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Comparative experiments on the technological performance of disc filters

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Abstract. The filtration performance of JY disc filters was compared with that of Arkal disc filters when a parallel filtration system was designed under lab-scale devices. The comparisons of working and backwash performance were made for different filtration level. The experimental results showed that the two kinds of filters had similar process performance and effluent water quality under the same experimental condition. JY filter has higher filter performance index (FPI) than Arkal disc filters with the micron rating from 20 to 55μm discs, on the other hand, FPI value of JY filter has lower FPI than Arkal disc filters with the micron rating from 100 to 200μm discs. The removal rates of suspended solid(SS) for both filters vary in the range from 64% to 91.5%, moreover, the mean removal rate of SS for JY and Arkal filter was 78.2% and 79% respectively. The removal rates of turbidity were lower than 13% and the mean removal rate of turbidity was 7% for both filters. The critical backwash time and the critical backwash water loss for both filters were 5 seconds and 15 litres respectively.

1. Introduction

Disc filters have been applied on many industries. Compared with other filtration methods, the disc filters have the features of high filtration accuracy, adjustable, low energy consumption vast suitable range and less covered area etc. The automatic switching and quickly self-cleaning process to a completely new state are realized in disc filers. Currently, disc filters are the advanced technology in water treatment field [1, 2, 3].

In this paper, the filtration performance of JY disc filters made in China) was compared with that of Arkal disc filters made in Israel). By adding various amounts of reagents into discs with different filtration level, we compared the difference of both filters in parameters such as turbidity, suspended solids, periodic quantity of water produce, FPI, head loss, flux, and backwashing and so on. By sampling discs of the filters, the mechanism of groove's clogging was initially discussed. Moreover, backwash performance of disc filters was studied. The experimental results can be taken as a reference in practice.

2. Experimental

2.1 Analytical Methods

The turbidity of water sample was determined using a portable turbid meter (Model 2100P, Hach Company, and Loveland, CO, USA). The results were reported in cephalometric turbidity units (Ntu). Standard methods [4] were used to measure the value of suspended solids (SS). Supernatant was filtered with 0.45μm filter after sample was taken from the water tube. The head loss was measured by piezometer (0.5-2.5Mpa, Lei-da Instrument Factory, Zhejiang, and China) and the filtering velocity was measured by glass rotameter (Model LZB-50, Yuyao, China).

2.2 The evaluation parameters of filters performance

In general, filter performances are considered to be in better condition when the time of filtration is longer and head loss is less. Existing filter evaluation indexes are mainly FPI formula, FI formula method, F formula, SC formula, and JP formula method. The filtration performance can be partially evaluated by above indexes, but they are not suitable for evaluating the filtration performance of disc filters. Water quality is judged by turbidity in the traditional evaluation method, however, the disc filter is a kind of filter with mechanic sieving as a main role, which has a low removal rate of turbidity. In this paper, FPI is adopted as the evaluation parameter of filters performance [5].

$$FPI = \frac{VT}{H_t} \tag{1}$$

Where: V—— Filtration velocity, m/h; T—— Filtration time, h; H_t—— Head loss in the end of filtration, m.

The index of FPI has no dimension and the filtration velocity necessary for computing FPI is the average filtration velocity for a whole filtration cycle. The index of FPI is the ratio of cyclic water production and head loss in the end of filtration, which is used to evaluate the filtration performance. The bigger the FPI value, the better the filter performance. It means the quantity of water production will be obtained at best when the energy is consumed at least. However, the index of FPI cannot involve filter evaluation with water quality evaluation in the influent and effluent. To some extent, FPI can reflect the performance of the filter.

