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The Efficiency of Ceramic Rings and Bio Media in BAFs Application in Wastewater Treatment According to Flow Changes

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Abstract: This experimental research compares the Polyethylene Bio-media and Ceramic Rings for their ability to treat the effluent wastewater from the primary sedimentation tank utilizing biological aerated filter BAFs. The filters were designed and worked in a parallel process under the same variables. These variables are the hydraulic retention time (HRT). The ceramic rings were used as submerged media, while the other filter used filter polyethylene bio media as floating media. The BAFs operated continuously with a variation of (HRT) equal to 24 minutes, 36 minutes, and 72 minutes under a DO ratio equal to 4.67±0.2 mg/l to find out the efficiency of each media in (COD), (BOD), and TSS) removal. The optimum removal efficiency 83.93%, 83.65%, and 85.60%, for COD, BOD, and TSS, respectively, by using ceramic rings media; to the other side, the removal efficiency reached 68.06%, 69.18%, and 71.07% when using bio media, respectively. The experiment results revealed that the ceramic rings showed more efficiency than the polyethylene bio media according to COD, BOD, and TSS.

Keywords: Biological aerated filter, submerged media, Floated media, Hydraulic retention time.

1. Introduction and Background

Because of the great expansion in urbanization as a natural result of population increase, this expansion helps to increase water consumption, which in turn leads to the rise in wastewater resulting from human activity, industrial and commercial development. So it is useful to investigate new technologies and different wastewater treatment methods, provided these methods are highly efficient and environmentally friendly.

1.1 Historical Brief about BAFs:

BAFs can be classified according to the type of utilized media. It could be submerged media if the utilized media density is more than the wastewater density or floated media if the media density is less than the wastewater density.

A huge variety of submerged and floated aerated biological filters were applied. Biocarbone, Biostyr and Biofor are three of the biological aerated filter technologies. Biocarbone is an example of a down-flow Sumberged filter, which employs a martial known as biodamine; it is turned into fabricated from an expanded bituminous shale as a supportive media. On the other hand, the Biostyr process is an example of the floating biological aerated filter system that was first introduced in Denmark [1].

Despite that, there are a lot of papers on the BAFs, but few have directly compared the performance of submerged and floated media.

[2] has compared sunken media polyvinylchloride and floating media recycled polypropylene. In this study, the floating media was more effective than the sunken media for suspended solid (SS), COD, and ammonia removal. That probably happened because of the buoyancy force of the media and the up-ward system flow [2] . Also, [3] has compared ceramic rings as submerged media and bio balls as floated media for industrial wastewater treatment by using two parallel aerated reactors and investigating the efficiency of removing nutrients such as nitrogen, phosphorus, and organic substance. The results showed that the efficiency of the ceramic rings (submerged media) is better than the bio balls (floated media) [3] .

This paper will illustrate the full comparison between the ceramic rings as submerged media and polyethylene bio-media as floated media.

2. Material and Methods:

The experimental study planned to evaluate the efficiency of the submerged biological filter. The floated biological filter used as a secondary treatment stage using a ceramic ring in the case of submerged biological filter media and polyethylene bio media in the floating biological filter. The two parallel filters were designed and installed in Zenien wastewater treatment plant located in Giza, Egypt. It was designed to work continuously, 24 hours per day, from January 2021 to June 2021. Zenien wastewater treatment plant, found in Giza, Egypt, was developed in 1990 [4] .

2.1 Characteristics of the Wastewater:

Characteristics of the influent wastewater (Primary sedimentation Tank effluent are shown in (Table 1)

