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The Effects of Submerged Biofilter on Water Quality of Polluted Drains in Egypt

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***Abstract*—The use of unconventional water sources, e.g., reusing treated wastewater and drainage water, could be an important water source for agriculture irrigation in order to overcome the water scarcity in Egypt. In this study, the effect of using submerged biofilters on water quality in the Bilbeas drain as a case study of polluted drains in Egypt is investigated. This study showed that the reuse of treated wastewater and drainage water for irrigation is an attractive option to alleviate water scarcity in Egypt. Furthermore, the case study in the Bilbeas drain showed that using submerged biofilters increased the removal efficiency of the chemical oxygen demand to 40.8% in comparison with natural self-purification, which was 9.8%.**

***Keywords*—Treated Wastewater; Drainage Water; Submerged biofilter; Agricuture Irrigation; Egypt**

I. Introduction

Egypt is one of the developing countries that faces crisis in sustainability and management of water resources. Moreover, the water sector in Egypt faces several problems, such as water scarcity and water quality deterioration, due to its increasing population [1]. Currently, water scarcity is one of the most serious problems facing Egypt, in addition to the pollution of water resources due to several types of contaminants from agricultural drainage water (DW), sewage, and industrial wastewater. This represents great challenges that the Egyptian government has to face in order to save its national water resources by rationalizing the water consumption, minimizing contaminant wastes, and implementing strict laws/policies to control the industrial wastewater pumping process on water resources. Another challenge is to improve current treatment methods to reduce pollution and lastly search for alternative sources of water [2].

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In contrast, the increase in the Egyptian population and the changes in lifestyle during recent decades are the main reasons for the rise in the water consumption for drinking and healthy uses [4]. Furthermore, developments in Sudan, Ethiopia, or other riparian countries may reduce the availability of water to Egypt [5-6].

The use of unconventional water sources, e.g., treated wastewater (TWW) and recycled water, especially recycled agricultural DW, could be important sources to combat water scarcity in Egypt [7]. The TWW provides an attractive, unconventional water source for irrigation [8], moreover, TWW used in irrigation is estimated to reach 2.4 billion m^3 (BCM) in 2027 [3]. In contrast, the DW is used for irrigating crops, especially when water in the irrigation canals is scarce during the summer season [8].

In contrast, the increase in population as well as the leakage of sewerage facilities have enforced people to discharge all their types of wastes into agricultural drains. Therefore, the direct use of water from these polluted drains for irrigation has become risky and attiributed to severe impacts on human and environmental health [9]. In order to improve the quality of such water before reusing, further efforts are required by both the government and research centers to improve its quality. Thus, the main objective of this paper is to investigate the effect of using submerged biofilters (SBs) on water quality in the Bilbeas drain as a case study of polluted drains in Egypt.

II. Experiment

In this experimental study, a field experimental model was built at El-Sahafa bridge (Bilbeas, Egypt) on the berm of the Bilbeas main drain. The drain water is a mixture of treated, untreated, and partially treated domestic and industrial wastewaters in additional to agricultural runoff. The total solids in the drain water ranged between 600 and 900 ppm, and the dissolved oxygen ranged between 0 and 1.3 ppm.

The quality of the treated drain water was measured in terms of its chemical oxygen demand (COD) as an important indicator of organic pollution content. The removal ratios of COD were investigated using varying influent flowrates and three different types of media (as SBs). These various types were mutually-compared and compared to a reference channel without any media to obtain the optimum conditions used in this study.

In this experiment, four stream pilots (40 m length × 0.38 m width × 0.75 m height) were used, as shown in **Figure 1**. The first pilot was used as a reference channel without any media to simulate the 'natural' stream, i.e., self-purification process. The second, third, and fourth pilots were equiped with three different types of biofilter media (Egyptian Packaging and Plastic System (Makka), Cairo, Egypt) working as SBs: gravel, plastic star-shape, and pall rings, respectively, as shown in **Figure 2**. The model, shown in **Figure 1**, was constructed from reinforced concrete (Arab Contractors, Bilbeas, Egypt) and included two inlet chambers, the first received the pumped water and the second equally distributed it on the four streams. A rectangular weir was built at the influent of each stream to measure the influent discharge. In order to raise the level of the drain water up to the pilots, three diesel pumps (each of 10 horsepower, HP) were used.

The pall rings and star-shaped media were made of polyethylene. The pall ring unit was cylindrical with internal ribs and perforated walls with a 5.0 cm diameter and 5.0 cm height. The star-shaped unit was 6.0 cm in diameter and 1.50 cm height, while gravel had diameters ranging from 3.0 to 4.0 cm. The physical properties of the three medias are summarized in **Table 1**.

