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# Experimental Investigation of Environmental Hydraulic Parameters for Dual Mixed Media Biofilter for Greywater Treatment

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**Abstract:** Laboratory scale model of DMMBF (dual mixed media biofilter) were designed and installed in Al-Mustansiriya University Environmental Hydraulic Lab. Experiments were conducted using two mixed layers through PVR column—2.2 m height and 300 mm diameter. The first mixed media filter of depth 640mm mixed of sand, rice husk and granular activated carbon. The percentage volume mix is 1:1:1. While the other mixed media of depth 740 mm, consisting of coal, crash porcelinaite, rock and granite with equally percentage volume. Fifty samples were collected during the experiments, which was spread over a period of forty two weeks. The obtained results indicate that when the flow loading raised from 0.15 L/min to 2.7 L/min, the removal efficiency of BOD decreased 8%-11%, and the removal efficiency of COD deceased 3%-4%, while the removal efficiency of turbidity increased with the decreasing of hydraulic loading. The results showed that the removal efficiency of turbidity is more than 95% at the lower discharge (0.15 L/min). Therefore, infiltration should be conservatively designed using low loading rates.

**Key words:** Hydraulic parameters, dual mixed media, greywater treatment, removal efficiency, turbidity, COD, BOD.

## 1. Introduction

The mixed media concept combines the superior distribution properties of cross flow media with the reduced potential for clogging of vertical flow media to give consistent and efficient biological wastewater treatment. This configuration improves the mixing, hydraulics, surface area, ventilation, and physical strength of the media beyond that of either cross flow or vertical flow media alone. The biological aerated filter—a wastewater treatment technology developed in the 1980 and 1990, is similar to a traditional bio-filter in many ways, but also possesses several advantages over wastewater treatment technologies, such as activated sludge biological contact oxidation and feed water filtration [1]. The characteristics of the filtering media dictate, to a large degree, the biological aerated filter performance [2]. Popular filtering media includes sand, macadam, slag, coke, anthracite coal, zeolite and bioceramsite [3]. Zeolite and bioceramsite have certain advantages, including a rough surface, large adsorptive capacity and long term nondegradation, which make them two of the most widely applied filtering media [4]. Oh et al. [5] studied various different types of multilayered metal. Activated carbon bed has been used to investigate the catalytic removal COD, BOD, T-N and T-P from piggery wastewater. Zouboulis et al. [6] examined efficiency of filtration process through a comparison between a sand filter bed and a dual media filter, consisting of sand and anthracite. It was found that the dual media filter bed produced water of the same (high) quality as the single bed, but with the advantage of operating at greater filtration cycles (around three times higher), which resulted to a 10% higher water production. Majid et al. [7] conducted the effect of variation of influent raw water turbidity, bed

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composition, and filtration rate on the performance of mono (sand) and dual media (sand and anthracite) rapid gravity filters in response to the effluent water turbidity and head loss developments. Mostgrey-watertreatment plants include one or two-step septic-tank for pretreatment [8]. Thegrey-watertreatment needs both physical and biological processes for removal of particles, dissolved or ganic-matter and pathogens [9]. Recently, many researchers have studied the grey-watertreatment either by application of high-rate aero biosystems, such as the rotating biological contactor [10], fluidized bed [10], aerobic filter [11], membrane bioreactor [11], or by application of low-rate systems, like slows and filter [9], vertical flow wetlands [12], trickling filters with ozonation [13] and Multi Media Biological Activated Carbon [14]. Although high-rate anaerobic systems, which are low-cost systems, have both physical and biological removal, no research has been done until now on grey water in these systems. The grey water contains a significant amount (42%) of COD (chemical oxygen demand) in the domestic wastewater [15] and this amount can be removed by the high rate anaerobic systems.

The purpose of this research is to investigate the effects of hydraulic and environmental parameters for dual mixed biofilter performance. These parameters are important because they help determine the contact time of pathogens in the water to provide inactivation.