2.2 Design of the filters:

The two pilot filters consist of two parts; part one consists of a submerged pump with Max. Flow 300 L/min and max. head equals to 11-m; installed in the primary settling tank to raise the wastewater to the circular storage tank, delivering the wastewater to both filters after setting the required flow rate through the installed valves in both filters. The storage tank is circular with an 84 cm diameter and 84 cm height. The second part consists of two parallel boxes made from metal with the same shape, with 1*0.5*0.7 m dimensions (0.35 m3); two tabs are installed in each filter. The first tab is the sampling tab installed at 12 cm from the base; the second tab is 2 cm from the ground of both filters to drain the excess sludge. The perforated metal sheet is installed 25 cm from the bottom of the submerged aerated filter only to hold the ceramic rings and keep them away from the bottom of the reactor to avoid clogging. Diffuser systems were installed to provide air at 15 cm height from the bottom of both filters to ensure maximum aeration for the biofilm. A small reservoir was constructed to drain the collected wastewater. Flow rates for the air were adjusted through the installed control valve to control the percentage of air provided. The whole pilot filter is illustrated in the following figures

Table (1): Characteristics of influent wastewater

Property	Range for 1st run	Range for 2nd run	Range for 3rd run	Range for 4th run	Range for 5th run	Range for 6th run	Range for 7th run	Range for 8th run	Range for 9th run	Average Values
COD	220-330	220-344	217-319	215-360	235-332	279-323	239-341	240-326	221-340	272
BOD	150-170	73-183	115-156	110-225	120-161	130-155	137-159	131-170	131-173	128
TSS	143-180	106-157	171-230	130-153	140-163	115-156	125-149	140-180	137-159	168
PH	7.05-7.45	7.04-7.51	6.82-7.3	7-7.5	7.29-7.35	7-7.25	7.58-7.7	7.13-7.72	7.01-7.3	7.27
Temperature	22-26	24.2-26	23-25	24-25	29-35.5	26-29	25-27.8	26.5-28	27.9-29.5	28.75

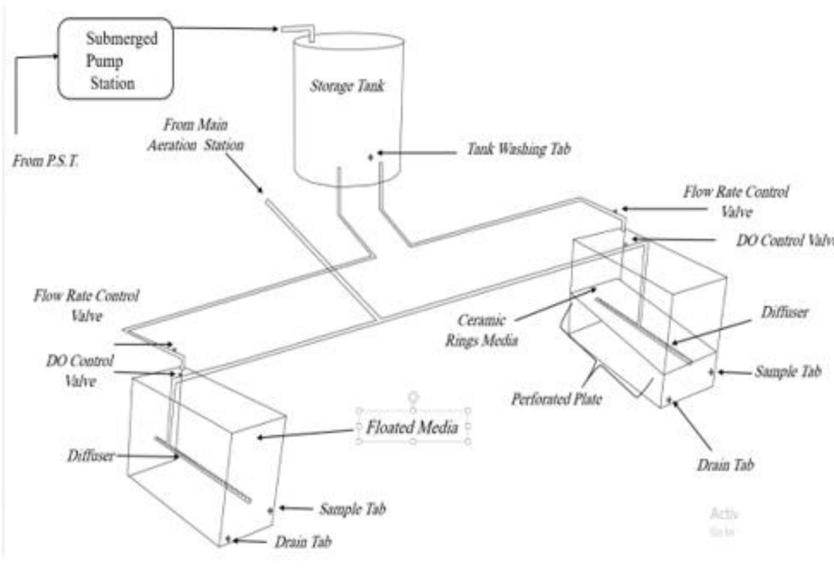


Fig (1) : The Whole pilot filter.

Fig (2) : The submerged ceramic ring media in the submerged aerated filter.

Fig (3) : The polyethylene floated bio media in the Floated aerated filter.

2.3 Characteristics of the Packing Media:

The packing media used in the submerged filter is ceramic rings with a filling ratio of 40% of the volume of the wastewater to be treated (Metcalf and Eddy, 2014). The raw materials of these ceramic rings are made mainly of the silica family, specifically silica dioxide (SiO_2), with a percentage higher than 92%. It has a wide specific surface area of up to 122.736 m2/g according to the BET test, which was measured in the National Research Centre located in Egypt, with high porosity of up to 50 % with a circular area of approximately equal to 1386Mm2 ± 18 Mm2, which was measured and analyzed by POM Leica Microsystems (Linka Temperature controller). Also, its bulk density is equal to 1.26 g/cm3. Its height is 1.2 cm with a hollow diameter equal to 0.5cm open, and 1 cm is circumferential to the hollow illustrated in figure (4), and its weight is 2.4584 g. At the same time, Bio media were used in the Floating aerated filter reactor with the same filling ratio of the total volume of the water to be treated. The bio media were made from polyethylene (Alandalus Company located in Obour city) with a density of 0.93 g/cm3, And a specific surface area of up to 13.1495 m2/g according to BET test, measured in the National Research Centre High porosity up to 90 %, the weight is 2.1531 g. The media height is 16 mm with a diameter equal to 22 mm, and its structure shape is a cylinder with external fines.

