Tikrit Journal of Eng. Sciences/Vol.15/No.1/March 2008, (52-62)

BREAKTHROUGH INDEX AND SPECIFIC DEPOSIT IN DUAL FILTERS

Dr. Awatif Soaded Al-Saqqar
Lecturer

Batool Mohammed Al-Bayaty
Engineer

Civil Eng. Dept.
University of Baghdad

ABSTRACT

The dual filter was tested in this study to improve the performance of the filtration process in water treatment plants. Porcelanite rocks were selected to be the dual media with sand in the experimental work. The work required installing a pilot filtration unit in the location of the filters in one of the water treatment plants. The pilot filtration consists of three plastic column filters, acting parallel and simultaneously. The first contains 70 cm sand, the second and third were dual filters (porcelanite with sand) of different types. The dual media was tested at different filtration rates (5, 7.5, 10, and 15 m/hr). The results showed that the dual filters had better performance than sand filters and reduced the specific deposit (σ) and the breakthrough index (BI). In the dual filters the specific deposit was about (16 to 65 %) less than in sand filters and the breakthrough index (BI) was specified weak for rates 5 and 7 m/hr, light at 10 m/hr, and medium at 15 m/hr.

KEYWORDS: porcelanite rocks, dual filter, breakthrough index, specific deposit, water treatment.

INTRODUCTION

Filtration is the most common process for the treatment of surface water, which is the fundamental system in a water treatment process train, [1]. The ideal filtration medium should have such a size and material that will provide a satisfactory effluent, retain the maximum quantity of solids, and is cleaned with a minimum volume of wash water [2] .In multi-media filters, a modification must be made by using an equivalent grain size (d_{eq}) that can be approximated as follows

$$d_{eq}=X_1d_1+X_2d_2+X_3d_3 \qquad \text{......... (1)}$$

d_1, d_2, d_3 = mean size of individual media.

X_1, X_2, X_3 = percentage by volume of individual media respectively [3].

Breakthrough Index (BI)

The breakthrough index is based on filter media size, bed depth, filtration rate and head loss. These factors together form the following formula:

$$BI = V\ d_{eq}^{\ 3}\ H / L \qquad \text{......... (2)}$$

BI = Breakthrough Index (implicit units). V = filtration rate, cm/min.
H = head loss at end of run, m.

L = bed depth, m.

The higher this BI is, the more stress has to be applied on the floc particles on their way through the filter. The classification of floc that could take these stresses on a matching scale is as follows:

BI=16 is very strong, BI=8 is medium, BI=4 is light, and BI=2 is weak.

If the BI is higher than the assessed floc strength, then the flocs will be sheared in the filter. This will result in particle release and filter breakthrough. The final water turbidity will rise. To keep the weakest particle held in its place, the stresses applied have to be as small as possible. For good filtration the BI should be low [4].

Specific Deposit (σ)

The specific deposit is defined as the volume of suspended solids removed per unit filter volume [5] .This term is difficult to be evaluated correctly because the exact relationship between measurements of floc concentration in suspension and the floc volume is not known. An attempt was made by Mohanka to determine a conversion factor to change the value of (σ) in weight of Fe^{+3} per volume as calculated in his experimental work to a (σ) value in volume per volume according to the definition. This was done by collecting the backwash water and observing the volume of deposited flow in an Imhoff cone [6].

Crittenden, indicated that the rate of head loss accumulation is best determined through a pilot study [7] . It can be used to determined the specific deposit that can be accumulated before reaching the limiting head as follows:

$$d_{eq}=X_1d_1+X_2d_2+X_3d_3 \qquad \text{.........(1)}$$

d_1, d_2, d_3 = mean size of individual media.
X_1, X_2, X_3 = percentage by volume of individual media respectively[3].

It can be used to determined the specific deposit that can be accumulated before reaching the limiting head as follows

Tikrit Journal of Eng. Sciences/Vol.15/No.1/March 2008, (52-62)

$$\sigma_{HL} = \frac{H_T - h_{l,o}}{k_{HL}} \quad \text{........... (3)}$$

$$k_{HL} = 1.76*10^{-6}\,\frac{L}{d_e} \quad \text{...........(4)}$$

σ_{HL} = specific deposit at time of limiting head, mg/l

H_T = limiting head, m.

$h_{l,o}$ = initial head loss of the clean bed, m

k_{HL} = head loss increase rate constant, .m/mg/l.