III. Results and Discussion

The quality of the treated water in the four drains using the different medias was evaluated in terms of COD removal ratios. As a result of the variation of influent COD (initial value before media) and the different influent flowrates, which, in turn, is based on the variation of influent water characteristics. The initial COD values ranged between 50 and 150 ppm, while the influent flowrates ranged between 3 and 9 L/s. **Figure 3**-a shows that the COD removal ratios in the stream packed with gravel biofilter range between 20.3 and 48.7%. Moreover, the COD removal ratios had noticeably increased with decreasing the influent flowrates, which can be attributed to the fact that high flowrates result in conditions of high load of organic matter, consequently decreasing the efficiency of COD removal. A flowrate of 3 L/s and a COD of 97.7 ppm showed the highest COD removal ratio equivalent to 48.7%.

The stream packed with the star-shaped biofilter showed the same behavior of gravel biofilters, where a decrease in the flowrate led to an increase in the COD removal ratios, as displayed in **Figure 3**-b. On the meanwhile, for the star-shaped media, the COD removal ratio reached 56.6% at the minimum flowrate of 3 L/s. In contrast, the pall rings biofilter recorded a 65% COD removal ratio at the minimum flow rate (3 L/s), as shown in **Figure 3**-c. Thus, the pall rings biofilter recorded the highest removal ratio among the different medias.

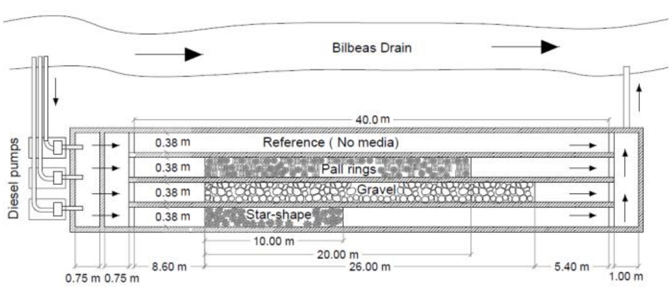

Figure 1: The experimental model installed at the Bilbeas drain, Egypt.

Table 1: Properties of the Media Used in this Study.

Media	*Specific Surface Area [m²/m³]*	*Porosity [%]*	*Length [m]*	*Cross-Section [m²]*	*Occupied Volume [m³]*
Star-shaped	175.7	87.0	10	0.37×0.20	0.47
Pall ring	87.8	87.0	20	0.37×0.20	1.48
Gravel	67.6	39.5	26	0.37×0.20	1.92

In order to compare the quality resulted from the different biofilters with the reference natural self-purification (without media) stream pilot, the average values of COD removal ratios were calculated for the reference without media and for each media. The values at 8.8 m were used as the initial COD values for each stream. The values at distances equivalent to 10, 20, and 26 m were considered the final values for the streams equipped with the star-shaped, pall rings, and gravel biofilters, respectively, as indicated in **Figure 1**. The removal efficiency values were then mutually-compared to their corresponding values of the reference channel.

The results in **Figure 4** illustrate that the average values of COD removal ratio at different flowrates.

a
b
c

Figure 2: Different biofilter medias used in the experiment: a) gravel, b) pall rings, and c) star-shaped.

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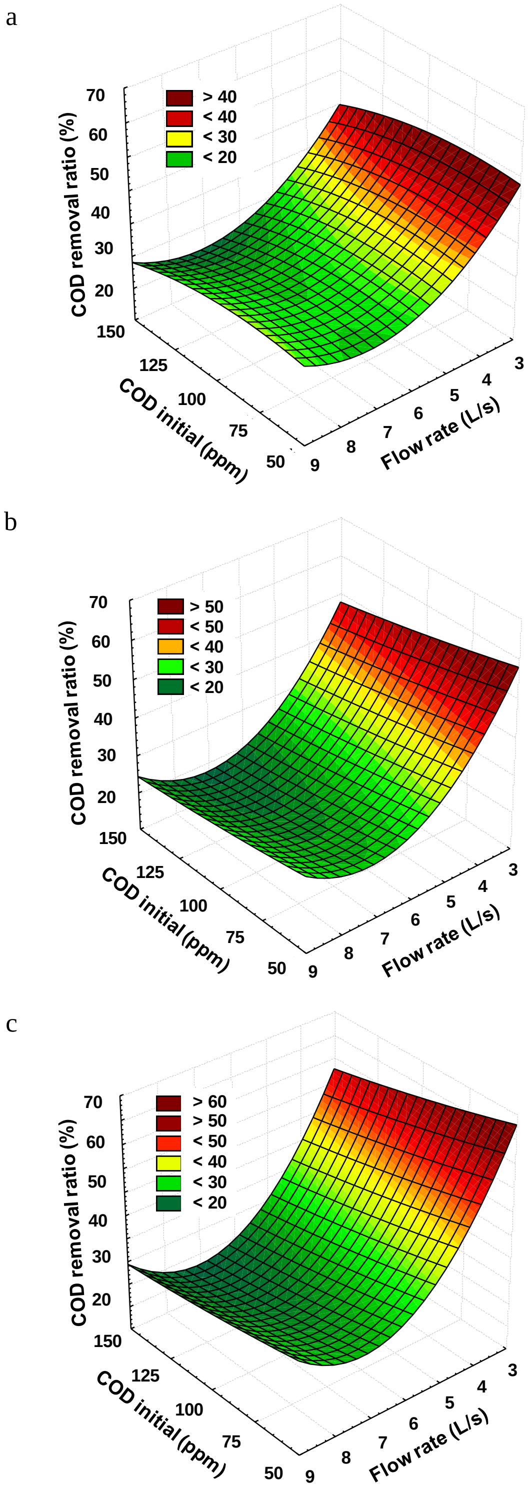

