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Enhancing Nutrients and Fecal Coliform Removal from Wastewater Using Aerated Modified Trickling Filter

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الخلاصة:

تواجه مصر حاليا مشكلة كبيرة في توفير مياه صالحة للزراعة نتيجة النقص المتزايد للمياه الوارده من دول المصب. في الوقت الحاضر، تنمو العديد من محافظات مصر بسرعة مثل القاهرة والأسكندرية، ...الخ ؛ وتعاني هذه المحافظات من مشاكل مختلفة فيما يتعلق بتوفير مياه صالحة للاستخدام الأدمي. ونتيجة لذلك ، نحن بحاجة الي تقليل كمية المياه الصالحة للشرب المستخدمة في الري والأستعاضة عنها بمياه الصرف الصحي المعالجة بشكل جيد. ويعد تنفيذ تقنيات اقتصادية وفعالة لمعالجة مياه الصرف الصحي مطلبا ملحاً وعاجلاً. الهدف الرئيسي من هذا البحث هو تقييم الأداء الفني لمرشح زلطي مهوي مطور ، تم رصد أداءه باستخدام طبقات متعددة للترشيح لعدة أشهر ، وركز التحليل علي الأمونيا (NH_3)، الفوسفور الكلي (T.P)، البراز القولوني (F.C) والأكسجين الذائب (D.O). تم تصميم محطة تجريبية وتركيبها وتشغيلها في محطة معالجة مياه الصرف الصحي بزينين ، محافظة الجيزة مصر. تم اختبار طبقات الترشيح متعددة تسمي ساندوتش طبقات يتكون من بوليستر غير منسوج وألياف نخيل التمر وبكرشعر محشو بالاسفنج. حققت الوحدة التجريبية كفائة ازالة وصلت الي 63 % ، 58 % و 60 % للأمونيا والفوسفور الكلي والبراز القولوني علي التوالي وزادت نسبة الاكسجين الذائب بنسبة 69 % وذلك بفضل استخدام الشلالات.

Abstract:

Egypt is currently facing a major problem to provide water suitable for agriculture as a result of the growing shortage of water received from upstream countries. Nowadays, many governorates in Egypt are rapidly growing like Cairo, Alexandria, etc.; these governorates suffer from various problems regarding the availability of potable water for human usage. As a result, we need to reduce the amount of potable water used in irrigation and substituting it with well treated wastewater. Implementing economical and effective wastewater treatment techniques is an urgent requirement. The main objective of this research is to assess the technique performance of the aerated modified trickling filter (AMTF) which was monitored for several months using different multimedia and the analysis focused on Ammonia (NH_3), Total Phosphorus (T.P), Fecal Coliform (F.C) and Dissolved Oxygen (D.O) of the influent and effluent wastewater. A pilot plant was designed, erected and operated in Zenien wastewater treatment plant, Giza Egypt. A media configuration was tested named as sandwich media consists of non-woven polyester, date palm fiber and hair buckles with sponges. The pilot plant achieved removal efficiency of 63 %, 58 % and 60 % for (NH_3), (T.P) and (F.C) respectively and percentage increase in

(D.O) reached 69 % using the cascade setup.

Keywords: Ammonia (NH_3), Total Phosphorus (T.P) and Fecal Coliform (F.C)

1-Introuduction

The trickling filters with rock packing have been used for more than a hundred years in wastewater treatment. The first trickling filter was placed in operation in 1893; the modern trickling filters have a bed media of highly permeable media and operate on continuous flow. The classifications of trickling filters depend on the hydraulic and organic load. Metcalf & Eddy, Inc. 1991 3rd ed. [1]

Usually the influent is applied at the top of the media through the distributor arms or another distribution system. The underdrain system used to collect the effluent from the trickling filter also it is important for air circulation to keep the aerobic condition during the treatment, which is provided either by natural draft or blowers, the collected effluent settled in sedimentation tank to collect the sloughing suspended solids, then return portion –or no- to dilute the strength of the incoming wastewater and to keep the wetting of the biological slime layer moist. Metcalf & Eddy, Inc. 2003 4th ed. [2]