## 2. Experimental Work

Biofilter column was designed and constructed in Al-Mustansiriya University at Environmental Hydraulic Laboratory using local available PVR pipe of diameter of 300 mm and of 2.20 m length as shown in Figs. 1 and 2. The reactor was divided into three pieces, one of 640 mm depth of media mixed of sand, rice husk, and granular activated carbon with volume percentage 1:1:1 respectively, the second media is with 740 mm depth filled with mixed of coal, crash porcelinte, rock, and granite. It was selected with volume percentage 1:1:1 respectively. The properties of mixed media are shown in Table 1. The other zone was above the first mixed media as water tanks for constant head. Five piezometer holes are well done on different levels are made to measure water pressures at difference levels. Three flow outlets were made at different distances using ½ inch (12.5 mm) diameter PVR pipe, the outlets ended with copper nozzle of 8 mm inner diameter. The polluted water was pumped from the 1 $m^3$ storage tank through a sprinkler ended plastic pipe to 300 mm above the reactor the top of the filter column. Characteristic of influent polluted water at sixth month is shown in Table 2. A continues monitoring of the water head, discharge, and water temperature at different water levels and outlet positions. The samples were taken from the pipe filter at certain times in the day with an overall aim to obtain realistic average for a 24-hour period. Then samples were accordingly labeled indicating sample number, date and time of collection and place of collection. Fifty samples were collected and analyzed during the experiments, which was spread over a period of forty two weeks. Several tests were achieved for the influent and effluent of the biofilter. Measurements include $BOD_5$, COD, turbidity, pH, *E-coli* and total coliform, which were determined as described by standard methods [16].

## 3. Results and Discussion

### *3.1 Head Loss Behavior*

Fig. 3 shows the difference in pressure head, *Δh* with several of water discharge. The discharge is loading between 0.15 L/min and 2.7 L/min, resulting increasing in Δ*h* (4-10 cm) with increasing in discharge (from 1 L/min to 2.7 L/min) and if water elevation above media, WEL increasing (from 10 cm to 30 cm) the Δ*h* is increased.

This was due to the head loss continued to increase because the filter deposits continue to settle causing gradual clogging of the filter bed. This continues until