Figure 3: Effect of using a) gravel, b) star-shaped, and c) pall rings biofilters on the stream COD removal efficiency.

The highest COD removal ratio occurred at the lowest flow rate (3 L/s). Moreover, the pall rings recorded the highest removal ratio, where the star-shaped came on the second place surpassing the values obtained by the gravel biofilters.

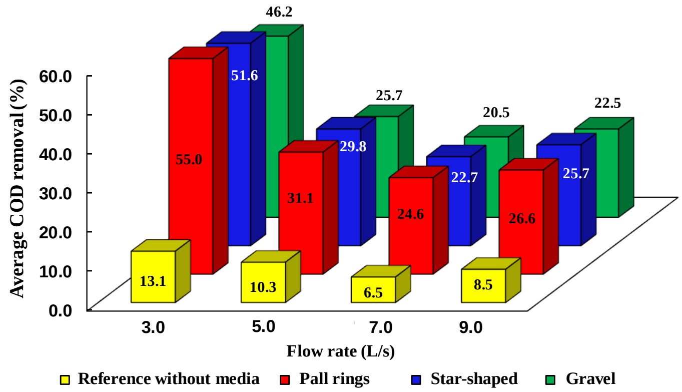

Figure 4: Effects of using different medias compared to the reference stream on COD removal ratio at different flowrates.

On the meanwhile, the reference natural self-purification (without media) stream showed the lowest COD removal ratios. Thus, using the pall rings biofilters increased the efficiency of COD removal from 26.6 to 55.0% compared to 6.5 to 13.1% achieved by the natural self-purification in the reference channel.

These results are consistent with El-Gohary [9] who found that using SBs in polluted drains increases the COD removal efficiency from 1.4 to 18.4% with respect to the natural self-purification reference channel to 14.0 to 58.0% in the channel packed with the media.

Moreover, the obtained results also agree with Daif et al. [10] who studied the performance of rotating biological contactors (RBC) under varying flowrates and their results showed that using self-RBC in the drain water increases the COD removal efficiency from 39.50 to 44.35% compared to 6.3 to 16.5% obtained by the natural self-purification efficiency in the reference channel. Also, they showed that using self-RBC in the drain water increases the COD removal efficiency from approximately 34.10 to 65.32% compared with 3.8 to 16.5% for the reference channel.

The results of the current study showed that the COD removal efficiency was improved using SBs compared to the reference stream using no-media.

On the other hand, suspended micro-organisms are bacteria that are present in any polluted water. Biological degradation is the degradation of organic matter due to these bacteria. The results of this study indicated that the natural stream self-purification depended on biological degradation of the organic matter via suspended micro-organisms in the wastewater. Meanwhile, two removal mechanisms of organic matter were achieved using the SBs. The removal mechanisms included the removal of organic matter by both suspended bacteria and bacteria attached to media. Regarding the former mechanism, i.e.. removal of organic matter by suspended bacteria, a portion of suspended organic matters was removed due to the filtration action fulfilled by passing through the media. For the second mechanism, the biological degradation of the organic matter was carried out via the attached micro-organisms that grow attached to the media [11].

IV. Conclusion

The quality of the treated water in the three drains using submerged biofilters in order to improve the quality of drain water in comparison with the natural self-purification stream. While, the pall rings biofilter recorded the highest COD removal ratio of 65% at the minimum flow rate of 3 L/s, the COD removal ratios by the star-shaped and gravel medias were 56.6% and 48.7%, respectively.

Finally, the achieved COD removal efficiency has increased from 6.5 to 13.1% for the reference natural self-purification (without media) stream and from 26.6 to 55.0% when plastic submerged biofilters were utilized.

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