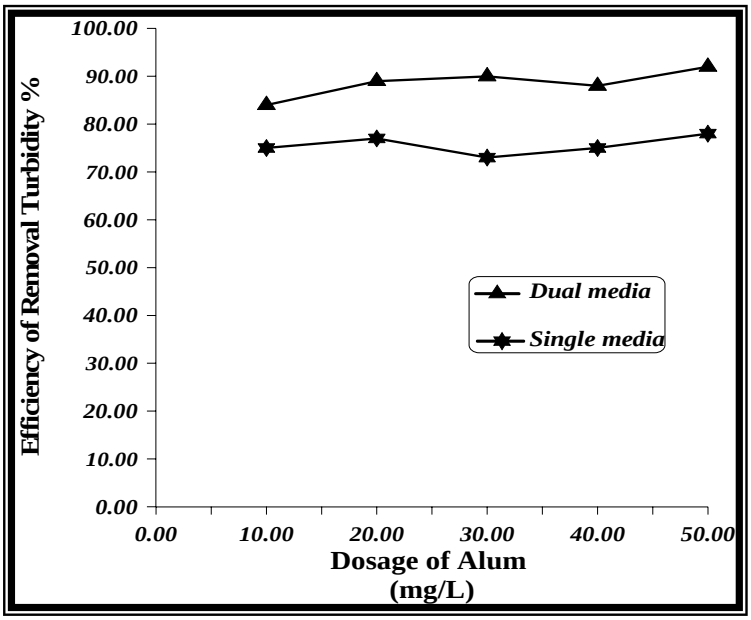

Fig. (13): Turbidity Removal Versus Dosage of Alum of Both Single and Dual filters

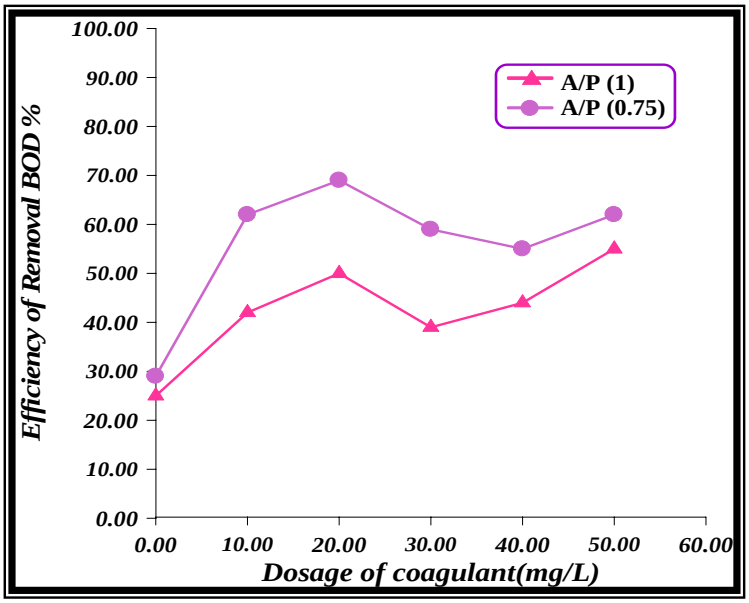

Fig. (14) Turbidity Removal Versus Dosage of Alum with Coagulant Aid Porcelanite of Both Single and Dual Filters

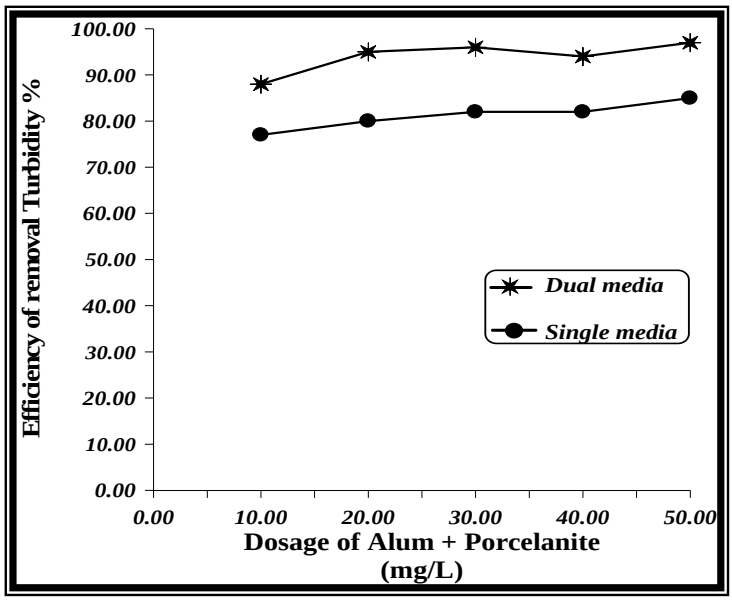

Fig. (15): Removal Efficiency of BOD_5 Versus Dosages of Coagulant

All the pH values of the effluent of the coagulation and filtration processes are within the limits of (6.5 to 8.5) (according to the Iraqi standards, 2001).Analysis of results indicate that the pH of the effluent of coagulation process was slightly less than the influent, while the pH value of the effluent of filtration process was slightly more than the influent.