2.3 The design of experimental apparatus

Since disc filter has a larger flow of work, laboratory cannot meet such conditions of work. The methods of decreasing disc number were adopted in order to reduce flow. The original disc filter load height is 22.95 cm and the current disc filters load height in the test is 6.00 cm. Consequently, the flow rate of current filter in test is one fourth that of the original filter. In this way, the basic operating conditions, such as pressure, filtration rate, were consistent with actual operating conditions. The diameter of both filter disc is 11.6 cm and the working area is 0.02185 m^2. The surface area ratio of current filtration and original filtration is 0.26. The comparisons of operating parameters between the current filter and the original filter are shown in table 1. The comparisons of disc's number of both filters in fieldwork are listed in table 2. It is found from table 2, each slice of Arkal disc is a little bit thinner and flatter than that of JY disc.

Table 1 The comparisons of operating parameters of filters

Operating parameters	Original filter	Current filter
Working pressure	80~800KPa	80~280KPa
Backwash pressure	280~750KPa	150KPa/280KPa
Backwash time	5~20s	1~10s(modification)
Backwash water volume	3~30L	1~20L(modification)
Backwash flow	8m^3/h	1.7 m^3/h
head loss	1~80KPa	1~80 KPa

Table 2 The comparisons of disk's number of both filters in fieldwork

Different disc level(μm)	20	55	100	200
JY disc filters slices)	101	120	60	38
Arkal disc filters slices)	104	120	65	40

Diatomite has the properties of being easily dispersed into small size, stable solution, small pilot error, whereas activated carbon has relatively larger size and is suitable to simulate poor water quality. Therefore, diatomite is used in the filter operation with the micron rating from 20μm to 55μm, meanwhile, granular activated carbon was added in the filter operation with the micron rating from 100μm to 200μm. The parallel system of filters was designed under the condition of lab owing to the comparative test.

3. Comparison of filters performance with different precision discs

In this paper, comparisons between JY disc filters and Arkal disc filters are made in these areas of filtration effects, head loss-time chart, flow-time chart, effluent quality, filter discs performance and backwash property[6].

3.1 Comparison of filtration effects

Table 3 Influent/effluent water quality parameters during operation

Precision	Filter	Influent turbidity (Ntu)	Effluent turbidity (Ntu)	Influent SS_0 (mg/L)	Effluent SS_1 (mg/L)	Cyclic water production (m^3)	FPI	Removal rate of turbidity (%)	Removal rate of SS (%)
20μ	Arkal	0.50	0.48	4.5	0.6	0.66	15.68	4.0	86.6
	JY	0.51	0.49	4.5	0.5	0.56	18.60	3.9	88.9
	Arkal	1.55	1.45	8.8	0.8	0.2	4.83	6.5	90.0
	JY	1.53	1.43	8.8	0.8	0.16	5.31	6.5	90.0
	Arkal	1.6	1.46	10.4	1.0	0.18	3.77	8.1	90.4
	JY	1.55	1.40	10.5	0.9	0.12	3.98	8.8	91.5
55μ	Arkal	5.80	5.40	49.4	14.1	0.7	9.14	6.9	71.5
	JY	5.95	5.50	49.6	14.6	1.4	8.57	7.6	70.6
	Arkal	6.40	6.05	76.4	23.2	0.4	5.67	5.5	69.6
	JY	6.50	6.11	77.1	25.2	0.56	6.65	6.0	67.4
	Arkal	10.70	10.20	99.1	34.6	0.36	4.20	4.6	65.1
	JY	10.60	10.26	99.5	35.9	0.56	6.52	3.2	63.9
100μ	Arkal	7.43	6.50	105.5	46.2	6.4	138	12.5	56.2
	JY	7.40	6.64	106.2	45.1	4.5	90	10.3	57.5
200μ	Arkal	8.27	7.60	130.2	60.7	11	110.86	8.1	53.3
	JY	8.63	7.86	129.9	59.1	10	94.78	8.9	54.5

Under different influent quality, filtration properties with different precision discs (20, 55, 100, 200μm) were contrasted. The results are listed in table 3.