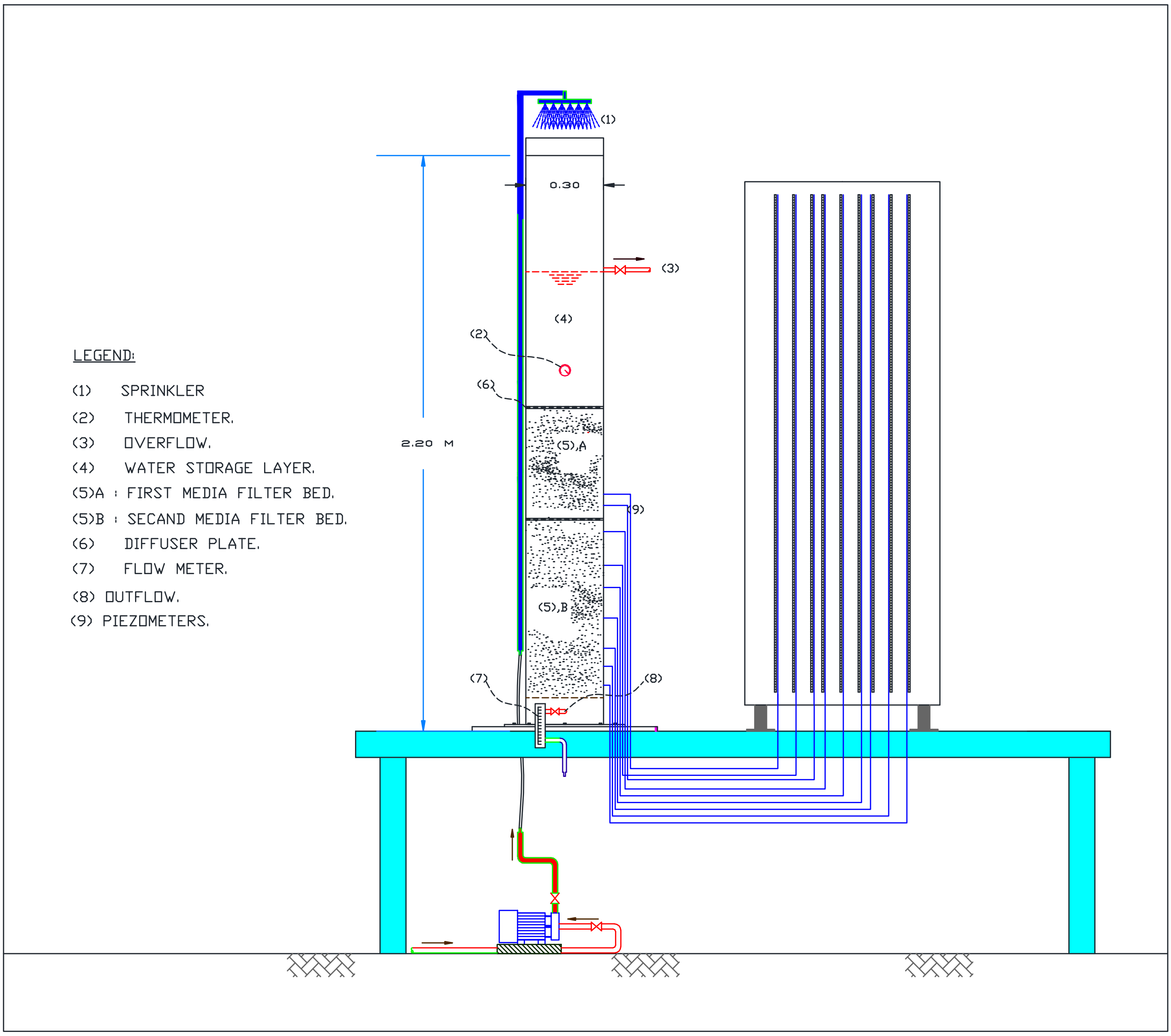


**Fig. 1 Schematic of filter column.**

**Fig. 2 Filter column.**

the bed was completely clogged or reaching the terminal head loss. Fig. 4 shows variation of pressure head with time for constant discharge of 0.5 L/min and different influent turbidity trend $\Delta h$ increases with increasing influent turbidity. This may be referred to the reduction occurred in the free void area as the particles accumulate in the bed which causes the bed to offer resistance to the flow of water and lead to increase the hydraulic loads on the filter bed.

*3.2 Impact of Hydraulic Loading on BOD and COD*

The profiles of BOD and COD removal efficiencies

**Table 1 Media characteristics of two layers.**

| Layer No. | Uniformity coefficient | $d_{10}$ | Porosity |
|---|---|---|---|
| 1. Mixture of sand, rice husk, and granular activated carbon. | 2.8 | 1.8 | 0.54 |
| 2. Mixture of coal, crash porcelinaite, rock, and granite. | 2.4 | 1.2 | 0.52 |

**Table 2 Influent greywater characteristics.**

| Parameters | October | November | December | January | February | March |
|---|---|---|---|---|---|---|
| $BOD_5$ (mg/L) | 75 | 123 | 74 | 112 | 70 | 55 |
| COD (mg/L) | 230 | 211 | 230 | 198 | 160 | 74 |
| $NH_3$-N (mg/L) | 14 | 37.6 | 9 | 35.6 | 16 | 5.9 |
| pH | 7.6 | 8.3 | 7.5 | 7.7 | 8 | 7.2 |
| TSS (mg/L) | 17 | 196 | 31 | 185 | 22 | 16 |
| Total phosphorus(mg/L) | 16 | - | 12 | - | 10 | 3.4 |
| *E. coli* (CFU/g dry soil) | 24.52 | 39.17 | 24.52 | 16.34 | 14.03 | 12.25 |
| Total coliform (CFU/g dry soil) | 73.46 | 97.98 | 97.98 | 81.57 | 14.03 | 24.5 |

