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Dynamic Sand Filter Performance against High Solids Loads in Raw Water

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Abstract:

Dynamic sand filter is a new technique for filtration depends on the continues washing for the up flow sand filter using diffused air for sand stirring to remove solids impurities from it. Egypt started to apply this system in its new plants for its high efficiency that leads to minimize required area. With the pollution increase in the water resources that raise the solids loads in it and increase the rewash needs in the traditional rapid sand filters specially these solids mainly are algae and bacteria. Also, the increase in water needs with the high cost for extension land for existing plants increase the need of applying such system to overcome this problem and increase the plant productivity.

This study was made to check the dyna- sand filter suitability to meet high suspended solids loads and overcome it to ensure its capability for application in different cases as direct filtration water plants. Tertiary treatment for wastewater and replacing rapid sand filters in existing plants without any changes in prior treatment units.

A lab scale pilot used was designed according to the Nordic company system book and synthetic water was applied with variable TSS loads form 50 - 150ppm under several filtration hydraulic rates variable from 150-250 m3/m2/day to determine the study aim.

The results showed that the removal ratios of turbidity varied between (80-89%) with 50 ppm TSS and R.O.F 150 m3/m2/d down to (40-63%) with 150ppm TSS and R.O.F 250 m3/m2/d which could be more in the real plant scale. The system suitability was very successful to meet high solid loads with high filtration rates that achieves the targets of application as direct filtration in water treatment, minimize the area for filtration in new plants and give the suitability for replacing the existing filters without changing the prier treatment units just decrease their removal efficiency depending on the system ability to meet higher loads.

Keywords: Water treatment, Water filtration, Dynamic filter.

1. Introduction

Most of water sources for human uses are surface water. The main problem in this source is the impurities suspended in its water that creates color, odor and sometimes tastes that could prevent its portability. Consequently, water from most surface sources must be treated before it can be consumed by people.

Water treatment plants typically purify water by passing it through several processes starting by coagulation, sedimentation or flotation, filtration and disinfection. This study covers one of the filtration methods in water purification

2. Literture review

Dyna-sand filtration was successfully applied at its beginning in wastewater treatment, this success led to try it with potable water treatment. Anonymous company used the Dyna-sand filtration for both water and waste water treatment, and they prove that he Dyna-sand filtration eliminate the need for backwash cleaning equipment [1].

Hultman et al.,[2] made full-scale studies of the use of Dyna-sand filtration for the combined removal of suspended solids, phosphorus and nitrogen. Experiments were performed using methanol as a carbon source for denitrification and ferric chloride for an improved phosphorus removal. Influent nitrate concentrations up to 20 mg N/L were tested and they decreased to 0.5 mg N/L. an concentration of 0.15 mg P/L was obtained. The influence of phosphate concentration on denitrification rate was found minimal at phosphate concentration over 0.1 mg P/L. Several water treatment plants used Dyna-sand filtration technique have been built around the world, now more than 10.000 units are installed around the world, like Parkson Corporation plant in USA.

Braviken,[3] of Sweden benefited from improved water supply at its paper mill. Braviken met its requirements of good quality water with the installation of 20 Dyna-sand filters. The filters provided a continuous sand cleaning process and eliminate the problem of downtime for back washing. These filters also provided additional benefits such as light maintenance and reduction in the quantity of polymer required for retaining fines on the paper. Minett et al.,[4] found in its use for water treatment that the filters provide a continuous sand clearing process, eliminate the problem of down time backwashing, light maintenance and reduction in the quantity of polymer required for retaining fines.