Excess growths of microorganisms slough from the media. This would cause high levels of BOD and suspended solids in the plant effluent if not removed in the sedimentation tank. As in the case of the activated sludge process, this sedimentation basin is referred to as a secondary clarifier. Unlike the activated sludge process, the solids are not returned to the attached growth process. They are collected and removed for processing and disposal. This according to Water and Wastewater Engineering Design Principles [3]

The new attached growth sponge tray bioreactor (STB) was evaluated at various operating conditions for removing organics and nutrients from primary treated sewage effluent. This STB was also assessed when using as a pre-treatment before micro-filtration (MF) for reducing membrane fouling. At a short hydraulic retention time (HRT) of 40 min, the STB remove up to 92 % of COD and 40 – 56 % of TKN and Phosphorus at an organic loading rate (OLR) of 2.4 kg COD/m³ sponge day. This OLR is the best for the STB as compared to the OLRs of 0.6, 1.2, and 3.6 kg COD/m³ sponge day. At 28 ml/min of flow velocity (FV), STB achieved the highest efficiencies with 92 % of COD, 87.4 % of Phosphorus, and 54.8 % of TKN removal. Finally, at the optimal OLR and FV, the STB could remove around 90 % of organic and nutrient; significantly reduce membrane fouling with HRT of only 120 min. This according to Tien Thanh Nguyen, et. Al. (2010), [4]

A porous sheet which is made of the parallel, cross, or randomly laid webs of long fibers bonded together mechanically by applying heat or pressure. This sheet works as a barrier for separating impurities from liquids. This according to Milin Patel, et. Al. (2015), [5]

Fabric media characteristics as a filter media depend on the weight of the material, thickness, water, and air permeability and non-woven fabrics have higher permeability and more pores for the unit area. Therefore, non-woven materials are widely used as separation media which have high filtration efficiency, temperature resistance, and lower in the cost.

Mesh filtration bio-reactor (MFBR) was tested using nylon mesh as a filter media with 100-micron pore size and obtained effluent BOD under 5 mg/l and TSS under 1.5 mg/l as two weeks of operation till the filter clogging. This according to Yoshiaki Kiso, et. Al. (2000), [6]

The non-woven module of polypropylene fabric fixed on the spool at based filtration device for treating wastewater obtained removal efficiency of about 50 % for BOD and 70 % for TSS. This according to Craig Stuart Riddle, (2002), [7]

The non-woven module was installed in membrane bioreactors to treat wastewater. Non-woven materials gave low filtration resistance compared to the micro-porous membrane and obtained effluent COD under 60 mg/l and TSS under 10 mg/l. This according to Wang-Kuan Changa, et. Al. (2005), [8]

A unit equipped with non-woven fabric and oyster-zeolite submerged in activated sludge bioreactor obtained removal efficiency of about 94 % for COD while having low removal efficiencies of nitrogen and phosphorous. This according to Yoo-Jin Jung, et. Al. (2005), [9]

Three different fabric materials (Nylon, Polyester, and Acrylate) were tested as separation media for the MBR unit for treating municipal wastewater and obtained removal efficiency of about (93 - 95 %) for COD, (99 %) for TSS and (89 - 94 %) for TKN. This according to Waleed M. Zahid, et. Al. (2011), [10]

Various types of fabric materials were tested at different operating conditions on a filtration unit using synthetic wastewater. Nonwoven fabrics were found to be promising as separation media for the wastewater and obtained removal efficiency of about (83 - 95 %) for COD and (87 - 94 %) for TSS. This according to Bayoumi, G.B. et. Al. (2016), [11]

2-Material and Method

The experimental study plan was performed to investigate advanced filtration by using aerated modified trickling filter (AMTF) and multi-media (sandwich media). The pilot plant was designed and installed in Zenien Wastewater Treatment Plant, Giza Egypt. The pilot plant is designed to work continuously 24 hours per day during April 2018 till to December 2019.

2-1 Pilot Plant Description

A continuous flow pilot plant was designed as an advanced filtration system to serve the experimental program and objectives of this research. The pilot scale plant designed was as illustrated in fig. 1.