L = filter bed depth, m

d_e = effective size of the medium, m

During a run the filtration coefficient (λ) changes due to the accumulation of deposits in the pore spaces of the filter. Many equations have been proposed for the relation between λ and σ. Shekhtman and Lerk's model can be obtained from the relationship as follows:

$$\lambda = \lambda_0 (1 - \sigma_{HL} / \varepsilon_0) \quad \text{.........(5)}$$

λ = filtration coefficient

λ_0 = initial filter coefficient

ε_0 = porosity of clean bed

It is clear from this equation that the filtration coefficient decreases as the specific deposit increases [8]

FILTER MEDIA

Sand

The specifications of the sand media used in all filters of the water treatment plants in Iraq are durable, hard, spherical form, and of density 2500 to 2670 kg/m^3. It must be of no organic material content, the sulfate does not exceed 1 %, and the silica not less than 90 % [Iraqi specification no. (1555) in year 2000].

Porcelanite Rocks

Porcelanite rocks in Iraq, is from an industrial bed of (0.5 to 1.3 m) thickness in the Safra, and Trafawi site of the Jeed formation in Al-Rutba region, western of Iraq. Rocks of these deposits are composed of medium ordered crypto and microcrystalline opal-CT, associated with authigenic quartz, carbonates, clay minerals, halite, and apatile. Porcelanite rocks are largely composed of sponge spicules (pores) and some other siliceous micro fossils (diatoms and radiolarian) as well as silicified forminifera and nannoplankton[9]

Some of the chemical and physical analysis for the porcelanite samples is shown in Table (1)

EXPERIMENTAL WORK

A pilot filtration unit was installed in the location of the filters in Al-Wathba Water Treatment Plant in Baghdad city. Fig.(1) is a schematic representation of the pilot filtration unit that was installed in this plant. The pilot filtration unit consists of:

- Galvanized cylindrical tank of capacity 500 L, was set at a distance of (3m) above ground level to achieve the required head of flow; the tank was filled by pumping water from the settling tank of the plant .
- Three plastic columns were designed and constructed to run in parallel with down flow direction, these columns are (10 cm) in diameter according to Robeck(10) and AWWA Manual(11) and (180 cm) in length. The arrangement of layers for the three down flow filters are shown in fig.(2).for set no.(1) and fig(3) for set no.(2)The height of the filter media inside these columns as shown was 70 cm .
- Manometer Board fitted on it 12 plastic tubes was used to record the head of water at different depths for each filter

The installation of the pilot unit in the location of the existing filters , is to use the same influent water of these filters (the effluent from the settling tank) so the results will be more logic ,acceptable and nearby suited for the existing plant .

The filtration rate in Al-Wathba Water Treatment plant is about 5 m/hr and it can be increased if any expansion is required in the future .So the filtration rate was tested in the experimental work to reach 7.5, 10, and 15 m/hr

The different types of dual filters used in set no. (1 and 2) were designed according to Eq. (1). Fifteen runs were performed as down flow filtration in order to compare the performance of the sand filter and dual filters.

RESULTS

Turbidity

The influent to the filter columns is taken from the settling tank in Al-Wathba water treatment plant . The average turbidity of this water ranged between 6 NTU and 15.5 NTU as shown in Table (2). It could be observed that the filters were efficient in turbidity removal with in the range of 82 - 96 % for set no.(1) and 73 - 85 % in set no.(2) The turbidity of the treated water in all runs did not exceed 3 NTU. It is worthwhile to indicate that the quality of the effluent from pilot filter units is often significantly more than that produced by actual filters[12]

Specific Deposit (σ)

Table (3) shows the specific deposit for the three filters in set no. (1 and 2), calculated at running time (8 hrs). Figures (4) and (5) show the average specific deposit for the three filters at different filtration rates in the two sets, the calculations were based on Equations (3) and (4).

Increasing the filtration rate caused an increase in the specific deposit, and in the dual filters it was less than in the sand filter. In the dual filters the specific deposit was about (16 to 65 %) less than the sand filter which is clear from figures (4 and 5),describing that the pores in the dual media may have large volumes to retain larger amounts of suspended solids. As the specific deposit in the dual filters in the two sets was less than in sand, indicating that the voids are not filled and can retain more solids, leading to a better filtration process so the filtration coefficient will increase.

Breakthrough Index (BI)

Tables (4) and (5) show the breakthrough index for the three filters in set no. (1 and 2), respectively. The breakthrough index (BI) was calculated at different depths for each filter using different filtration rates. The calculations were based on Equation (2), where deq for the dual filter was determined from Equation (1).