Comparison study made between the dyna-sand filter pilot unit and the existing pulsator followed by rapid sand filter in Ell Fostat water treatment plant resulted the efficiency improve in dyna-sand filter line than existing line in algae removal by 85%, in aluminum by 66% and in bacterial removal by 9.9%. These results save in chemicals addition for coagulation by 15%, 25% of post chlorine and 45% of pre chlorine. The Dyna – sand filter from this study saves 96% of area required, 86.7% of tanks volume, 15% of needed building and 60% of needed piping & valves that leads to save about 64.4 % from initial cost. Also, it saves 4.5% from power consumption, 30% of needed labors and 66.67% of needed maintenance that achieve saving in running costs by 39% than what happened now in Fostat plant. In general Dyna- sand achieved 51.7% saving in total cost required to purify the same raw water from River Nile source than Fostat plant [5].

Aly, O.H.[6] studied the application of dynamic up flow sand filter to treat polluted water under optimum conditions. The study was carried out to determine the removal efficiency of solids loading rate, residual aluminum, sludge volume index and the biological count.The study approved that the removal efficiency of suspended solids does not exceed 200 mg/l was found to be between 80-90% and the corresponding sludge index shows a significant improvement. So that, the wash water will show better stability if subjected to further treatment.

The residual aluminum was found to be less than 50% compared to that found in the influent. The experimental analysis also proved that the filter efficiency was declining slightly when the SLR increased from 5 to 20 m/hr. These results illustrate the suitability of Dayna Sand filter to be applied for polluted water treatment in water treatment plants.

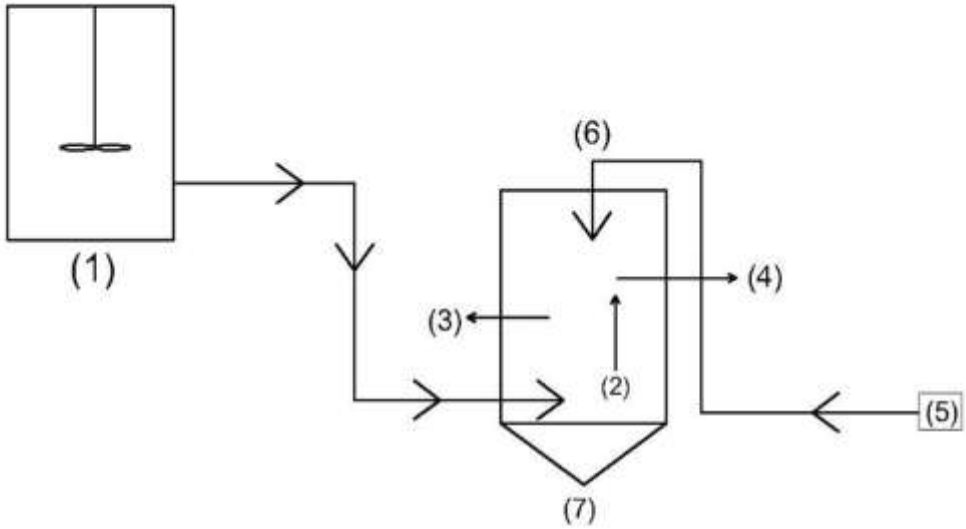
Wu, C, Zhou,[7] found that the dyna-sand filtration used to pretreat the petrochemical secondary effluent especially when the subsequent unit is catalytic ozonation process. The micro-flocculation and dyna-sand filtration can reduce the ozone consumption as high as 25%.

The study of Ibrahim, M. k. M.[8]approved that; the Dyna-sand filter system is a very highly effective solution for water treatment sludge (WTS) produced from water treatment plants under the Egyptian Standard Specification. Significant improvement in Turbidity removal was found, the effluent treated water turbidity was between 0.45 to 2.5 NTU. Drastic Drop in Total suspended solids for the effluent waste water were reached, the total suspended solids dropped from 1400 to 2600 PPM in the influent to 120 to 200 PPM in the effluent. The Algae count concentration in the effluent reached 230 to 560 unit/ml. The Biological Oxygen Demand (BOD) of the effluent was found 3.2 to 5.4 mg/l, after 19 to 42mg/l for the influent. The Bacterial count of the influent waste water ranged between 400 to 200 unit/ml, where the corresponding values of the effluent were found to be 120 to 220 mg/l. Compared with conventional water treatment plants in Egypt such as; El Fostat plant that use Carli-flocculation followed by rapid sand filter system produced large quantities of water treatment sludge (WTS) discharged directly to nearest surface water bodies without any treatment or reuse, the Dyna-sand filtration system achieved removal ratio of turbidity higher by 94 %, total suspended solids higher by 90 % and also for Algae. Compared with using Thickeners and drying beds, the Dyna-sand filtration system offered more reuse for water treatment sludge higher by 80 %, also the treated water quantities could be piping directly to rabid sand filter after applying disinfectant to release of bacteria to use it as potable drinking water which reduce massive foot print, labors and save environment. Dyna-sand compared with Fostat plant saves 65% of initial cost and 35% of running cost that obtained 50% saving in total cost required to treatment the same water treatment sludge (WTS).