Experimental Group No. 3

This group includes all the experimental work of coagulation and filtration processes of the wastewater. In order to give inclusive evaluation of performance of coagulation process in treating pollutants of water and wastewater , the present study deals with the removal of organic matters of wastewater by using this process of treatment .

Fig. (15) shows the efficiency of coagulants in removal of the biochemical oxygen demand (BOD_5), the BOD_5 is considered as a measurement of organic matter. The experiments were done by adding different dosages of (alum)and (alum with porcelanite).

The efficiency of alum with coagulant aid of porcelanite material in removal of BOD_5 was better than that the efficiency of removal BOD_5 obtained by using alum only.

Table (5) presents the results of the BOD_5 before and after filtration process . These results are obtained by adding different dosages of coagulant and coagulant aid with the coagulation process , and also by using two types of filter media with the filtration process .

Fig. (16) and (17) indicate that the efficiency of removal of BOD_5 by using (alum)and (alum with porcelanite)respectively, for both single and dual filter media.

It was noted that the efficiency of BOD_5 removal by using alum with coagulant aid of porcelanite material in the coagulation process and when using of porcelanite material with sand as a dual media in filtration process was being better than the efficiency obtained by using alum only with single media filter.

Analysis of results refers that the efficiency by using alum only with dual media was better than the efficiency by using single media by about of (18 %) .

Fig. (17) presents that the efficiency by using alum with coagulant aid porcelanite by using dual media was better than that of efficiency obtained by using single media by about of (25 %)

Table (5): Efficiency of Removal BOD_5 in the Filtration Process

Coagulant type	Dose mg/L	Filter type	Residual BOD		Eff. %
			Before filtration	After filtration	
Alum	10	Single media	52	37	29
	20		79	40	40
	30		89	56	37
	40		85	50	41
	50		61	37	39
Alum	10	Dual media	60	28	53
	20		74	32	57
	30		82	33	60
	40		51	18	65
	50		78	40.5	48
Alum+Porcelanite	10	Single media	77	40	48
	20		60	40	33
	30		48	38	21
	40		49	32	35
	50		104	50	52
Alum+Porcelanite	10	Dual media	75	24	68
	20		56	17	70
	30		78	38	51
	40		77	31	60
	50		71	30	66

