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IMPROVEMENT OF DYNAMIC UPFLOW SAND FLTER PERFORMANCE USING DUAL COAL SAND MEDIA

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Abstract

This study aimed to improve the Dyna-sand filter performance using dual coal sand media with different ratios to achieve the required efficiency. Two ratios of coal sand were applied in this study 4 sand to 1 coal and 2 sand to 1 coal to determine the best removal ratio for the Dyna sand filter unit, against different high solids loads (50 -150 ppm) and several rate of filtration (150- 250) m3/m2/d.

The study results showed that media with ratio (4 sand: 1 anthracite carbon), the Dyna-sand filter achieved turbidity removal ratio between (93 and 94%) with different rate of filtration and under different TSS loads. The increase of A.C. ratio achieved very smaller effect on removal efficiency between 1: 2% than the previous starting media ratio. This achievement with the coal increase is not economic effective when compared with the starting ratio.

The study concluded that; the application of dual media with ratio 4 S :1 A.C. is the best modification to Dyna sand filter. The improvement in its turbidity removal ratio between 10: 20% compared with sand only against high inlet solids loads with different rates of filtration.

Keywords : Water treatment; Water filtration; Dynamic filter

Introduction

Surface water the main source of drinking water treatment plants that reflects on the main issue of having impurities. Suspended solids lead to a lot of effects on color, odor and taste, so having a controlled process of water treatment is a Must-To-Do processes before usage

Water treatment process requires full set up of plants that can accommodate all treatment processes such as coagulation, sedimentation, floatation, filtration and disinfection. Hereby, this study will spot the light on one pillar of water treatment process which is filtration methods in water purification.

Dyna-sand filtration was successfully applied at its beginning on wastewater treatment, because of this, it was shafted to be used in the flirtation of potable water treatment. The Dyna-sand pilot can be modified with different types such as: increasing the discharge of raw water, air controlled and filter media. Last studies approved that the filter media has the great effect on the efficiency of the filter compared with either the increasing of raw water discharge or air control.

LITERATURE REVIEW

Anonymous company used the Dyna-sand filtration for both water and waste water treatment, and they prove that the Dyna-sand filtration eliminate the need for backwash cleaning equipment **[1].**

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.

Hultman et al. **[2],** succeeded to remove 97% of Nitrogen with application of methanol before dyna sand filter. Also, applying Dyna sand filter after adding ferric chloride improved phosphorus removal up to 90%.

Braviken **[3],** proved the Dyna-sand filter application in improving the paper mill feeding water quality to meet the industry needs

Minettetet et al. **[4],** found that the use of Dyna sand filter for water treatment 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 El Fostat water treatment plant resulted the Dyna-sand filter achieved better efficiency than existing line in algae removal by 85%, and in aluminum removal 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 study showed that the Dyna sand filter saved 96% of area required, 86.7% of tanks volumes, 15% of service buildings and 60% of piping & valves that leads to save about 64.4 % from initial cost. Also, it saved 4.5% of consumed power consumption, 30% of labors and 66.67% of needed maintenance that achieve saving in running costs by 39%. In general, Dyna sand achieved 51.7% saving in total cost required to purify the same raw water from River Nile source than existing line in El 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 approved that the removal efficiency with inlet suspended solids less than 200 mg/l was between 80-90% with a significant improvement in sludge index and the removal ratio of aluminum was more than 50%.

Zhou, Wu, C. **[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,*** **[8],** approved that; the Dyna-sand filter system is a very highly effective solution for water treatment plants sludge under the Egyptian Standard Specification. The Dyna-sand filtration system achieved removal ratio of turbidity higher by 94 %, total suspended solids and Algae higher by 90 % 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 piped directly to rapid 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.

The study of ***El Taher,*** **[9],** showed the suitability of d yna- sand filter application against variable solid loads TSS (50-250) mg/l with variable ROF (200-500) m3/m2/d and acceptable removal efficiency.

Yousra Hamdy et al. **[10],** compared between rapid sand filtration process and dyna sand filtration process. The study showed the dyna sand technique advantages include the reduction in the treatment plant area and the continuous sand wash process which saves the water quantity used in the backwash process.

Abuelkhair, N.Y. et al. **[11],** achieved in their work the success of dyna sand filter to meet all manufacturer conceptual criteria against all loads especially high TSS in raw water with removal efficiency between 72% with high load (150mg/l) and 89% with low load (50mg/l) for normal ROF of dyna sand.