Fig (4) : Ceramic rings submerged media.

2.4 Experimental Plane and Operating Procedure:

The tested samples were collected from the effluent of the designed-filters (Samples were usually collected from 9 a.m. to 1 p.m. daily and then transferred directly to the laboratory for analysis).

After placing ceramic rings above the perforated plate and placing the same volume of the polyethylene bio media, the wastewater flowed over both of them until they reached a higher equal to 50 cm from the bottom of the filters. The ceramic rings were completely immersed because their density is more than wastewater density. In contrast, the polyethylene bio media were floated because their density is less than wastewater. Both filters were operated for 15 to 30 days for biofilm formation and development as a startup period to ensure active growth for the biofilm.(Aslam et al., 2017). Three main factors have a huge influence on the results. Those factors are the hydraulic retention time (HRT), dissolved oxygen (DO)(E. Mousa, 2012), and the utilized packing filter media, which is the scope of this research. Different values of flow rates (5 m3/d, 10 m3/d, and 15 m3/d), which have an equivalent (HRT) (24, 36, and 72 minutes) respectively, with a constant (DO) ratio of 4.67±0.2 mg/ were investigated for both parallel filters. This percentage of dissolved oxygen was used based on the recommendations of Metcalf and eddy's book, which recommended that the optimal DO ratios be from 2 to 5 mg/l. Both filters were washed daily or day after day by treated wastewater diluted for a period ranging from 15 to 30 minutes; to prevent media from clogging, rinse and sludge disposal, which gives a longer lifetime to the media and the system.

2.5 Analysis:

Influent and effluent-treated waste water were analyzed according to the standard methods for wastewater treatment examination (APHA-2005). Chemical oxygen demand (COD), biological oxygen demand (BOD), and total suspended solids (TSS), were the main examinations that were measured. In addition, pH and temperature were to investigate all factors that could affect the study, as shown in table (2)

Table (2): The Study Plan

Study Plan	Operating Parameter							
	Flow Rate (Q)	HRT	DO	COD	BOD	TSS	Temperature	PH
	(m^3/d)	(mins)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	°C	_
Run (1)	5	72	4.67±0.2	√	√	√	√	√
Run (2)	10	36	4.67±0.2	√	√	√	√	√
Run (3)	15	24	4.67±0.2	√	√	√	√	√

3. Results and Discussion

3.1 Performance of both filters at DO= 4.67±0.2 mg/l:

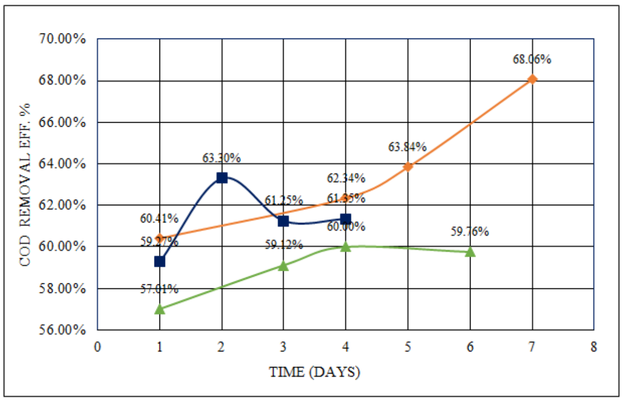
The following trails were operated under different Q and HRT with DO ratio= (4.67±0.2 mg/l. It reached the highest value according to prior scientific studies for the percentage of DO (2 mg/l to 5 mg/l) in the biological wastewater treatment that assures good aerobic condition for the filters (Metcalf and eddy, 2014). The following trails were conducted:

Trial 1: Q was 5 m3/d, and the equivalent HRT was 72 minutes.