These Tables show that the breakthrough index decreased as the depth increased. Also These tables show that the breakthrough index increased when the filtration rate and running time increased. Considering depth 70 cm, all filters in set no. (1) had a weak BI at filtration rate 5 m/hr which increased to a light BI at 10 m/hr and medium at 15 m/hr.

Filter no.(3) in set no.(2) showed a high BI, this is due to the mixed granular particle size used in the filter (high equivalent grain size). Filter no (1 and 2) in the same set had a weak BI at 5 and 7.5 m/hr filtration rate.

As mentioned previously, it is better to have a weak BI in the working filters, therefore it is clear that filter no.

(2) in the two sets, had the lower BI, indicating that dual filters can hold the most weak particles in its voids.

This kind of dual media may improve the performance of the existing sand filters in water treatment plants.

CONCLUSIONS

This study introduced a dual filter to improve the filters performance in water treatment plants both in breakthrough index and specific deposit. To approach this aim a local material known as porcelanite was used as the dual filter. From the experimental work of the pilot filtration unit this filter gave the following results:.

1. The turbidity removal efficiency decreased with increasing the filtration rate .Dual filters produced water with turbidity not exceeding 3NTU.

2. Increasing the filtration rate caused an increase in the specific deposit. In the dual filters the specific deposit was about (16 to 65 %) less than in sand filters, where this will lead to an increase in the filtration coefficient.

3. The breakthrough index increased when the filtration rate and running time increased. When filtration rate increased from (10 to 15 m/hr) at the same running time the BI in the dual media increased from (3 to 8) and in sand from (4 to 13), respectively. Overall BI in the dual and sand filters were classified as weak for rates 5 and 7.2 m/hr, light for rate 10 m/hr, and medium for rate 15 m/hr, and the dual filters had the lower BI values.

4. To improve the performance of the existing filters in water treatment plants changing the sand media may help. From the above results filter no. (2) in the two sets had the better performance (10-20 cm of porcelanite on top of the sand could be used).

REFERENCES

1. Kawamura, S., (1999). “Design and operation of high-rate filters”, J.AWWA, Vol. 91, No. 12: (77-90).
2. Steel, E. W., and McGhee, T. J., (1984). “Water Supply and Sewerage”, fifth edition, McGraw-Hill International Book Company.
3. Conley,W. R. and Hsiung, K., (1969). “Design and Application of Multimedia Filters”, J. AWWA, Vol. 61, No. 2: 97.

4. Unit Standard 18452, (2002). “Describe drinking water treatment filtration processes, and management of critical points”, National Diploma in Drinking Water Assessment, Tutor Notesand Home Assignment, Otago: Polytechnic.
5. Fox,D,and Cleasby,J.L. (1966).“Experimental Evaluation of Sand Filtration Theory”, J. Sanitary. Eng-ASCE, Vol. 92 No. SA5: 61
6. Mohanka, S. S., (1969). “Theory of Multilayer Filtration”, J. Sanitary. Eng-ASCE, Vol. 95, No. SA6: (1079-1093).
7. Crittenden, J,C,Trussell.R. R., Hand, D. W., Howe, K. J., and Techobanoglous, G., (2005). “Water Treatment: Principles and Design”, 2nd edition, MWH
8. Al-Ansary, H.A.,(1998) “Purification of Water by using Porcelanite as a local material “, M.Sc Thesis, University of Technology.
9. محمد، إبراهيم قاسم، (1993). "معدنية وصخارية وبيئات الصخور الطينية والسيليسية في غرب العراق". رسالة دكتوراه، كلية العلوم، جامعة بغداد
10. Robeck, G. G. and Woodward, R. L., (1959). “Pilot Plants for Water Treatment Research”, J. Sanitary. Eng-ASCE, Vol. 85, No. SA4: 1.
11. AWWA Manual of Water supply practices-M37,(2000). “Operational Control of Coagulation and Filtration Processes “. 2nd edition.
12. Kawamura S., (2000). “ Integrated Design and operation of Water Treatment Facilities”,2nd edition ,John Wiley and Sons, New York.