MATERIAL & METHODS

The study held at the Sanitary Engineering Laboratory at Faculty of Engineering, Ain Shams

University on lab-scale pilot for dyna-sand filter showed in figure (1) using raw water samples for each run with variable concentrations of TSS for each run to simulate the variations of the water criteria from River Nile and its branches around Egypt.

The pilot was made of fiber glass with dimensions 30cm, 35cm and 150cm and the holding capacity of sand is 0.40 m^3.

The study applied a modification made on the pilot by changing the filter media properties by adding anthracite coal on sand with different ratios to improve the removal efficiency under higher TSS loads and higher rates of filtration.

Two stages were applied; one with media mixing ratio 4 sand to 1 Anthracite coal, and the second with media mixing ratio 2 sand to 1 Anthracite coal.

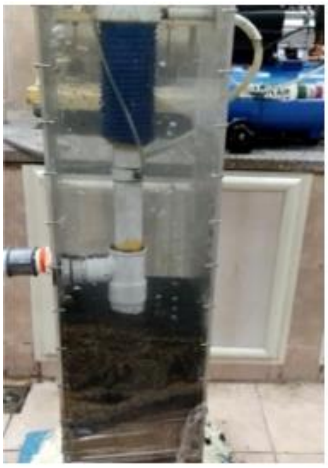

Fig (1) Applied Pilot

The modifications were made individually one by one, each stage had three runs, each run took one week with day by day of sampling. The samples were taken 4 times with different periods (30, 60, 120, 240min).

The used sand has the following properties, particle sizes sand (0.5-2mm) for effective sizes, D60=2mm, D10=0.5mm, Uniformity coefficient =1.75,

The used anthracite coal has the following properties, particle sizes sand (0.7-1.9mm) for effective sizes, D60=1.9mm, D10=0.7mm Uniformity coefficient (Cu) = D60/D10=2.714.

The pilot was operated in each run under variable raw water TSS loads between (50 -150) ppm and with variable rates of filtration between (150 – 250) m3/m2/d.

RESULTS AND DISCUSSION

First stage was made by adding anthracite coal with sand with ratio 4 sand: 1 A.C. to determine the possible success of this new applied media and its improvement in turbidity removal ratio under different ROF and different solid loads. Tables from (1-9) show the results of the effluent turbidity during the experiments. The stage was divided to three runs due to influent solid loads. First run has inlet TSS (150mg/l) with inlet turbidity (15.50 NTU).

Table (1) Effluent turbidity with ROF (250$m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.97	0.99	0.98	0.98	93.6%
2(after 60 min.)	1.03	0.96	0.91	0.95	93.8%
3(after 120 min.)	1.0	0.92	0.89	0.93	94%
4(after 240 min.)	0.94	0.90	0.90	0.91	94.1%

Table (2) Effluent turbidity with ROF (200$m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.99	0.93	0.92	0.94	93.9%
2(after 60 min.)	0.74	0.92	0.88	0.88	94.3%
3(after 120 min.)	0.88	0.91	0.86	0.85	94.5%
4(after 240 min.)	0.85	0.84	0.85	0.85	94.5%

Table (3) Effluent turbidity with ROF (150 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.88	0.9	0.85	0.87	94.3%
2(after 60 min.)	0.94	0.87	0.79	0.86	94.4%
3(after 120 min.)	0.91	0.86	0.77	0.85	94.6%
4(after 240 min.)	0.80	0.85	0.80	0.83	94.7%

In spite of this run was made under the high inlet TSS load, but it illustrated the success of the new mixed media in improving the dyna-sand removal efficiency from (70-80%) with sand alone **[11]** to (93.6-94.7%) under different ROF.

Second run had inlet TSS (100mg/l) with influent turbidity (12.20NTU) achieved results illustrated in tables from (4 - 6) under different ROF.