Trail 2: Q rate was 10 m3/d, and the equivalent HRT was 36 minutes.

Trail 3: where Q was 15 m3/d and HRT was 24 minutes.

3.1.1 According to COD Removal Efficiency:



Fig(5) :COD removal efficiency for Floated Biological Filter (Bio rings).

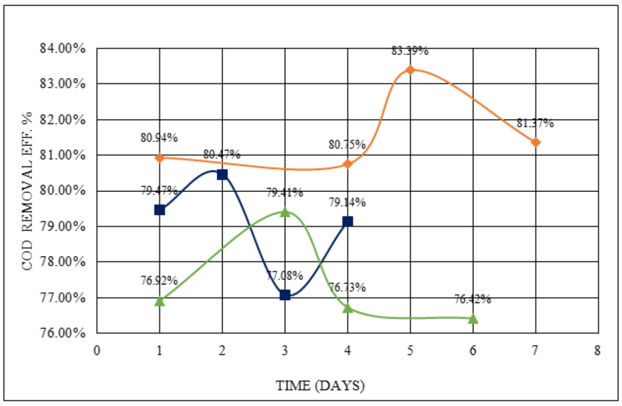


Fig (6): COD removal efficiency for Submerged biological filter(Ceramic rings).

As Figure (5) showed, the COD removal efficiency varied from 57.01% to 68.06 % to reach its maximum value in trail no. 1 under HRT = 72 minutes; in contrast, the minimum value was obtained in run 3 under HRT= 24 minutes. But, some times, the results showed some values that are higher than logical, as it records higher removal rates, which is conflicting with the scientific approval, which states that, due to the increase in HRT (72 minutes), the contact time between the biofilm and the wastewater will increase in turns and giving more time to bacteria to degrade the organic substance. This behavior can be explained by many reasons which may also affect the treatment efficiency, such as the temperature, because when the temperature increases, the DO ratio increases, and therefore, the treatment efficiency increases. The strength of influent wastewater also affects the efficiency, as when the concentration of contaminates increases, the efficiency decreases. On the other hand, figure (6) shows the effect of the Q and the (HRT) using a high rate of DO; the maximum removal efficiency obtained was 83.39% at Q = 5 m3/d and (HRT) = 72 minutes in the fifth day at trail 1. The minimum removal efficiency was recorded during trail 3 with 76.42%. This may be explained by the role and impact of the (HRT) in achieving the highest efficiency rate. Also, the biofilm layer greatly affects the results as it is developed and matures with time passing. These media have an effective role as they hold the biofilm, and the layer becomes thicker with time. The periodic washing also enhances the obtained result as it keeps the system clean, drains the sludge from the filter, and prevents media from clogging, giving more life to the press and the filter. That can explain the slight varying in the removal efficiency result in the same run because it depends on the filter's washing day.

3.1.2 According to BOD Removal Efficiency:

Figure (7) illustrates the behavior of the bio-media in the floating biological aerated filter under different values of HRT and Q. The BOD maximum removal efficiency gained was 69.18% at Q = 5 m3/d and (HRT) = 72 minutes. While the BOD minimum removal efficiency gained was at, trail 3 with a percentage of 57.58 % at Q= 15m3/d and (HRT) = 24 minutes. This can be explained by the effect of the biofilm, which is gaining more thickens, passing the time. Also, the periodic washing of the filter from time to time plays a role in improving the results because it keeps the filter clean and removes the excess sludge from it, and this explains the slight change in the removal efficiency in the same trail, depending on the day the filter was washed.