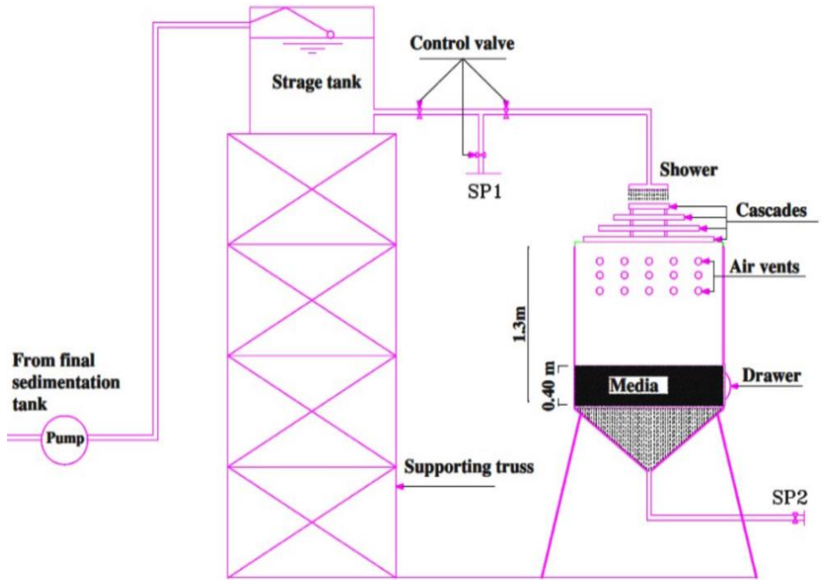

Fig. 1: Schematic diagram of Pilot Plant

The pilot plant consists of two parts as follows: -

- Part one consists of four cascades with different sizes (25*25), (30*30), (35*35) and (40*40) cm. The space between each cascade is 10 cm and made of PVC sheets with thickness 6 mm.
- Part two consists of the filter unit made of insulated sheet plates with dimensions (50*50*220), the filter media layer is placed in a drawer box at a height of 90 cm from the ground, while stairs have circular slots on the bottom to drain filtered water. Down the drawer, there is a cone shaped treated wastewater collection unit for subsequent disposal.

2-2 Filter Media

Based on the literature review and the previous researches, Non-woven fabric materials, sponge put in hair buckles, palm fiber, sand and light weight bricks were found to be effective in the treatment process of wastewater in small communities.

2-2-1 Non-Woven Polyester

The filter material is non-woven polyester 800 gm/m^2, with thickness of 1.5 cm and a rate of clean water permeability of 3.03 l/m^2/sec with a 1.5 meter of operational water head.

2-2-2 Sponge

Pieces of sponge with dimension (30mm*30mm*70mm), these were put in hair buckles with diameter 25 mm and length 70mm, void ratio 82.8% and water wetted after 2 seconds from lifting from water is 24.92%, according to the experimental test.

2-2-3 Date Palm Fiber

The physical properties of date palm fiber are as shown in table 1.

Table 1: The Physical Properties of Date palm Fiber

Physical Properties	Date palm
Density (gm/cm³)	0.9: 1.2
Length (mm)	0.1:1
Diameter (mm)	100: 1000
Specific modulus (approx.)	7
Thermal conductivity (W/m K)	0.083

2-3 Wastewater Sampling

Influent wastewater samples to the experimental pilot plant were collected from the effluent of secondary treatment of Zenien Wastewater Treatment Plant in Giza-Egypt and collected samples from the effluent of pilot plant. All experiments and analysis of wastewater samples were carried out at Zenien Wastewater Treatment Plant laboratory.
Samples were normally daily collected on a routine basis between 10 a.m. and 12 p.m. and transferred to the Zenien laboratory at once after collection for analysis.

2-4 Monitored Parameter

1. Dissolved Oxygen (D.O)
2. Total Phosphorous (T.P)
3. Ammonia (NH_3)
4. Fecal Coliform (F.C)

The analyses were carried out according to the Standard Methods for Water and Wastewater Examination (APHA- AWWA – WPCE, 19th Edition, (1999)).