Table (4) Effluent turbidity with ROF (250 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.74	0.73	0.78	0.75	93.8%
2(after 60 min.)	0.71	0.75	0.73	0.74	93.9%
3(after 120 min.)	0.70	0.71	0.73	0.72	94%
4(after 240 min.)	0.71	0.71	0.70	0.71	94.1%

Table (5) Effluent turbidity with ROF (200 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.72	0.72	0.71	0.72	94%
2(after 60 min.)	0.66	0.65	0.66	0.66	94.5%
3(after 120 min.)	0.66	0.65	0.65	0.65	94.6%
4(after 240 min.)	0.64	0.64	0.64	0.64	94.7%

Table (6) Effluent turbidity with ROF (150 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.66	0.66	0.65	0.66	94.5%
2(after 60 min.)	0.66	0.65	0.66	0.66	94.5%
3(after 120 min.)	0.66	0.65	0.65	0.65	94.6%
4(after 240 min.)	0.64	0.63	0.64	0.64	94.7%

Similar to the first run, the removal efficiency for turbidity was between (93.8-94.7%) that ensure the success of the mixed media. Also, the third run results that shown in tables from (4 - 6) were made under inlet TSS (50mg/l) and influent turbidity (10.10NTU).

Table (7) Effluent turbidity with ROF (250 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.61	0.61	0.62	0.61	93.9%
2(after 60 min.)	0.61	0.60	0.60	0.60	94%
3(after 120 min.)	0.60	0.58	0.60	0.59	94.1%
4(after 240 min.)	0.60	0.60	0.60	0.58	94.2%

Table (8) Effluent turbidity with ROF (200 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.58	0.57	0.59	0.57	94.3%
2(after 60 min.)	0.54	0.55	0.54	0.54	94.6%
3(after 120 min.)	0.54	0.53	0.53	0.53	94.7%
4(after 240 min.)	0.52	0.52	0.51	0.52	94.8%

Table (9) Effluent turbidity with ROF (150 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.54	0.54	0.53	0.54	94.6%
2(after 60 min.)	0.54	0.54	0.54	0.54	94.6%
3(after 120 min.)	0.53	0.52	0.6253	0.53	94.7%
4(after 240 min.)	0.52	0.51	0.52	0.52	94.8%

The third run results ensure the first and the second runs results that achieved the success of the applied mixed media in improving the dyna-sand removal efficiency.

The second stage of this study had applied mixed media with ratio 2 S: 1 A.C. to try to get more removal efficiency using the concept of mixed media. The study was made with the same concept on three runs, one for each TSS and turbidity inlet load under the same three rates of filtration that applied previously as shown in tables from (10 - 18).

Table (10) Effluent turbidity with ROF (250 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.84	0.85	0.87	0.86	94.2%
2(after 60 min.)	0.82	0.83	0.82	0.83	94.6%
3(after 120 min.)	0.81	0.80	0.82	0.81	94.7%
4(after 240 min.)	0.80	0.80	0.80	0.80	94.8%

Table (11) Effluent turbidity with ROF (200 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.82	0.82	0.80	0.81	94.7%
2(after 60 min.)	0.81	0.81	0.82	0.81	94.7%
3(after 120 min.)	0.81	0.80	0.80	0.80	94.8%
4(after 240 min.)	0.79	0.79	0.79	0.79	94.9%

Table (12) Run No.7, Effluent turbidity with ROF (150 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.78	0.78	0.76	0.77	95%
2(after 60 min.)	0.75	0.76	0.75	0.76	95.1%
3(after 120 min.)	0.71	0.71	0.70	0.71	95.4%
4(after 240 min.)	0.70	0.70	0.70	0.70	95.5%

Table (13) Effluent turbidity with ROF (250 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.65	0.66	0.66	0.65	94.4%
2(after 60 min.)	0.65	0.64	0.65	0.64	94.7%
3(after 120 min.)	0.63	0.63	0.62	0.63	94.8%
4(after 240 min.)	0.60	0.61	0.61	0.61	95%

Table (14) Effluent turbidity with ROF (200 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.60	0.61	0.61	0.60	95%
2(after 60 min.)	0.56	0.56	0.58	0.57	95.3%
3(after 120 min.)	0.56	0.55	0.56	0.56	95.4%
4(after 240 min.)	0.55	0.55	0.55	0.55	95.5%

Table (15) Effluent turbidity with ROF (150 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.53	0.51	0.52	0.52	95.7%
2(after 60 min.)	0.51	0.50	0.51	0.51	95.8%
3(after 120 min.)	0.50	0.50	0.51	0.50	95.9%
4(after 240 min.)	0.50	0.50	0.50	0.50	95.9%