On the other hand, figure(8) shows the behavior of the ceramic rings in the submerged biological aerated filter; it illustrates the effect of the HRT and Q on the BOD removal efficiency by using DO = 4.67±0.2 mg/l. The maximum removal efficiency for the BOD removal was 83.65%, gained under operating parameters: 5 m3/d Q and 72 minutes HRT on the fifth day in trail 1. While the minimum removal efficiency obtained was 73.28% at Q = 15 m3/d with corresponding HRT =24 minutes. At trail 3, the BOD

the removal efficiency decreased from 83% to 73.28% that could be attribute to the influence of many factors, such as the utilized flow rate. When the flow rate increase, the HRT decreases, the removal efficiency decrease, and the influent concentration of the organic load; as when the influent contaminate concentration increase(Gaber et al., 2020).; the removal efficiency decreases, and finally the rate of the utilized DO; as the DO increase (Imran A. et al, 2016).; the removal efficiency increases as long as it is within the scientifically recommended range (2 mg/l to 5 mg/l) (Metcalf and eddy, 2014).

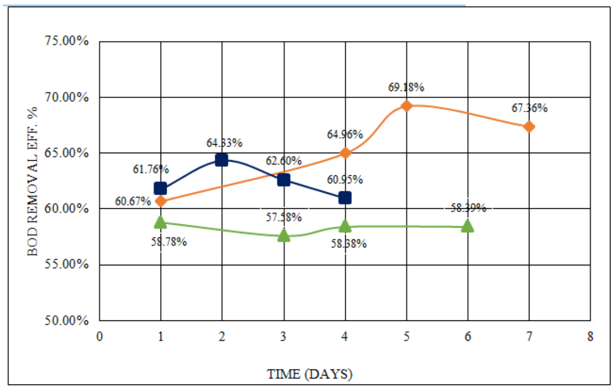


Fig (7) :BOD removal efficiency for Floated Biological Filter (Bio rings).

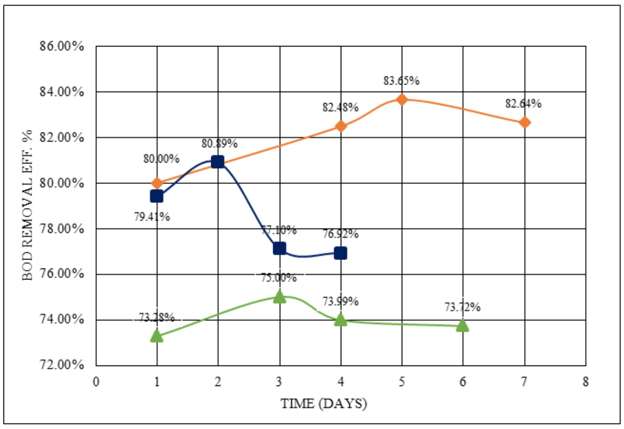


Fig (8) :BOD removal efficiency for Submerged biological filter(Ceramic rings).

3.1.3 According to TSS Removal Efficiency:

Figure (9) illustrates the TSS maximum removal efficiency for polyethylene bio-media which was 71.07 %. This result was obtained on the second day in the last trail (trail no.3) under Q = 15 m3/d and HRT =24 minutes. The second maximum result obtained was 70.40%, which was a very small difference between the two results, and in fact, the first result (71.07%) did not make sense according to the HRT obtained in trail (9) because the HRT is not much (24 minutes). But, as mentioned before, many other factors could affect the obtained results. On the other hand, the TSS minimum removal efficiency gained was 61.67 at trail (2) under-utilized Q = 10 m3/d, and HRT = 36. This conflicts with the scientific facts, which state that the minimum result should be obtained in trail 3 as the HRT in this trail is less than the HRT in trail 1. This can be explained by the effect of the difference in organic load on the tributaries of trail no.2 is more efficient and higher than the effect of the time difference (HRT) in particular, especially when the difference in HRT between the two trails was only 12 minutes.

Figure (10) illustrates that the TSS maximum removal efficiency recorded was 85.6 % on the first day in trail (1) with Q = 5 m3/d and HRT = 72 minutes. This obtained result could be explained by the effect of the periodic washing for the filter, as the filter is always washed before starting a new trail which helps improve TSS removal efficiency. Also, the HRT gives more contact time between the liquid and the media containing the biofilm (Raj SA et al, 2008). The minimum recorded TSS removal efficiency was 73.83 at trail (3) under-utilized Q = 15 m3/d and HRT = 24 minutes.