In common, the removal rate of turbidity is low for both filters with the micron rating from 20 to 55μm discs. On the whole, the operation effectiveness of 55μm filter is quite opposite to that of 20μm filter. For JY filter (55μm), the volume of cyclic water production and the value of FPI is larger (48 mg/L exceptions), whereas it's suspended solid (SS means suspended solid) removal rate is lower than that of Arkal filters. The results show the connection between the volume of filtered water per cycle and effluent effect was inverse for disc filters.

The operation effectiveness of 100μm discs is similar to that of 200μm discs. For Arkal filters, the volume of filtered water per cycle and the value of FPI is larger, whereas its suspended solid removal rate is lower than that of JY filters. For JY filters, the cycle of water production is shorter, the volume of filtered water per cycle and the value of FPI is smaller, whereas its suspended solid removal rate is higher than that of JY filters. Similarly, the removal rates of turbidity are very low for both disc filters. The removal of turbidity is related to the absorption of van der Waals force and Coulomb force [7], so that the role of contact flocculation is very weak for disc filter.

3.2 Comparison of head loss-time chart and flow-time chart

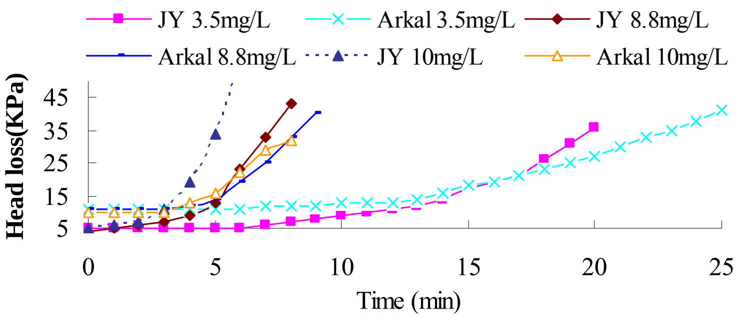

Figure1 Head loss chart with 20μm disc

The operations of four kinds of filtration rating were done in the experiment, however, the tendency were similar for head loss-time charts and flow-time charts. In order to save space, we just take the disc of one kind of filtration rating as an example. Head loss-time chart and flow-time chart of JY and Arkal filters were measured (as shown in figure 1 and figure 2) when dosage of suspended solids in the influent was 3.5 mg/L, 8.8 mg/L, 10 mg / L, respectively.

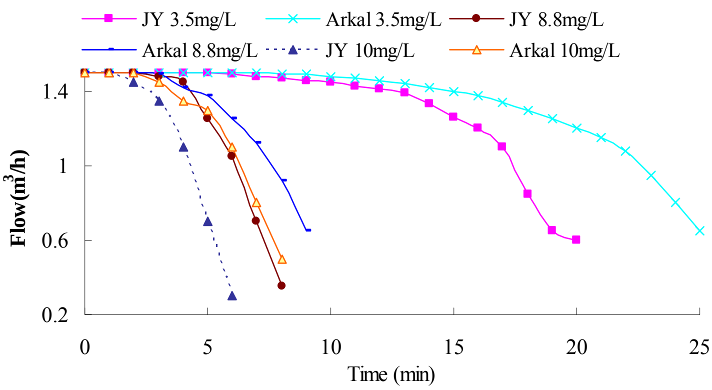

Figure 2 Flow-time chart with 20μm disc

Obvious conclusion from figure 3 and figure 4 are as follows. For the same kind of filter, the lower the suspended solids in the influent, the longer the water making cycle. Under the same conditions in the influent, the cycle of Arkal filter is longer than that of JY filters. There exists inflection point in the head loss-time and flow-time graphics, and inflection point is the formation of relatively stable conditions, namely the pressure is about 0.015 MPa, flow is about 1.3m^3/h. The head loss-time and flow-time curve of 55, 100, 200μm disc filter are basically similar to those of 20μm disc filter. Only the value of head loss and flow is different when a turning point is come into being.