The study location is held at the Sanitary Engineering Laboratory at Faculty of Engineering, Ain Shams University on lab-scale pilot using raw water samples for each run. The raw water source was variable in different concentrations of TSS for each run to simulate the water criteria from River Nile and its branches around Egypt. The study was using a lab-scale pilot that simulates the dyna-sand filter unit from fiberglass as shown figure (1).

The flow diagram for pilot Dyna-sand system which describes the unit erection is shown in figure (2).

Fig. (1) Applied Pilot.



1. Mixing Tank
2. Direction of Filtration
3. Effluent
4. Wash water
5. Compressor
6. Air feeding
7. Dyna-sand Filter

Fig. (2) Flow Diagram for Pilot Dyna-Sand System.

Sand that was used as a filtration media has the following properties, particle sizes sand (0.5-2mm) for effective sizes, D60=2mm, D10=0.5mm, Uniformity coefficient (Cu) = D60/D10=1.75, Soil separate equivalent diameter size (mm), gravel > 2 mm, Sand (0.05 - 2 mm), very coarse (1 - 2 mm), coarse (0.5 - 1 mm), medium (0.25 - 0.5 mm), fine (0.1 - 0.25 mm), very fine (0.05 - 0.1 mm), Silt (0.002 - 0.05 mm), Clay < 0.002 mm (< 2 micrometer).

The pilot was operated for several runs under different loads of TSS and variable R.O.F. one run for each type. The run cover one week operation with 3 days of sampling and the 4th day was for washing the tank and prepare it for the operation of the next week, the runs were as follows:

1- Test run to ensure the system operation (with one-time measurements).
2- Run no. Ⅰ with high TSS content (150 mg/l).
Run no. Ⅱ with medium TSS content (100 mg/l).
Run no. Ⅲ with low TSS content (50 ppm).

From the results of the operation, the best type of the pilot was chosen as the final pilot unit, and it was applied under the same water types that were used in normal operation to determine its performance and applicability.

3. Results & Discussion

This phase was made to ensure the pilot simulation for the Dyna-Sand filter and determine the removal efficiency under several solids and hydraulic loads with sand media. Tables (1 - 9) show the results of effluent turbidity during the experiments by using sand only as filter media. The samples were taken at different working periods (30, 60, 120, 240min).

The conditions of Run No. Ⅰ that are shown in tables from (1 to 3) are TSS (150mg/l) and influent turbidity (15.50ntu).

Table (1) Effluent Turbidity with ROF (250m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency %
1(30min)	9.17	9.99	9.19	9.45	40%
2(60min)	7.90	8.37	7.44	7.90	49%
3(120min)	5.50	6.71	5.80	6.00	61%
4(240min)	5.30	5.90	5.60	5.60	63%

Table (2) Effluent Turbidity with ROF (200m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	6.50	6.60	6.40	6.40	59%
2(60min)	5.50	5.60	5.20	5.40	65%
3(120min)	4.95	4.80	4.84	4.90	69%
4(240min)	4.70	4.90	4.80	4.70	69%

Table (3) Effluent Turbidity with ROF (150m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	4.73	4.54	3.76	4.34	72%
2(60min)	4.02	3.59	3.40	3.67	76%
3(120min)	3.70	3.49	2.97	3.38	78%
4(240min)	3.60	3.30	2.80	3.23	79%

From tables (1 to 3) we notice that, the removal efficiency is opposite proportional with the ROF with values between (40-79%). Also, the increase of working period affects the turbidity removal efficiency due to the system stability with operation time. The system stability increases according to the media saturation with impurities under the dynamic operation.