Tikrit Journal of Eng. Sciences/Vol.15/No.1/March 2008, (52-62)

Table (1)Chemical and physical analysis for the porcelanite samplesof Traifawi site H_3[9]

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					

Table (2) Turbidity Removal Efficiency For the Filters in set no. (1 and 2)

Run No.	F. R. m/hr	Average Influent Turbidity NTU	Turbidity Removal Efficiency %		
			Filter No. (1)	Filter No. (2)	Filter No. (3)
Set No. (1)					
1	5	10.67	95	96	95
6		13.71	93	92	92
7		10.31	86	87	87
3	10	7.49	90	91	91
5		7.9	90	90	88
8		15.5	82	82	83
2	15	6.33	90	93	93
4		8.25	90	90	90
9		10.95	85	86	85
Set No. (2)					
1	5	6.26	82	81	81
3		13.25	82	81	78
5		14.6	79	79	79
2	7.5	10.0	80	81	80
4		8.0	85	81	79
6		7.04	75	73	73

Table (3) The specific deposit for the three filters in set no. (1 and 2)

Run No.	F. R. m/hr	Specific deposit (σ) (mg / l)		
		Filter No. (1)	Filter No. (2)	Filter No. (3)
Set No. (1)				
1	5	58	52	51
6		64	36	10
7		64	43	38
3	10	64	70	63
5		126	100	85
8		99	73	82
2	15	140	103	101
4		134	115	133
9		321	140	158
Set No. (2)				
1	5	58	19	18
3		82	31	18
5		41	19	26
2	7.5	58	44	44
4		87	44	35
6		111	69	53

Table (4) The breakthrough index (BI) for the three filters in Set No. (1)

Run No.	F. R. m/hr	Run time hr	BI at depth 10 cm (Top layer)			BI at depth 40 cm (Middle layer)			BI at depth 70 cm (Bottom layer)		
			Filter No. (1)	Filter No. (2)	Filter No. (3)	Filter No. (1)	Filter No. (2)	Filter No. (3)	Filter No. (1)	Filter No.(2)	Filter No. (3)
1	5	29	13	9	10	4	3	3	2	2	2
6		30	12	10	10	4	3	3	2	2	2
7		8	4	4	3	3	1	1	1	1	1
3	10	25	22	26	31	9	9	10	6	5	6
5		16.5	32	29	30	10	9	10	6	5	6
8		8	11	10	11	5	5	5	4	3	4
2	15	16	37	46	43	15	18	19	11	11	12
4		18	38	43	51	16	16	19	11	11	12
9		8	30	24	33	18	12	12	13	8	9

Table (5) The breakthrough index (BI) for the three filters in Set No. (2)

Run No.	F. R. m/hr	Run time hr	BI at depth 10 cm (Top layer)			BI at depth 40 cm (Middle layer)			BI at depth 70 cm (Bottom layer)		
			Filter No. (1)	Filter No. (2)	Filter No. (3)	Filter No. (1)	Filter No. (2)	Filter No. (3)	Filter No. (1)	Filter No. (2)	Filter No. (3)
1	5	10	4	3	4	2	1	2	1	1	3
3		10	6	3	3	2	1	2	1	1	3
5		10	4	3	3	1	1	2	1	1	3
2	7.5	10	6	5	8	3	3	4	2	2	8
4		10	12	5	7	4	3	4	3	2	7
6		10	12	9	9	4	3	5	3	3	8

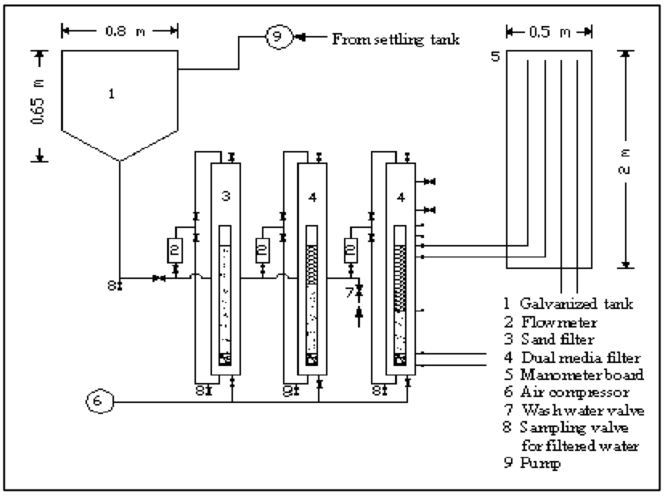


Fig.(1) Schematic diagram of the pilot filtration unit

Fig.(3) Arrangement of layers of filter columns for set no. (2)

Fig.(2) Arrangement of layers of filter columns for set no. (1)