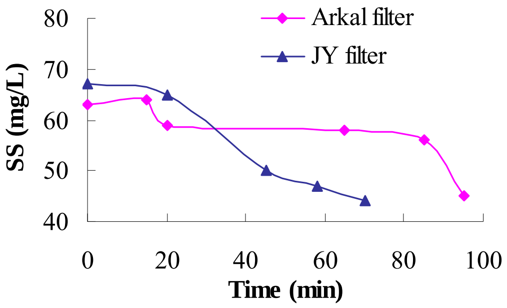

Figure 3 SS change with 100μm disc

3.3 Comparison of changes in effluent quality

In order to compare the changes in effluent quality of JY and Arkal filters, the experiments of both filters have been made with the micron rating 100μm discs. The reason to select 100μm filter as an example is that its longer water cycle can facilitate the sample analysis. The suspended solids in the influent are controlled as the scope of 111.0±2.0mg/L, and the changes of effluent SS are shown in figure 4. From figure 4, the quality of effluent is gradually improved in both filters, and a faster decline of SS value is found in the effluent of JY filter. At the same time, the formation of sieve layer can be observed through transparent cylinder. It is obvious that in-surface filtration exists in the filtration mechanism of discs filter, namely filter cake factors.

These phenomena can be explained as follows: in the early stages of filtration, a bigger gap existed in relatively clean discs, therefore only relatively larger particles were blocked; in the middle stages of filtration, the surface aperture of disc was monished, some middle-size particles were also closured; by the end of filtration, since internal closure of filter has not yet fully played the role, the surface will continue to play a role in filtration, causing the surface to the lower deck over the closure of impurities, resulting in seriously intercepting of filtration channel. At that time, the aperture of filtration was further reduced, thus product flow was reduced and effluent quality was improved.

For disc filter, the frequency of backwash will be reduced when the cycle of water production is long in the whole operation process, which means energy consumption will be reduced. From figure 4 and results in 3.2, we can observe that the energy consumption of Arkal filter is low and the effluent quality is poor. Contrarily, the energy consumption of JY filter is high and the effluent quality is fine.

4. The determination of filter discs performance

4.1 The cross test

Discs with the micron rating 55μm were selected as an example to make cross-test. Namely the discs of JY filter are put into Arkal filter, contrarily, the discs of Arkal filter are put into JY filter in the operation. The tendency of pressure-time curve and flow-time curve in the experiments are similar to those of figure 2 and figure 3. The corresponding data is listed in table 4, obvious difference doesn't exist after cross tests are done. The results show that disc is the main factors to affect the filtration performance.

Table 4 Results of cross test

Operation	Filter	Influent turbidity(Ntu)	Effluent turbidity(Ntu)	Influent SS (mg /L)	Effluent SS (mg /L)	Periodic product flow (m^3)
Normal test	Arkal	17.7	16.0	106.7	53.6	0.37
	JY	17.6	16.1	107.8	57.8	0.74
Cross test	Arkal	17.6	16.0	106.5	53.5	0.39
	JY	17.5	16.0	107.2	58.0	0.75

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4.2 Analysis of disc surface observation

Before the backwash performance of disc filters was produced, from the observation of disc surface, it is found that the contaminated site was focused on the outside disc of Arkal filter, while the contaminated site was extended to the internal disc of JY filter and was not penetrated yet. Combined cyclic water production and water quality data with disc surface observation, it can be concluded that the filtration mechanism of Arkal filter is mainly in-surface filtration, while the filtration mechanism of JY filter is not only in-surface filtration but also in-depth filtration [8, 9].