Table (16) Effluent turbidity with ROF (250 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.50	0.51	0.50	0.50	95%
2(after 60 min.)	0.49	0.48	0.49	0.48	95.2%
3(after 120 min.)	0.47	0.48	0.49	0.48	95.2%
4(after 240 min.)	0.47	0.47	0.47	0.47	95.3%

Table (17) Effluent turbidity with ROF (200 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.48	0.47	0.47	0.47	95.3%
2(after 60 min.)	0.46	0.46	0.44	0.45	95.5%
3(after 120 min.)	0.45	0.44	0.45	0.44	95.6%
4(after 240 min.)	**0.43**	**0.43**	**0.43**	**0.43**	**95.7%**

Table (18) Effluent turbidity with ROF (150 $m^3/m^2/hr$)

Sample No.	Day 1	Day 2	Day 3	Average	Removal efficiency%
1(after 30 min.)	0.48	0.42	0.42	0.42	95.8%
2(after 60 min.)	0.41	0.40	0.41	0.41	95.9%
3(after 120 min.)	0.41	0.40	0.41	0.41	95.9%
4(after 240 min.)	0.40	0.40	0.40	0.40	96%

It can be noticed that the new mix of media increased the removal efficiency than the starting mix by (1 - 2%) only that raise the removal efficiency to (95 – 96%) under all variables of loads and ROF.

Figures from (2 - 6) show the comparison of the turbidity removal efficiency between the two stages of different ratios of the modified media at different rates of filtration and different applied TSS concentrations (150, 100, 50mg/l).

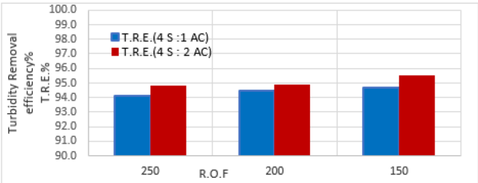

Fig (2) Effect of ROF on T.R.E. at TSS (150mg/l)

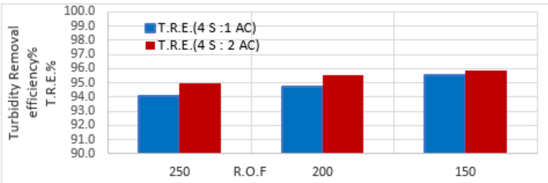

Fig (3), Effect of ROF on T.R.E. at TSS (100mg/l)

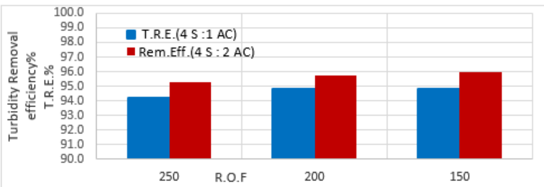

Fig (4), Effect of ROF on T.R.E. at TSS (50mg/l)

From figures (2 - 4) it was noticed that, the turbidity removal efficiency increased with the decrease of the rate of filtration which is a normal behavior that the load share on the area decreased with the decrease of rate of filtration.

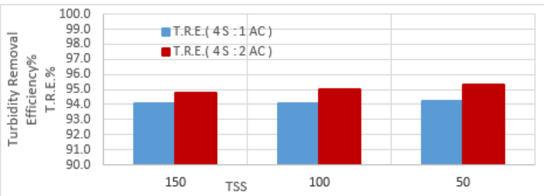

Fig (5), Effect of TSS On T.R.E at R.O.F (250$m^3/m^2/d$)

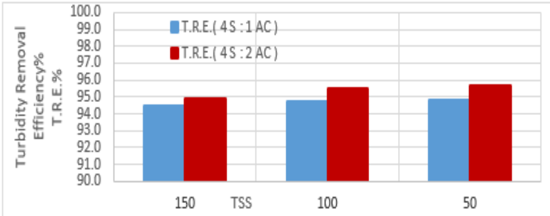

Fig (6), Effect of TSS on T.R.E. at R.O.F (200$m^3/m^2/d$)

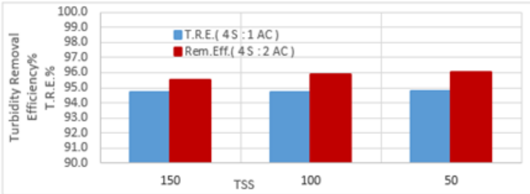

Fig (7), Effect of TSS on T.R.E. at R.O.F (150$m^3/m^2/d$)

From figures (5 - 7) it was noticed that, the turbidity removal efficiency increased with the decrease of the inlet solid load which is anormal behavior.