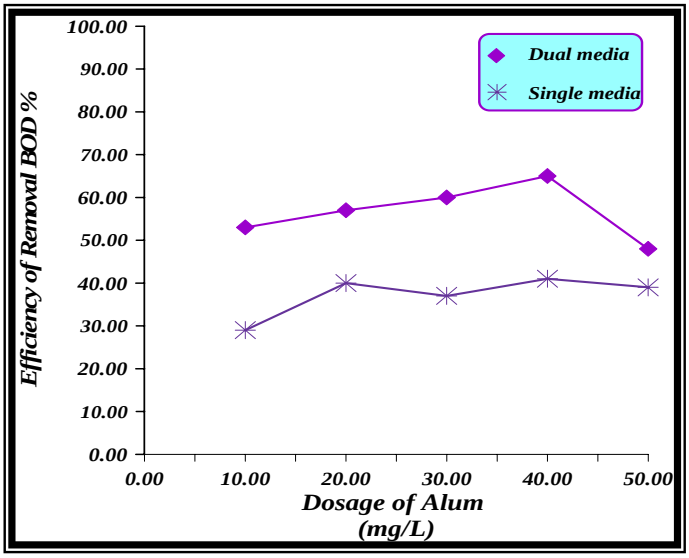

Fig. (16): BOD_5 Removal Efficiency by Filtration Process

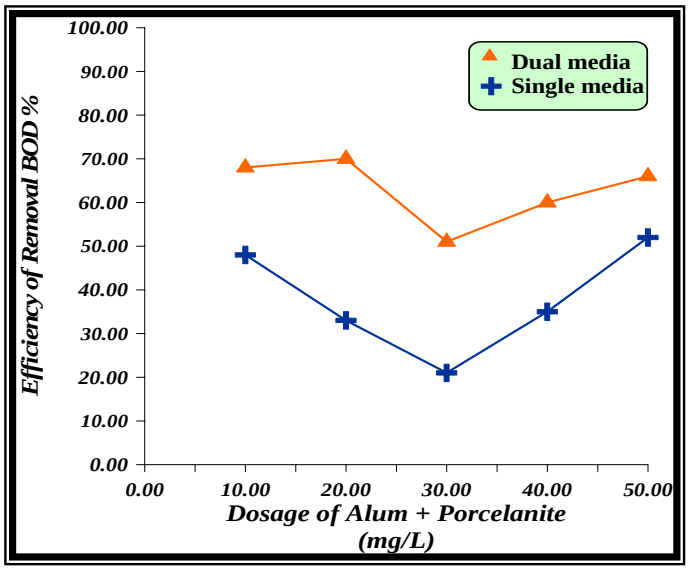

Fig. (17): BOD_5 Removal Efficiency by Filtration Process

Regression Analysis Technique

Data of water and wastewater are arranged in four studies (Efficiency of removal turbidity and BOD_5, with coagulation and filtration processes). The data are analyzed to achieve the main objective of this research. Along with data of factors (independent variables) that are assumed to have a reliable impact on efficiency of removal (initial concentration , pH, temperature , dosage of coagulant, alum to porcelanite ratio ,and sand to the porcelanite ratio) are also analyzed to assess their effects.

In study No.1 in the regression analysis the predicted model was as:

$$\mathbf{Y= 3.897 + 8.15E\text{-}04\ X_1 +0.108\ X_2 -1.197\ X_3 -0.257\ X_4+2.444\ X_5}$$

The model gives a coefficient of determination of (R^2=0.565) to show that 0.565 of the variation in dependent variable was explained by all independent variables appeared in regression equation, and the standard error of the estimate of (5.183).

In study No.2 in the regression analysis the predicted model was as:

$$\mathbf{Y= 124.165+0.357X_1 +1.839X_2 +0.486X_3 -26.400X_4+0.157X_5-52.154X_6}$$

The model gives a coefficient of determination of (R^2=0.798) to show that 0.565 of the variation in dependent variable was explained by all independent variables appeared in regression equation, and the standard error of the estimate of (3.97).

In study No.3 in the regression analysis the predicted model was as:

$$\mathbf{Y= 535.216+0.106X_1 -51.168X_2 -2.993X_3 -48.283X_4-9.8334X_5}$$

The model gives a coefficient of determination of (R^2=0.908) to show that 0.565 of the variation in dependent variable was explained by all independent variables appeared in regression equation, and the standard error of the estimate of (3.68).

In study No.2 in the regression analysis the predicted model was as:

$$\mathbf{Y= 187.105+0.248X_1 -9.996X_2 -0.269X_3 -7.327X_4-8.045X_5-74.819X_6}$$

The model gives a coefficient of determination of (R^2=0.7184) to show that 0.565 of the variation in dependent variable was explained by all independent variables appeared in regression equation, and the standard error of the estimate of (8.904).

Conclusion

1-The best percentage of alum with coagulant aid of porcelanite material was 75 % of alum and 25% of porcelanite material. This percentage was appeared for all dosages used in this study.

2-The Porcelanite gives better efficiency when using with alum to remove turbidity more than efficiency obtained when using alum only and for the different levels of turbidity used in this study.

3-It can be obtained high level of BOD removal efficiency after coagulation process by about (15%) when adding alum with coagulant aid of porcelanite material more than when adding alum only .

4- There is no significant effects on the pH, conductivity and TDS of the treated water as the alum material does not affect these properties for water and wastewater.

5-It can be concluded that the using of dual filter composed of porcelanite and sand gives a better performance than that of single media filter of sand material only .

6- The dual filter was efficient in turbidity removal better than of sand filters. The turbidity of the treated water was less than(3.8 NTU).The maximum turbidity removal efficiency for the sand was (85 %) and for dual filters was (97 %)when using porcelanite as coagulant aid with alum. The maximum turbidity removal efficiency for the sand was (81%) and for dual filters was (92%)when using alum without coagulant aid.

7-The BOD removal efficiency was greater than that of sand filter by about (18 %) more in the dual filter than in sand filters when adding alum in coagulation process, and about (25 %) more in the dual filter than in sand filter when adding porcelanite with alum in coagulation process.

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