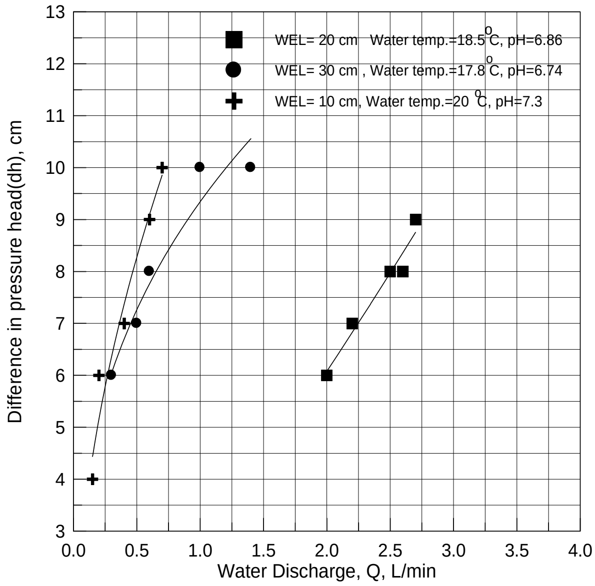


**Fig. 3 Water discharge with difference of pressure head.**

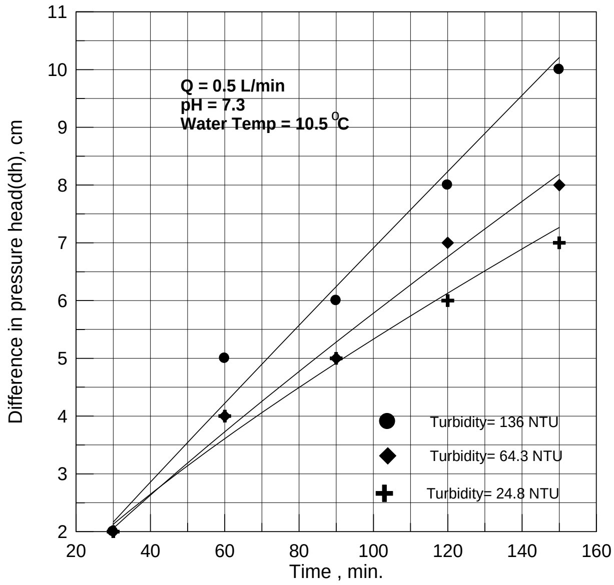


**Fig. 4 Difference in pressure head with time.**

are depicted in Figs. 5 and 6. It is noted that BOD removal efficiency decreased 8%, 10%, and 11% for run time of 90 min, 120 min and 180 min. respectively, following an increase in flow discharge from 0.15 L/min to 2.7 L/min COD removal efficiency decreased 3%-4% with increase flow discharge from 0.15 L/min to 2.7 L/min and removal efficiencies increase with time of about 80% of BOD and more than 67% of COD. Figs. 7 and 8 show the removal efficiencies of BOD and COD with variation of influents respectively and observe that removal efficiencies increase with increasing the time of run. These are also noted that the efficiencies are decreased with increased influents of BOD or COD.

### *3.3 Effect of Filtration Rate on Turbidity*

Fig. 9 shows the removal efficiency of turbidity with different time and at different influent of turbidity (24.6 NTU, 42 NTU and 41 NTU) for different hydraulic loading (0.15 L/min, 1 L/min and 2.7 L/min).

It is indicated that the removal efficiency increase at the start of the run and continue to increase until it reaches a point in which the removal efficiency begin

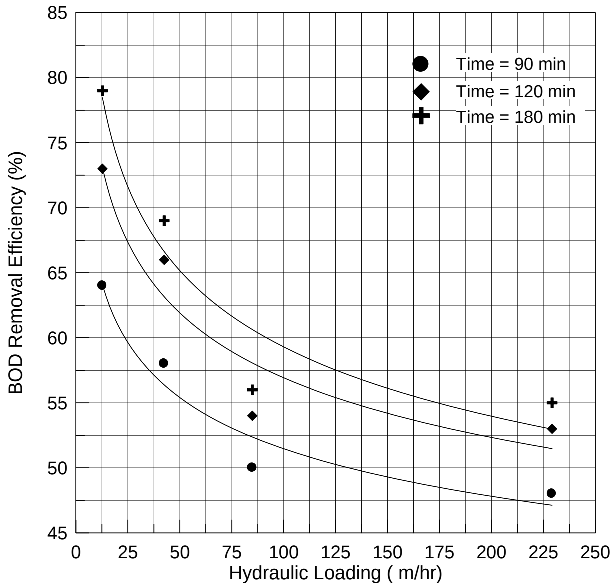


Fig. 5 Removal efficiency of $BOD_5$ with hydraulic loading.

