Review the performance of the filtration media in bioreactors for wastewater treatment

Adel S. Faskol[1]

Gabriel Racovițeanu[2]

Elena Vulpasu[3]

adel.faskol@aonsrt.ly

[1]**Libyan Authority for Scientific Research Branch Benghazi-Libya.**

[2,3]**Department of Hydraulics, Sanitary Engineering, and Environmental Protection, Technical University of Civil Engineering Bucharest, 122-124, Lacul Tei Bvd., Sect. 2 RO 020396, Bucharest 38/Romania.**

Abstract:

The majority of centralized wastewater treatment plants in low-income countries required rehabilitation or renovation over the next decade. In most cases, centralized treatment plants for low-income countries generated long-term financial burdens for governments and local administrations. As a result, the decentralization appears to be a reasonable solution to the problem. The term decentralized treatment plants also refer to systems that serve small areas (clusters) of the urban area based on hydrology, terrain, and local ecological concerns. Sustainable decentralized treatment emphasizes on-site treatment and recycling of materials. Decentralization may therefore be helpful in achieving the sustainable development goals (SDGs), mostly SDG6 – Clean Water and Sanitation. The Biological Aerated Filter (BAF) technology is considered attractive and well-suited as a decentralized wastewater treatment that can easily remove carbonaceous and nutrients by the biomass growth on the surface of support media, as well as, the physical removal of suspended solids in a single-stage. Furthermore, it can be used both for secondary and tertiary stages of wastewater treatment. The main objective of this research is a review of the performance of three several filtration media as follows: activated carbon, sand, and ceramic particles, all used as attached growth zones in the biological aerated filters, for the creation of local bio-filtration beds

low cost, and improving the effluent quality. The results of this research indicated that for a hydraulic retention time HRT of 12 hours with 100% recirculation of the influent, all three-filtration media-based beds performed extremely well in nitrification and carbonaceous matter removal.

The research has been developed in the Colentina Laboratories of the Hydrotechnics Faculty from the Technical University of Civil Engineering Bucharest, Romania.

Keywords: Biological aerated filter, Carbonaceous matter removal, Nitrification.

Introduction:

In the 1980s recently, has been an increase in the number of proprietary processes used in the advancement of the Biological Aerated Filter (BAF) systems [1]. The BAF was originally developed in Europe and subsequently widely utilized globally as a decentralized wastewater treatment plant due to its advantages over other technologies [2]. The idiom biological aerated filter BAF derives from the integration of air and the bacterial filtering process. The BAF is typically composed of a media that processes carbonaceous and nitrogenous matter by biomass that grew on the surface media and apprehending suspended particles in the media [3]. The technology of BAF comes in a variety of varieties on the market, and according to the manufacturer's design specifications. The BAF is operated either in an up−flow or down−flow mode depending on the feed position of the wastewater [4]. When removing carbonaceous matter and nutrients from the bioreactors the down−flow mode of BAF is useful, since nitrifying microorganisms are often located near the bottom of the bioreactors and there is no oxygen restriction, consequently oxygen limitation is not an issue [5]. Up−flow mode of BAF with co−current air can handle higher influent flow rates than a down−flow mode of BAF. Oxic and anoxic zones may be present in the BAF's up−flow mode to facilitate nitrification and denitrification. The aerated zone oxidizes the remaining organic matter and ammonia, while the anoxic zone eliminates soluble organic matter and nitrate [6]. It has been demonstrated that the wastewater's carbon−to−nitrogen ratio (C/N) affects biological filters delivering nitrifiers and heterotrophs[7], [8]. To comprehend how nitrogen is removed from BAF, the C/N−Low ratios were examined [9].

Types of filtration media in the BAFs:

The filtration media is an important component of biological aerated filter BAF. The hydraulic characteristics and the oxygen−substrate transition rate are clearly affected by the filter content [5]. Choosing filtration media for BAF is thus a critical component of the operation and design of BAF since it allows the effluent output to match the controlled norm [10]. The biological aerated filter BAF uses two types of filtration media: floating media, for example (plastics, polyester pellets, and polyurethane pellets) and submerged media, for example (zeolite, ceramics, and sand) [11]. Submerged filtration media can be utilized in both up−flow and down−flow arrangements while floating filtration media can only be used in up−flow configurations [5], [12]. For roughing, coarse filtration media

>6 mm is suggested medium filtration media is 3–6 mm for a typical application, and fine filtration media (3 mm) for tertiary treatment and/or effluent polishing [13].