In the first ratio 4S :1 A.C., the turbidity removal efficiency increased due to the addional of anthracite coal that covered mostly the voids of the sand and the additional A.C. In the second ratio 2S: 1A.C. more add of anthracite coal cannot find more voids to fill it that make its effect very very small.

CONCLUSION

In general, the application of mixed media ratio (4 sand: 1 A.C) in the dyna-sand filter achieved removal ratio of turbidity between 93.6-94.8%with different rates of filtration and different loads of inlet TSS. This removal efficiency is higher than the traditional sand media by 14 – 24 % **[11]**. This also showed the success of applying the mixed media in the Dyna sand filters with promising results. The increase of A.C. ratio had very small increase in turbidity removal efficiency between 1: 2% which can be neglected compared with the higher cost of A.C. compared with sand.

The study concluded that the application of dual media with ratio 4 S :1 A.C. is the best engineering modification to dyna sand filter that achieved improvement in its turbidity removal ratio between 14: 24% compared to sand only against high inlet solids loads with different rates of filtration.

REFERENCES

[1] Anonymous company, "Continuous Sand Filter", Conference of new techniques in water & wastewater treatment, Sweden, Journal of science, Sweden, V.22, No.3, pp 156-163, (September, 1982).

[2] Hultman, B., Jonsson, K., Plaza, E. l., "Combined nitrogen and phosphorus removal in a full- scale continuous up-flow sand filter", Sweden Journal of science, V.34, No.2, Sweden (1994).

[3] Abdel Azeem, M.M., "Evaluation of the performance of Dynamic Sand Filtration Under Real Working Conditions", Sci Bull. Faculty of Engineering Ain Shams University, v.41, no.4, (December, 2006).

[4] Ahmed, H. M. H., "Dyna-sand Filter Application in Water Treatment", M.Sc. Thesis, Faculty of Eng., ASU, Cairo, Egypt, (2007).

[5] El Nadi, M.H, Abdel Azeem, M.M. & Aly, O.H.I., "Performance of the Dynamic Up Flow Sand Filter for Treatment of polluted water using variable surface loading rate", 2nd International Conference & Exhibition, Sustainable water supply & sanitation, (SWSSC2012), holding company for water and wastewater, Cairo, Egypt, (December, 2012).

[6] El Nadi, M.H., Abdelazeem, M.M. & Aly, O.H.I., "Application of Dynamic Up Flow Sand Filter for Treatment of Polluted Water in Water Treatment Plants", El Azhar Univ., Faculty of Eng., CERM of civil Eng., V. 33, No. 3, (October, 2011).

[7] Aly, O.H.I., "Application of Dynamic Up Flow Sand Filter for Treatment of Polluted Water Under Optimum Conditions", Ph. D. Thesis, Faculty of Eng., ASU, Cairo, Egypt, (2011).

[8] Ibrahim, M.K.M4, Abdelazeem, M.M.A1, Aly, O.H.I2, Ahmed, H.M.H3, "The Application of Dynamic Up – Flow Sand Filtration in Water Sludge Treatment", Australian Journal of Basic and Applied Sciences, 12(12): pp. 61-66. DOI: 10.22587/ajbas. (December, 2018).

[9] El Taher, E.M., El Nadi, M.H., Wahab, E.S. &Ahmed, S. I. A., ElAzhar Univ., "Feasibility of Dyna-Sand Filter Application Against Variable Solid Loads in Water", by Faculty of Eng., Civil Eng. Research Magazine CERM, V. 44, No. 1, (January, 2022).

[10] Y. Hamdya, A. Mohamed, M. A. Othman, M. S. Abu-Alenieenc, U. Abdelghany, "Drinking Water Treatment Plant Design for Administrative Capital in Egypt" International Journal of Advanced Engineering and Business Sciences, V.3, Issue 1, (March, 2022).

[11] Abuelkhair, N.Y.1, El Nadi, M.H.2, Fouad, H. A.1& Rehab Hefny, "Dynamic Sand Filter performance Against High Solids Loads in Raw Water", Benha Journal of Applied Sciences, (May, 2022).