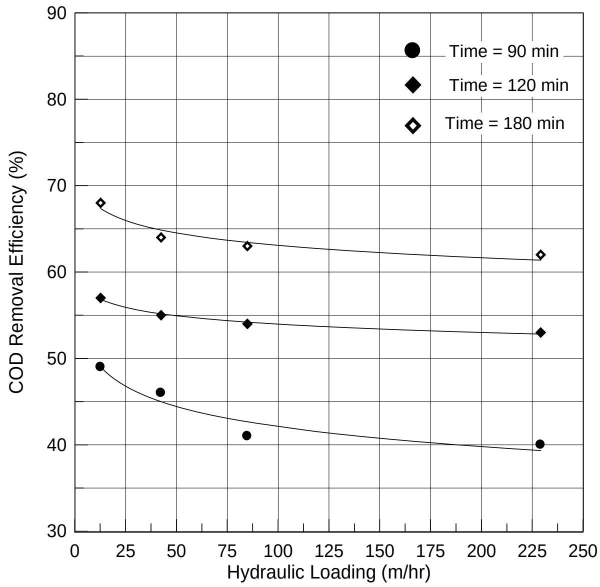


Fig. 6 Removal efficiency of COD with hydraulic loading.

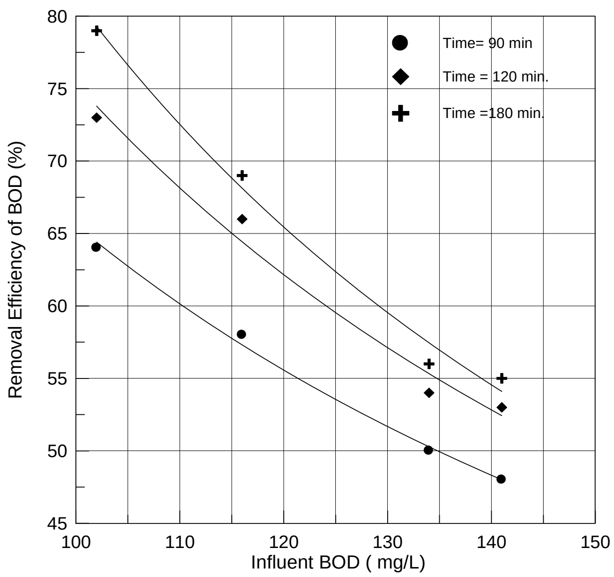


Fig. 7 Removal efficiency of BOD with influent BOD.

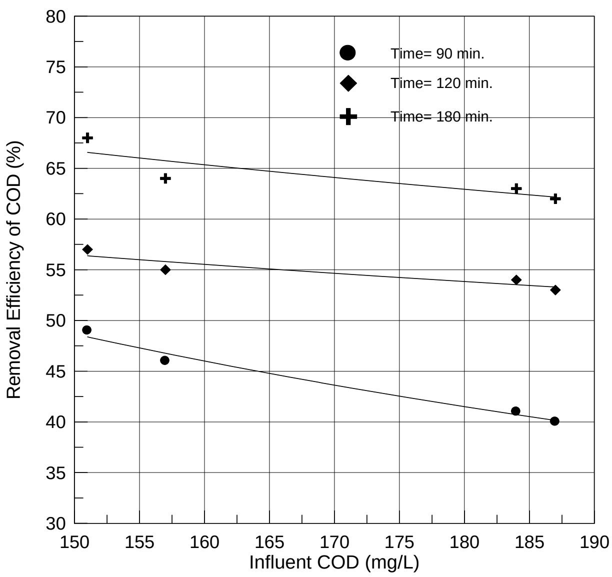


Fig. 8 Removal efficiency of COD with influent COD.