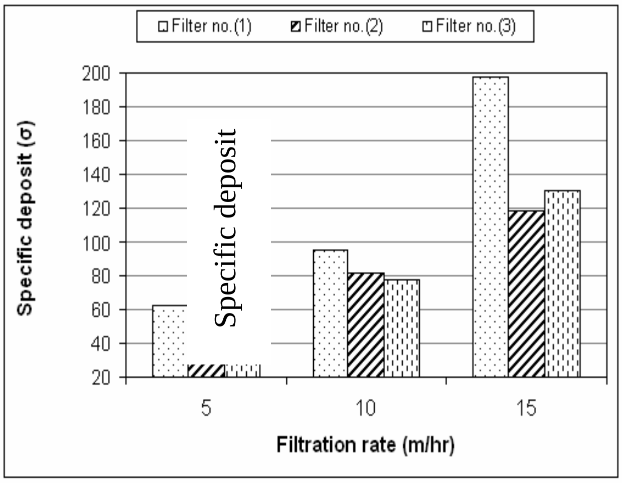
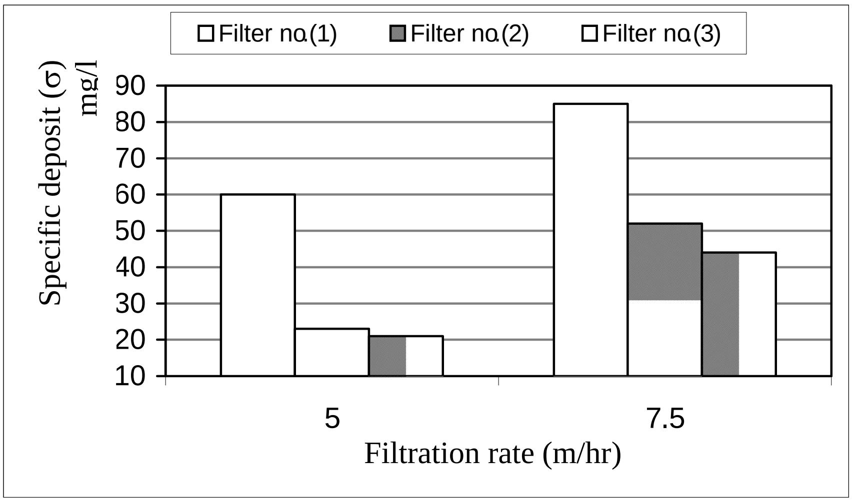


Fig (4) The average specific deposit for the three filters at different filtration rates in Set No. (1)



Fig(5) The average specific deposit for the three filters at different filtration rates in Set No. (2)

مؤشر الاختراق و تراكم العوالق في المرشحات الثنائية

د.عواطف سؤدد الصقار
مدرس

بتول محمد البياتي
مهندس

قسم الهندسة المدنية
جامعة بغداد

الخلاصة

في هذه الدراسة تم اختبار المرشح الثنائي لتحسين أداء عملية الترشيح في مشاريع تصفية المياه.اختيرت صخور البورسيلينايت لتكون وسط ثنائي مع الرمل في هذه الدراسة لتحسين أداء عملية الترشيح في مشاريع تصفية المياه. تطلب العمل إنشاء منظومة ترشيح في موقع المرشحات لإحدى محطات التصفية. تتكون المنظومة من ثلاث أعمدة ترشيح تعمل بشكل متوازٍ وفي آن واحد بحيث احتوى الأول على 70 سم من الرمل والثاني والثالث على مرشح ثنائي من البورسيلينيايت والرمل وبأعماق مختلفة. فحصت أنواع مختلفة من المرشحات ة الثنائية لمختلف معدلات الترشيح (10,7.5,5و16)م/ساعة. أظهرت النتائج بان المرشحات الثنائية كفوءة في تقليل تراكم العوالق(σ) و مؤشر الاختراق (BI) من المرشحات الرملية. تراكم العوالق في المرشحات الثنائية كان حوالي (16 إلى 65 %) اقل من مرشحات الرمل . ومؤشر الاختراق صنف ضعيف لمعدلات ترشيح (5 و 7.5 م/ساعة)، خفيف لمعدل ترشيح 10 م/ساعة، ووسط لمعدل ترشيح 15 م/ساعة.

الكلمات الدالة: صخور البورسيلينايت- المرشحات الثنائية- مؤشر الاختراق- تراكم العوالق- معالجة المياه.