The conditions of Run No. Ⅱ that are shown in tables (4 to 6) are TSS (100mg/l) and influent turbidity (12.20ntu).

Table (4) Effluent Turbidity with ROF (250m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	4.96	5.25	5.29	5.16	58%
2(60min)	4.86	4.22	4.21	4.43	64%
3(120min)	4.08	3.51	3.63	3.74	69%
4(240min)	4.00	3.40	3.50	3.63	70%

Table (5) Effluent Turbidity with ROF (200m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	3.73	3.52	3.69	3.64	70%
2(60min)	3.72	3.42	3.55	3.56	71%
3(120min)	3.05	3.19	3.21	3.15	74%
4(240min)	3.00	3.10	3.10	3.10	75%

Table (6) Effluent Turbidity with ROF (150m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	2.78	3.03	3.14	2.98	76%
2(60min)	2.49	2.7	2.75	2.65	78%
3(120min)	2.30	2.39	2.51	2.4	80%
4(240min)	2.20	2.30	2.40	2.30	81%

From tables (4 to 6) we notice that, the removal efficiency is opposite proportional with the ROF with values between (58 - 81%). Also, the increase of working period affects the turbidity removal efficiency due to the system stability with operation time. The system stability increases according to the media saturation with impurities under the dynamic operation.

The conditions of Run No. Ⅲ that are shown in tables from (7-9) are TSS (50mg/l) and influent turbidity (10.10ntu).

Table (7) Effluent Turbidity with ROF (250m3/m2/hr)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	2.34	2.35	2.35	2.34	77%
2(60min)	1.89	1.92	1.9	1.9	82%
3(120min)	1.58	1.66	1.59	1.61	84%
4(240min)	1.50	1.60	1.50	1.50	85%

Table (8) Effluent Turbidity with ROF (200m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	2.30	2.10	2.20	2.10	79%
2(60min)	1.62	1.78	1.75	1.72	84%
3(120min)	1.03	1.31	1.41	1.25	88%
4(240min)	1.00	1.20	1.30	1.20	88%

Table (9) Effluent Turbidity with ROF (150m3/m2/hr).

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(30min)	1.89	1.98	2.04	1.97	80%
2(60min)	1.66	1.62	1.73	1.67	85%
3(120min)	1.22	1.14	1.27	1.21	88%
4(240min)	1.10	1.00	1.10	1.10	89%

From tables (7 to 9) we notice that, the removal efficiency is opposite proportional with the ROF with values between (77 - 89%). Also, the increase of working period affects the turbidity removal efficiency due to the system stability with operation time. The system stability increases according to the media saturation with impurities under the dynamic operation.

4. Conclusion

According to these results, the pilot achieved the all-manufactural conceptual criteria to meet all loads especially high TSS in raw water achieving removal efficiency between 72% with high load (150mg/l) and 89% with low load (50mg/l) for normal ROF of dyna-sand as manufactural instruction.

In general, it was noticed that the removal efficiency is less than 100% which is up normal for filtration in water supply. This may be for two reasons, the first is due to the high solid loads that applied in this experiment to check system applicability with high loads. Even inlet TSS to filter is normally in WTP proceeded by chemical precipitation is ≤ 20ppm only for both tertiary treatment of waste water and direct filtration in water supply.

The second reason was that the study used synthetic water with one size of suspended solids due to the applied silt, this affect the sand capability to remove all impurities for there is no variation in these impurities sizing which help normally in improving filtration action. This is why the system should be developed to improve its removal efficiency under high ROF and high solid loads.

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