Experimental Set-up:

These experiments use 3 similar pilot-scales of biological aerated filters BAF (Figures 1, 2), the feed position with municipal wastewater is downflow mode, and the description of

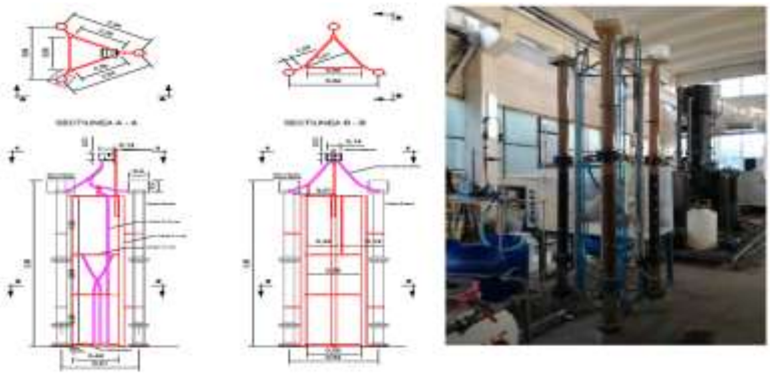

Figure 1. Plan and photo of the pilot-scales downflow of BAF

Activated carbon filtration media bed | Sand filtration media bed | Ceramic particle filtration media bed

Figure 2.View of filtration media beds used in the pilot-scales of BAF

Table 1.Summary description of the pilot-scales of BAF

Characteristic	Value
constructed	using PVC pipe
number of reactors	3
internal diameter of each reactor height of each reactor	0.10 m
	2.76 m
clearance at the head total height of each reactor	0.20 m 2.96 m
column area of the pilot-scale	2.648 m^2
filtration media-based bed	activated carbon, sand, ceramic
particle size	0.78±0.60 mm, 0.95±0.58 mm, 3.28±2.14 mm
total bed height of each reactor	1.00 m
volume bed of each reactor	7.855 L
mean influent flowrates	0.18 L/min
hydraulic retention time	12-hours
air: liquid ratio	10 :1
recirculation	100%
backwash	once/day

Note: The particle size shown is the mean ± standard deviation.

Laboratory analyses:

The pilot-scales of BAF operated at an ambient air temperature of 8 to 29°C with an average of 17.93±7.27°C. As the feed loading rate of 3 pilot-scales of BAF was

0.007178±0.00 kg TKN/m^3.d, and 0.0434±0.01kg tCOD/m^3.d. During the testing phase, the influent and effluent samples were taken from the pilot-scales of BAF for daily lab analysis, five times per week, as follows: soluble chemical oxygen demand sCOD, Total Kjeldahl Nitrogen TKN, alkalinity as $CaCO_3$, pH. Samples analysis-based methods of the American Public Health Association 2017 [14].

Results and discussion:

During the experiments period, the influent have been recycled 100% and the hydraulic retention time HRT of 12 hours. The results are as follows:

For the pilot-scale of BAF used an activated carbon-based filtration media bed with a diameter of 0.78±0.60 mm and a height of bed 1 meter, showing that TKN and sCOD concentrations decreased from 10.46±6.74 mg TKN/L to 1.42±0.95 mg TKN/L, and from 41.50±12.86 mg sCOD/L to 3.53±0.79 mg sCOD/L, with removal efficiency has reached 86.37%, and 91.47%, respectively for TKN and sCOD, as shown in figure 3.

For the pilot-scale of BAF used a sand-based filtration media bed with a diameter of 0.95±0.58 mm and a height of bed 1 meter, showing that TKN and sCOD concentrations decreased from 10.46±6.74 mg TKN/L to

1.58±0.9 mg TKN/L, and from 41.50±12.86 mg sCOD/L to 3.75±0.8 mg sCOD/L, with removal efficiency has reached 84.82%, and 90.96%, respectively for TKN and sCOD, as shown in figure 3.

For the pilot-scale of BAF which used a ceramic particle-based filtration media bed with a diameter of 3.28±2.14 mm and a height of bed 1 meter, showing that TKN and sCOD concentrations decreased from 10.46±6.74 mg TKN/L to 1.70±1.00 mg TKN/L, and from 41.50±12.86 mg sCOD/L to 3.93±0.97 mg sCOD/L, with removal efficiency has reached 83.69%, and 90.51%, respectively for TKN, and sCOD, as shown in figure 3.