to fall gradually (forming a peak). Through period of times 315 min, 240 min and 144 min, for discharges 0.15 L/min, 1.0 L/min and 2.7 L/min, respectively, the removal efficiency continues to increase because the filter deposits continue to settle gradually causing clogging of the filter bed. This continues until the bed was completely clogged or reaching the terminal removal efficiency. This may be referred to the reduction occurred in the free void area as the particles accumulate in the bed which causes the bed to offer resistance to the flow of water and led to increase the hydraulic loads on the filter bed. The filter must be backwashed in order to continue operating correctly. The figure also shows that the minimum flow (0.15 L/min.) is greater removal efficiency of turbidity (of more than 95%) than the other discharges because in low loading the pores in the media and surrounding soil tend to become clogged. Fig. 10 shows the removal efficiency of turbidity with influent turbidity at constant discharge 0.5 L/min. It is noticed that removal efficiency deceases with increase influent turbidity and the

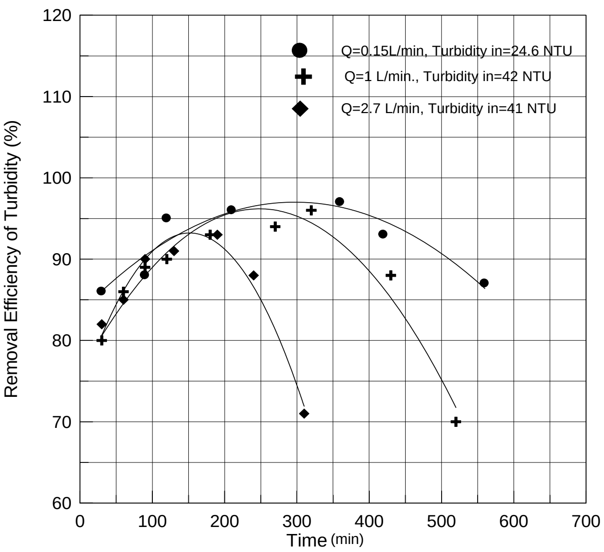


**Fig. 9 Removal efficiency of turbidity with different time.**

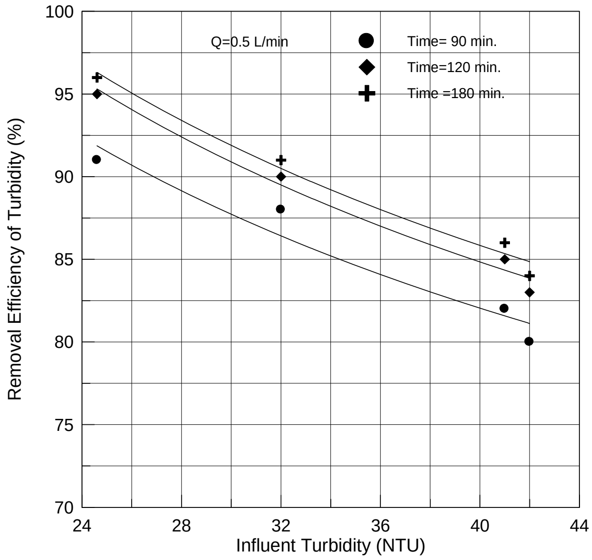


**Fig. 10 Removal efficiency of turbidity with influent turbidity.**

removal efficiencies increase with times (90 min, 120 min and 180 min) till the bed clogged and then removal efficiency begin to fall as shown in Fig. 9.

## 3. Conclusion

The conclusions drawn from the results discussed in this paper are summarized below:

When the hydraulic loading increases from 0.15 to 2.7 L/min, the difference in pressure head, $\Delta h$ increases from 4 cm to 10 cm. The head loss continue to increase because of the clogging of the filter bed during the processes.

During filtration, influent particles attach to the surface of the filter media grains and accumulate in the pore spaces resulting in a reduction in flow area and consequent increase in filter head loss. Once the filtrate quality begins to deteriorate and the maximum available head loss has been reached, the filter must be backwashed in order to continue operating correctly.

Infiltration should be conservatively designed using low loading rates because the pores in dual media tend to become clogged by settled particles.