2-5 Study Program

The study was carried out with certain media type and depth and also flow rate to be applied for the AMTF to be a low-cost technique for advanced wastewater treatment.
The Experimental Work:
Influent wastewater samples to the experimental pilot plant were collected from the effluent of secondary treatment of Zenien Wastewater Treatment Plant in Giza-Egypt and collected samples from the effluent of pilot plant. All experiments and analysis of wastewater samples were carried out at Zenien Wastewater Treatment Plant laboratory. Samples were normally every six days collected on a routine basis between 10 a.m. and 12 p.m. and transferred to the Zenien laboratory at once after collection for analysis.

3- Results and Discussion

3-1 Dissolved Oxygen (DO)

The average DO concentration of influent to AMTF was 2.72 mg/l. However, DO levels increased incrementally in the final effluent during the period of study. The average value of DO obtained was 7 mg/l and the increase in concentration remained within the range of 55.5 – 69 % during experimental period. Fig. 2 shows the variation in DO levels in the influent and effluent and their increasing efficiency during the experimental period.

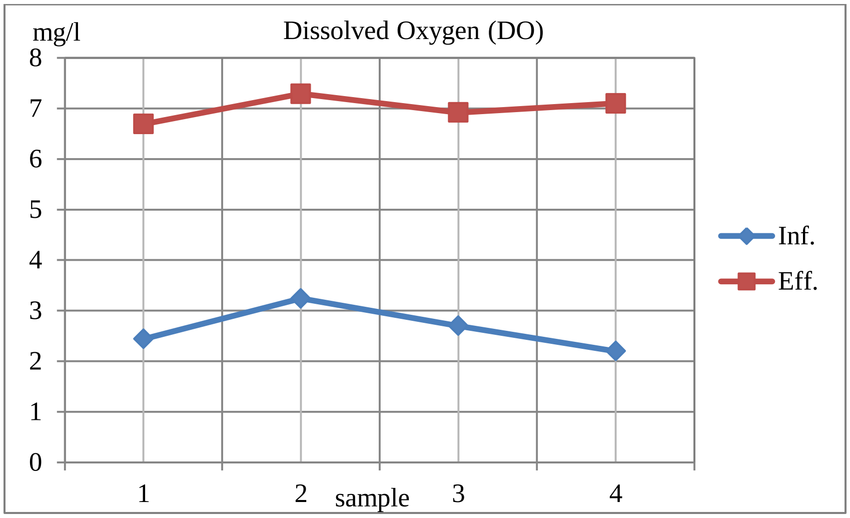

Fig. 2: Dissolved Oxygen Concentrations in Influent and Effluent.

These results showed the increase in effluent DO concentrations ranged from 6.69 to 7.29 mg/l, while the influent DO concentrations ranged from 2.44 to 3.24 mg/l. Thus results of dissolved oxygen increase are satisfactory to biological degradation of organic matters.

The efficient aeration of infiltrating wastewater resulted in significant oxygenation of the incoming water during the filtration process. The remarkable oxygen transfer from the atmosphere into the bulk liquid yielded effluent dissolved oxygen DO concentrations more than influent concentrations.

The capability of the AMTF system to sustain saturated oxygen concentrations in the effluent was due to the natural ventilation through cascades, the aeration holes, the high voidage and consistent configuration of the (sandwich media) filter media. Dissolved oxygen was presumed to penetrate only a portion of the carrier biofilm and aerobic substrate utilization was stopped in the deeper regions where oxygen was depleted.

Molecular oxygen in AMTF reactor is a terminal electron acceptor for bacterial metabolism. Both electron donor (COD) and oxygen must be transported to biofilm organisms to accomplish aerobic reactions. It was concluded that without forced ventilation in AMTF system, increase in DO, decrease in COD and BOD concentrations were achieved with natural draft, which provided sufficient aeration.