The removal efficacy was largely determined by the deposition of activated biological film in the filter media bed and the efficiency of mass transfer. The primary factor that could affect COD elimination was the variation in the surface features, unique surface area, and media morphological features [15], [16], [17]. For example, in a pilot-scale fixed-film bioreactor device, the COD elimination rate was consistently between 80-90% at an empty bed with a hydraulic retention time HRT of 8 hours. [18].

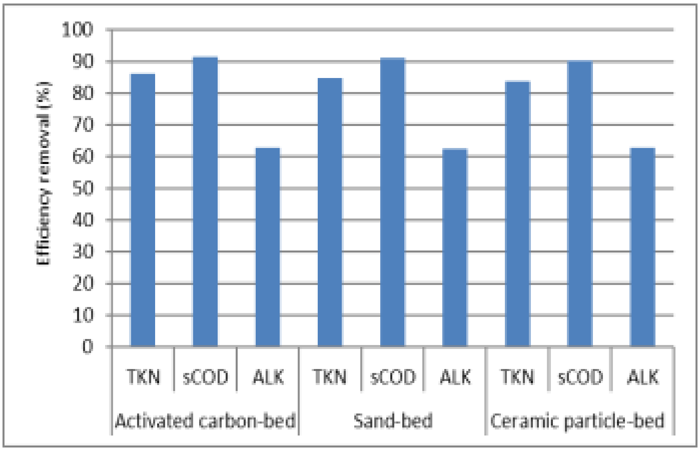

Figure 3.The average removal efficiency of TKN, sCOD, and alkalinity

comparison between the filtration media beds:

These experiments showed the mean influent pH value was 7.22±0.20 and the mean influent alkalinity was 207.25±8.97 mg $CaCO_3$/L, as direct evidence of nitrification, the experiments showed that more than 60 % of the influent alkalinity as calcium carbonate $CaCO_3$ was consumed (Figure 3), where the mean effluent concentration was 77.25±2.60 mg $CaCO_3$/L, 77.56±2.77 mg $CaCO_3$ /L, and 77.31±2.71 mg $CaCO_3$ /L, with pH value, was 7.21±0.20, 7.22±0. 20, and 7.22±0. 20, respectively for the pilot-scale of BAF using activated carbon-based filtration media bed, the pilot-scale of BAF using the sand-based filtration media bed, and the pilot-scale of BAF using the ceramic particle-based filtration media bed.

According to Gujer & Boller [19], an alkalinity level of at least 75 mg/L was needed to sustain the optimal nitrification rate in nitrifying biofilters used in urban wastewater treatment. The effect of alkalinity on the rate of nitrification is proportional to the pH value. For example, in a pilot-scales of BAF, the mean nitrification efficiency was between 85.17% to 90.11% as direct evidence of nitrification and more than 60 % of the influent alkalinity as $CaCO_3$ was consumed [20]. The pH value of wastewater should be held between (6 to 9) to protect organisms [21]. According to an analysis of the impact of pH on nitrification efficiency in an upflow biofilter, nitrification efficiency increased linearly by 13% per unit pH rise between pH 5.0 and 8.5 [22].

The main conclusion:

This study concluded that for all three filtration media beds proposed in this research, the mean removal efficiency reached between 83% to 86% for Total Kjeldahl Nitrogen TKN. For carbonaceous matter removal in terms of sCOD the mean removal efficiency reached between 90% to 91%. Regarding the alkalinity, all three filtration media beds consumed more than 60% of the influent alkalinity as $CaCO_3$ which is direct evidence of nitrification. Finally, the findings of this research revealed that all three-filtration media worked extremely well in terms of nitrification and carbonaceous matter removal.

مراجعة أداء مواد الترشيح في المفاعلات البيولوجية لمعالجة مياه الصرف الصحي

د. عادل صالح فصكول المجبري

الهيئة الليبية للبحث العلمي– بنغازي / ليبيا.

أ.د. غابرييل راكوفيتشينو

قسم الهيدروليكا والهندسة الصحية وحماية البيئة

أ.د. إلينا فولباسو**

الجامعة التقنية للهندسة المدنية بوخارست، رومانيا.