5. Comparison of backwash property

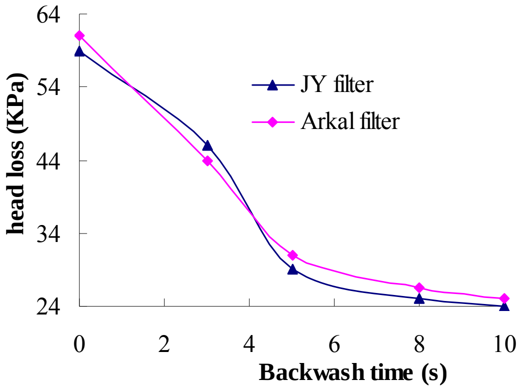

Figure 4 backwash head loss-time with 100μm disc

When the spring's pressure is increased to some extent, it means the discs are failed and backwash starts. The parameters, such as time, water consumption, and the recovery of the initial pressure are recorded in backwash experiments. After backwash started, critical backwash time could be measured when the initial pressure has reached 100% recovery [10]. Backwash head loss charts of Arkal filter and JY filter with 100μm disc are shown in figure 4. The figure shows that the shapes of backwash head loss charts are almost same for both filters. The head loss threshold of JY and Arkal filter is 59kPa, 61kPa when filter backwashing started. Collected at different moments, the backwash effluent quality is measured and the disc cleaning effects are observed. The results are as follows:

① for filter discs with the same micron rating, the shape of backwash curve is alike as the initial backwash flow is same. ② Minimum pressure of start-up backwash: 0.25 MPa for Arkal filter and 0.15 MPa for JY filter. ③ the critical backwash time for both filters are 5 seconds, then head loss is resumed to initial value. After backwash is completed, both filter discs are clean and bright. ④ the critical backwash water loss for both filters are 15 liters. When backwash is finished, the effluent water quality is the same as influent water quality.

6. Conclusion

(1) Both filters have general similar craft performance. A reliable backwash time is greater than 5 s, and water loss is about 15 L. The recovery rate on initial pressure is 100%.

(2) Turbidity removal rate is relatively low, and around 10% to 20%. The removal of turbidity is related to the absorption of van der Waals force and Coulomb force, so that the role of contact flocculation is very weak for disc filter.

(3) Suspended solids removal rate is relatively stable for both disc filters, such as 20μm filter about 90%, 55μm filter about 70%;

(4) It can be concluded that the filtration mechanism of Arkal filter is mainly in-surface filtration, while the filtration mechanism of JY filter is not only in-surface filtration but also in-depth filtration.

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References
[1] H.K. Lin, H. Zhou, the Application of Discal Filter on Industrial Water Treatment Field, Petro-Chemical Equipment Technology [J], 23 (2) (2002)16-18(Ch).
[2] Anon. Disc filter approved by California Water Recycling Criteria for wastewater reuse, Filtration & Separation. 45(9) (2008) 15-15.
[3] C.I. Ratiu, Modular disc filter with integrated and automated self-flushing operator. Bulletin of the University of Agricultural Sciences and Veterinary Medicine, 61(2004)464-464.
[4] APHA. Standard Methods for the Examination of Water and Wastewater 20th ed. Washington DC: American Public Health Association, 1995.
[5] Y.H. Jing , Y.H. Jin, J.C. Fan, Indicators to Estimate the Homogeneous Filtrating Material, Water & Wastewater Engineering, 26(3)(2000)13-16(Ch).
[6] T.A. Ribeiro, J.E. Patterning, R.P. Aroldis, et a1.Comparison between disc and non-woven synthetic fabric filter media to prevent emitter clogging. Transactions of the Asabe, 51(2) (2008)441-453.
[7] D.Z. Qian Water treatment engineering in power plant, China Electric Power Press, 1998 (Ch).
[8] J.L. Guo, J. Meng, G.P. Li, Z.K. Luan, H.X. Tang, Physicochemical interaction and its influence on deep bed filtration process, Journal of Environmental Sciences-China, 16(2)(2004) 297-301.
[9] B. Eikebrok, Coagulation-direct filtration of soft, low alkalinity humic waters, Water Science and Technology, 6 (1999)55-62.
[10] W.C. Dong, A study on the filtration and back flushing performance of the filters with crushed quatz sand for drip-irrigation, Journal of Hydraulic Engineering, 12(1997)72-77(Ch).