3-2 Ammonia Concentrations

Samples from the pilot plant were collected every six days from the beginning of operation the run. From the shown fig. 3, the influent ammonia concentrations ranged between 2.9 to 4.6 mg /l, while the effluent concentrations ranged from 1.4 to 1.7 mg/l. The removal efficiency ranged from 48 to 63 %. The average ammonia concentrations in the influent 3.6 mg/l and reduced by average percentage 56 % in the effluent, thus the average residual value of ammonia concentrations in the effluent 1.55 mg/l.

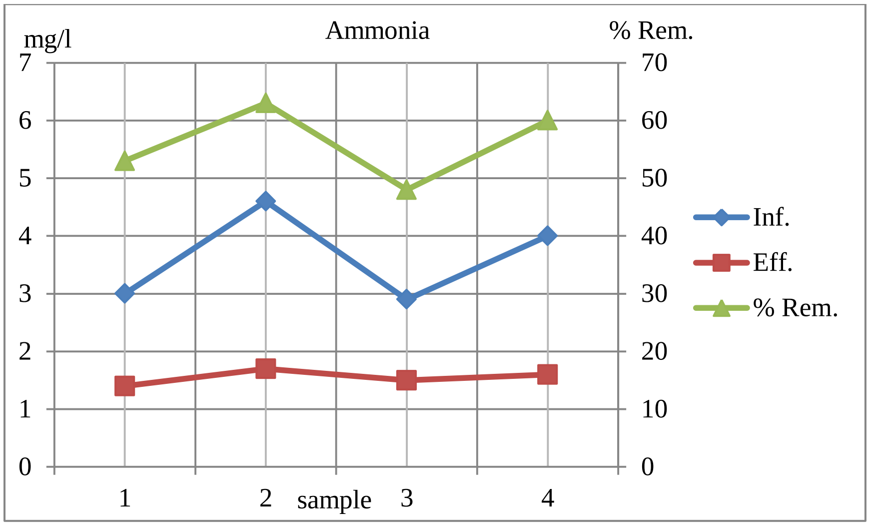

Fig. 3: Ammonia Concentrations in Influent, Effluent and Removal Efficiency.

The reason in this was due to the capability of the AMTF system to sustain saturated oxygen concentrations in the effluent was due to the natural ventilation through cascades, the aeration holes, the high voidage and consistent configuration of the (sandwich media) filter media. We can conclude that the increase in dissolved oxygen concentrations decrease in ammonia concentrations.

3-3 Phosphorous Concentrations

Samples from the pilot plant were collected each six days from the beginning of operation the run. From the shown fig. 4, the influent phosphorus concentrations ranged between 1.5 to 2.5 mg/l with average value 2 mg/l, while the effluent concentrations ranged from 0.8 to 1.1 mg/l with average value 0.95 mg/l. The removal efficiency ranged from 47 to 58 % with average value 52.75 %.

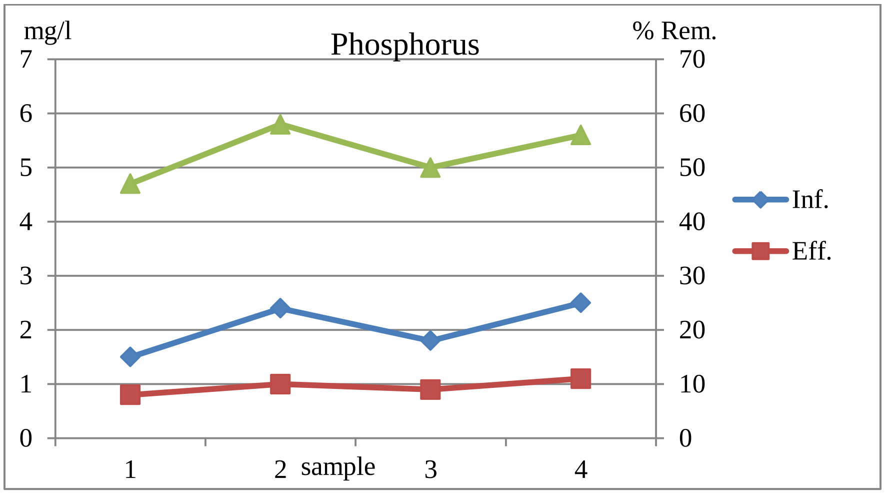

Fig.4: Phosphorus Concentrations in Influent, Effluent and Removal Efficiency.