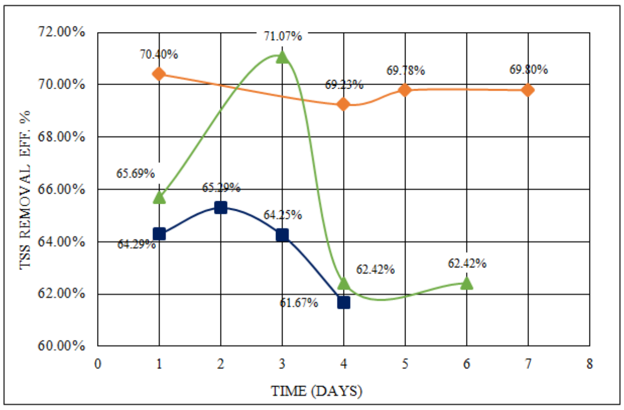


Fig (9) :TSS removal efficiency for Floated Biological Filter (Bio rings).

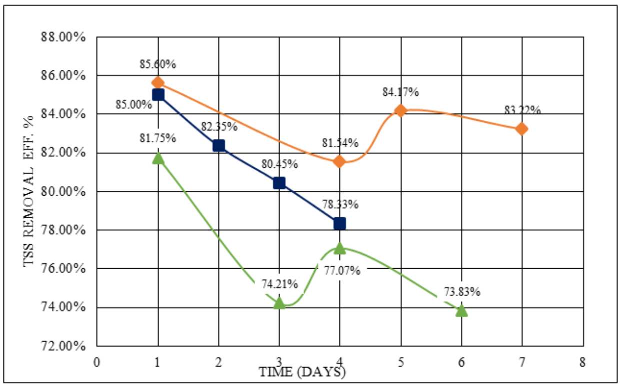


Fig (10) :TSS removal efficiency for Submerged biological filter(Ceramic rings).

4. Conclusions and Recommendations

4.1 Conclusions:

According to the experimental study program executed and the obtained results for both filters, the following conclusions were observed:

- Ceramic rings are effective media for the submerged biological aerated filter and obtained acceptable results.
- Polyethylene bio-media rings showed good results as a secondary treatment phase.
- Floated polyethylene bio media recorded good results in COD removal efficiency, it reached up to 68.06% under Q = 5 m3/d and HRT= 72 minutes.
- Ceramic rings were very effective in COD removal efficiency because they achieved removal efficiency up to 83.93% at DO = 4.67±0.2 mg/l with Q = 5 m3/d and HRT= 72 minutes.
- Floated polyethylene bio media recorded good results in terms of BOD removal efficiency; removal efficiency reached up to 69.18% at Q = 5 m3/d and HRT= 72 minutes.
- Ceramic rings were effective in BOD removal efficiency because they achieved removal efficiency up to 83.65% at Q= 5 m3/d and HRT= 72 minutes.
- The maximum removal efficiency recorded by the polyethylene bio media for TSS, was 71.07 % at Q= 15 m3/d and HRT= 24 minutes.
- Conversely, the maximum removal efficiency obtained by Ceramic rings for TSS was 85.60% at Q = 5 m3/d and HRT= 72 minutes.
- The utilized DO ratio of 4.67±0.2 mg/l was very effective in achieving a good removal efficiency for the both experimental systems
- The optimum flow rate for both systems was 5 m3/d. It obtained better results than other flow rates (10 m3/d and 15 m3/d).
- The optimum HRT utilized to achieve good removal efficiency for both systems was 72 minutes.

4.2 Recommendations:

The following recommendations can be further examined to improve and enhance results and get the most out of the BAF applications:

- Polyethylene bio-media has proven to be a good filter medium in BAF applications, more experiments with other raw materials should be investigated to obtain better results and including more technologies and parameters.
- Ceramic rings were showed a good results, so further are required to improve the results.
- Periodic filter flushing enhanced the treatment efficiency, so backwashing is highly recommended.
- This experimental work investigated the secondary wastewater treatment, so it is recommended to be used as a tertiary treatment or as advanced biological treatment.
- Improve the efficiency of both filters by adding chemicals, which will help enhancing the overall efficiency of the system

5. Acknowledgments

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