المخلص :

معظم محطات معالجة مياه الصرف الصحي المركزية في البلدان منخفضة الدخل تحتاج إلى إعادة تأهيل أو تجديد على مدى العقد المقبل. في معظم الحالات، تشكل محطات معالجة مياه الصرف الصحي المركزية في البلدان المنخفضة الدخل أعباء مالية طويلة الأجل تثقل كاهل الحكومات والإدارات المحلية. نتيجة لذلك، يبدو أن محطات معالجة مياه الصرف الصحي اللامركزية هي حل معقول للمشكلة. يشير مصطلح محطات معالجة مياه الصرف الصحي اللامركزية أيضًا إلى محطات المعالجة التي تخدم مناطق صغيرة (مجموعات) كجزء من المنطقة الحضرية بناءً على الهيدرولوجيا والتضاريس و الاهتمامات البيئية المحلية. تعتمد المعالجة اللامركزية المستدامة لمياه الصرف الصحي على المعالجة في الموقع وإعادة تدوير المواد. لذلك قد تكون المعالجة اللامركزية لمياه الصرف الصحي مفيدة في تحقيق أهداف التنمية المستدامة، وبالتحديد الهدف السادس من أهداف التنمية المستدامة (المياه النظيفة والصرف الصحي). تعتبر المرشحات البيولوجية المهواة تقنية جذابة ومناسبة تمامًا

كمعالجة لامركزية لمياه الصرف الصحي، حيث يمكنها بسهولة إزالة المواد الكربونية والمغذيات، وكذلك إزالة المواد الصلبة العالقة في وحدة معالجة واحدة. بالإضافة إلى ذلك، يمكن استخدامها في المعالجة الثانوية لمياه الصرف الصحي أو المعالجة الثلاثية (المتقدمة). كان الهدف العام من هذا البحث هو مراجعة أداء ثلاث مواد مختلفة من مواد الترشيح على النحو التالي: جزيئات الكربون المنشط بقطر 0.60±0.78 مم وجزيئات الرمل بقطر 0.58±0.95 مم وجزيئات السيراميك بقطر 2.14±3.28 مم، بحيث تستخدم كمنطقة نمو مرتبط تدعم الكتلة الحيوية في المرشحات البيولوجية المهواة ، وذلك لتطوير مواد ترشيح محلية وبتكلفة منخفضة ، لتحسين جودة مياه الصرف الصحي المعالجة. أظهرت نتائج هذه الدراسة بعد الحجز الهيدروليكي لمياه الصرف الصحي لمدة 12 ساعة مع إعادة تدوير المياه الخارجة بنسبة 100٪ تبين أن جميع مواد الترشيح الثلاثة المقترحة في هذه الدراسة كان أداءها جيد للغاية في علمية النترجة وإزالة المواد الكربونية.

تم إجراء هذا البحث في مختبرات كلية التقنيات المائية، منطقة كولنتينا، الجامعة التقنية للهندسة المدنية بوخارست ، دولة رومانيا.

References:

1. Carrand, G., Capon, B., Rasconi, A., & Brenner, R. (1990). Elimination of carbonaceous and nitrogenous pollutants by a twin stage fixed growth process. *Water Science and Technology* (22(1/2)), pp. 261-272.

2. Allan, M., Leopoldo, M. E., & Tom, S. (1998). A comparison of floating andsunkenmedia biological aerated filters for nitrification. *Chem. Technol. Biotechnol.* (72), pp. 273–279.

3. Biplob, P., Fatihah, S., Shahrom, Z., & Ahmed, E. (2012).biological aerated filters (BAFs) for carbon and Nitrogen removal: a review. *Journal of Engineering Science and Technology*. Vol. 7, No. 4, pp. 428 – 446.

4. Faskol, A. S., Racovieanu, G. (2021). Technology review of the biological aerated filter systems BAFs forremoval of the nitrogen in wastewater.IN: Proceedings of the 7th conference of the sustainable solutions for energy and

environment,Publisher: IOP Conf. Ser.: *Earth Environ. Sci.* 664, 012106.doi:10.1088/1755-1315/664/1/012106.

5.Mendoza-Espinosa, L., & Stephenson, T. (1999). A review of biological aerated filters (BAFs) for wastewater treatment. *Environ. Eng. Scie.* (16:3), pp. 201-216.