The AMTF system provides an abundant supply of food and natural oxygen from the cascades and voids (circular openings) on all sides of reactor, encouraging the microorganisms to absorb phosphorus.

3-4 Fecal Coliform Concentrations

Samples from the pilot plant were collected every six days from the beginning of operation the run.

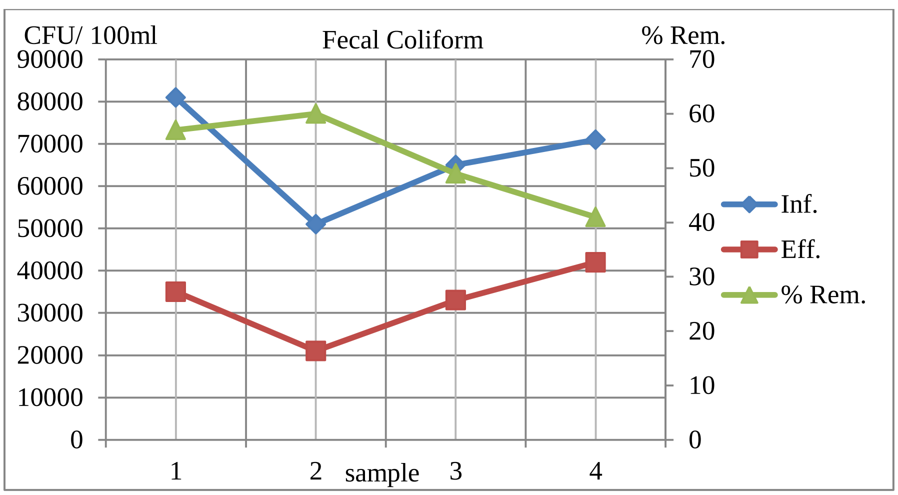

Fig.5: Fecal Coliform Concentrations in Influent, Effluent and Removal Efficiency.

In the shown fig.5, the influent fecal coliform concentrations to the AMTF ranged between 51000 to 81000 CFU/100ml with average value 67000 CFU/100ml , while the effluent concentrations ranged from 21000 to 42000 CFU/ 100ml with average value 33000 CFU/ 100ml. The removal efficiency ranged from 41 to 60 % with average value 51%. The reason in this was due to consistent configuration of the (sandwich media) filter media.

4- Conclusions and Recommendations

4-1 Conclusions

Based on the study program executed in this research and the results obtained and from the previous discussion, the following conclusions were recorded:

- AMTF system consumes less energy and power for operating than all other systems.
- There is no need for artificial aeration as the oxygen is naturally continuously diffused from the cascades and ambient air into the body of pilot (reactor) creating ideal conditions for oxidation and ammonization by bacteria.
- The average DO concentrations of influent to AMTF were 2.72 mg/l. However, its levels were increased incrementally in the final effluent during the period of study. The average values of DO obtained were 7 mg/l and its increase in concentrations remains within the range of 55.5 – 69 % during the experimental period.
- The AMTF achieved removal efficiency for ammonia ranging between 48 to 63 %. The average ammonia concentration in the influent was 3.6 mg/l and reduced by about 56 % in the effluent.
- The AMTF was achieved removal efficiency for Total Phosphorous (T.P) ranged between 47 to 58 %. The average Total Phosphorous (T.P) concentration in the influent was 2 mg/l and reduced by about 53 % in the effluent.
- The AMTF achieved removal efficiency for fecal coliform ranging between 41 to 60 %. The average fecal coliform concentration in the influent was 67000 CFU/100ml and reduced by about 51 % in the effluent.

4-2 Recommendations

The following topics may be further investigated in order to continue with the development and refinement of the aerated modified trickling filter (AMTF) system, so it is required to study:

- The effect of treating the effluent through a second stage of AMTF.
- The improvement of the system efficiency by chemical addition.
- Sandwich media (non-woven polyester, buckles hair with sponge and date palm fiber) were found to be promising as filtration media in AMTF so, many studies could be done on different materials to obtain the suitable material.

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