The removal efficiencies of BOD and COD increased from 8% to 11% and 3% to 4% respectively with increased flow discharge from 0.15 L/min to 2.7 L/min.

The removal efficiencies increased with time of about 80% of BOD and more than 67% of COD. These are also noted that the efficiencies are decreased with increased influents of BOD and COD.

The removal efficiency of turbidity increases with time for different of hydraulic loading (0.15 L/min, 1 L/min and 2.7 L/min) and this efficiency reach of more than 95% at minimum discharge of 0.15 L/min. It is also noted that the removal efficiency of turbidity decreased with increased influent turbidity.

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## References

[1] Z.Y. Wang, Z.F. Ye, M.H. Zhang, X. Bai, Degrading of 2,4,6-trinitrotoluene (TNT) by immobilized microorganism-biological filter, Process. Biochem. 45 (2010) 993-1001.

[2] J.Q. Sang, X.H. Zhang, I.Z. Li, Z.S. Wang, Improvement

of organics removal by bioceramsite filtration of raw water with addition of phosphorus, Water Res. 37 (2003) 4711-4718.

[3] A.P. Picanco, M.V.G. Vallero, E.P. Gianotti, M. Zaiat, C.E. Blundi, Influence of porosity and composition of supports on the methanogenic biofilm characteristics developed in a fixed bed anaerobic reactor, Water Sci. Technol. 44 (2001) 197-204.

[4] X.L. Zhang, S. Zhang, F. He, S.P. Cheng, W. Liang, Z.B. Wu, Differentiate performance of eight filter media in vertical flow constructed wetland: Removal of organic matter, nitrogen and phosphorus, Fresenius Environ. Bull. 16 (2007) 1468-1473.

[5] W.C. Oh, H.J. Lee, J.S. Bae, Removal Efficiency of pollutants by multi layered metal treated carbon filter, Environ. Eng. Res. 9 (5) (2004) 193-200.

[6] A. Zouboulis, G. Trasks, P. Sermaras, Comparison of single and dual media filtration in a full-scale drinking water treatment plant, Desalination 213 (2007) 334-342.

[7] M.I. Abdul-Wahab, N.N. Al-Ghanim, B.H. Essebbagh, Performance of dual media down flow rapid gravity filters, Iraq Journal of Chemical and Petroleum Eng. 8 (1) (2007) 19-25.

[8] R. Otterpohl, U. Braun, M. Oldenburg, Innovative technologies for decentralised water, wastewater and biowaste management in urban and peri-urban areas, Wat. Sci. Tech. 48 (11/12) (1999) 23-32.

[9] B. Jefferson, A. Laine, S. Parsons, T. Stephenson, S. Judd, Technologies for domestic wastewater recycling, Urban Wat. 1 (1999) 285-292.

[10] E. Nolde, Grey water reuse systems for toilet flushing in multi-storey building-over ten years' experience in Berlin, Urban Wat. 1 (1999) 275-284.

[11] B. Jefferson, A.L. Laine, S.J. Judd, T. Stephenson, Membrane bioreactors and their role in wastewater reuse, Wat. Sci. Tech. 41 (1) (2000) 197-204.

[12] R. Otterpohl, U. Braun, M. Oldenburg, Innovative technologies for decentralised water, wastewater and biowaste management in urban and peri-urban areas, Wat. Sci. Tech. 48 (11/12) (2003) 23-32.

[13] Improvement of gray water treatment using combination of trickling biofiltration and ozonation, in: 9th Canada-France-Japan-Korea Joint Conference on Geo-Environmental Engineering, The University of British Columbia, Vancouver, Canada, 1998.

[14] N. Muhmmed, Hydraulic investigation on multi-media biofilter perfomance, Ph.D. Thesis, A1-Mustansiyria University, College of Eng., Baghdad, Iraq, 2011.

[15] Grey water reuse for irrigation in Baghdad, in: Scientific Seminar with Advanced Technology 2: Water Purification and Environmental Remediation, Amman, Jordan, June 25th-29th, 2006.

[16] Standard Methods for the Examination of Water and Wastewater, 20th ed., APHA, AWWA and WEF, Washington, DC, USA, 1998.