6. Ha, J. (2006). Nitrogen and phosphorus removal in biological aerated filters (BAFs). *PhD thesis* (Major: Civil Engineering (Environmental Engineering) Iowa State University, Ames, Iowa).

7. Fdz-Polanco, F., Méndez M. A., UruenaS., VillaverdeS., and GarciaP. A., (2000). Spatial distribution of heterotrophs and nitrifiers in a submerged biofilter for nitrification, *Water Res.,* vol. 16, pp. 4081-4089.

8.Li, J., Zhu, Z., Gong, B. X., and Cangcong, P (2002). Effects of colloidal organic matter on nitrification and composition of extracellular polymeric substances in biofilms, *J. Chem. Technol. Biotechnol*. vol.77, pp.1333-1339.

9. Faskol, A. S., Racovieanu, G., Vulpasu, E., (2021). The ratio Carbon/Nitrogen - influence on the nitrification process in biological aerated filter.IN: Proceedings of the 10th International Conference on ENERGY and ENVIRONMENT (CIEM), Bucharest, Romania, 2021, pp. 1-4, Publisher: IEEE, doi: 10.1109/CIEM52821.2021.9614833.

10. Faskol, A. S., Racovieanu, G., (2020). Nitrification and Denitrification Process Employing Three Different Sunken Materials Types in Biological Aerated Filter (BAFs), *International Journal of Engineering Research And Management (IJERM)*,ISSN: 2349- 2058, Volume-07, Issue-10, pp. 1-5.

11. Faskol, A. S., Racovieanu, G., Vulpasu, E., (2021). Combined COD and Ammonium-Nitrogen Elimination –

a Comparison between Different Filtration Media on BAFs,*IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)*, 18(5), 2021, pp. 09-16.DOI: 10.9790/1684-1805010916.

12. Mann, A. T., Mendoza-Espinosa, L., & Stephenson, T. (1999). Performance of Floating and Sunken Media Biological Aerated Filters under Unsteady State Conditions. *Water Res*. (33 (4)), pp. 1108-1113.
13. Quickenden, J., Mittal, R., & Gros, H. (1992, September). Effluent nutrient removal with Sulzer Biopur and filtration systems. the European Conference on Nutrient Removal from Wastewater, Wakefield, UK.
14. American Public Health Association, American Water Works Association and Water Environment Federation. (2017). '*Standard Methods for the Examination of Water and Wastewater*, 21st Edition.

15. Kent, T. D., Fitzpatrick, C. S., & Williams, S. C. (1996). Testing of biological aerated filter (BAF) media. *Water Research*, (34(3-4)), pp. 363-370.

16. Tay, J. H., Chui, P. C., & Li, H. (2003). Influence of COD:N:P ratio on nitrogen and phosphorus removal in fixed-bed filter. *J. Environ. Eng.* (129), pp. 285–290.

17. Lee, J., Kim, J., Lee, C., Yun, Z., & Choi, E. (2005). Biological phosphorus and nitrogen removal with biological aerated filter using dentrifying phosphorus accumulating organism. *Water Sci. Technol.* (52 (10–11)), pp. 569–578.

18. Jou, C. G., & Huang, G. C. (2003). A pilot study for oil refinery wastewater treatment using a fixed-film bioreactor. *Adv. Environ. Res.* (7), pp. 463–469.

19. Gujer, W., &Boller, M. (1986). Design of a nitrifying tertiary trickling filter based on theoretical concepts. *Water Res.* (20 (11)), pp. 1353-1362.

20. Faskol, A. S., Racovieanu, G. (2021). Effect of DO, Alkalinity and pH on nitrification using threedifferent sunken materials types in biological aerated filter BAFs.IN: Proceedings of the 7th conference of the sustainable solutions for energy and environment, Publisher:IOP Conf. Ser.: *Earth Environ. Sci.* 664 (2021) 012079.doi :10.1088/1755-1315/664/1/012079.

21. Akpor, O. B., Momba, M. N., & Okonkwo, J. O. (2008). The effects of pH and temperature on phosphate and nitrate uptake by wastewater protozoa. *African J. Biotechnol.* (7 (13)), pp. 2221–2226.

22. Biplob, P., Fatihah, S., Shahrom, Z., & Ahmed, E. (2011). Nitrogen-removal efficiency in an upflow partially packed biological aerated filter (BAF) without backwashing process. *Journal of Water Reuse and Desalination* , pp. 27-35.