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AEROBIC TREATMENT OF WASTEWATER USING HYBRID SYSTEM

المعالجة الهوائيه لمياه الصرف الصحي باستخدام نظام الهجين (الملتصق و المعلق)

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الملخص

يتم معالجة مياه الصرف الصحي الخام في محطة معالجة الصرف الصحي في قرية ميت ابو الكوم باستخدام النمو الملتصق. تتم المعالجه باستخدام جهاز الأحواض المهواه بنظام البكتريا الملتصقه (AFFAR) من ألواح البلاستيك أو ألوح البلاستيك مع الشبك. الجهاز الأول يتكون من عدد من ألواح البلاستيك و الجهاز المعدل تم استخدام الالواح البلاستيك و متصل بها شبك من البلاستيك لتحسين المساحه البيولوجيه للألواح. تم تشغيل الجهازين لفتره زمنيه أكثر من ستة أشهر. عمليا، يتكون كل جهاز من أربع مراحل متساويه بواسطة حواجز و تحت معدل حمل هيدروليكي 0.1 , 0.2 م^3/م^2/يوم.

أظهرت النتائج تحت معدل حمل هيدروليكي = 0.1 م^3/م^2/يوم أن الجهاز الأول حقق كفاءة ازاله 89%, 95%, 90% و 93% لكل من TSS, NH_3-N, BOD_5, COD علي الترتيب. ولقد حقق الجهاز الثاني المعدل كفاءة أعلي في الازاله من الجهاز الأول وذلك لزياده المساحه السطحيه للوسط الذي ينمو عليه البكتريا وقد وصلت نسبة الازاله الي 94%, 98%, 95% و 97% لكل من TSS, NH_3-N, BOD_5, COD علي الترتيب. وقد قل تركيز BOD_5 من 600 مج/ل الي 7 مج/ل بنسبة ازاله 98% و بالمثل قد قل تركيز كل من TSS, COD من 800 مج/ل, 510 مج/ل الي 71 مج/ل, 20 مج/ل علي الترتيب. بالأضافه الي ذلك, أظهرت هذه الدراسة أن استخدام ألواح البلاستيك ساعد علي تحسين نمو البكتريا عليه و له مساحه كبيره نسبيا في حجم أقل. وأشارت النتائج إلى أن أفضل كفاءة إزالة ل BOD_5, COD يمكن الحصول عليها بتقليل معدل الحمل الهيدروليكي الي 0.1 م^3/م^2/يوم. وفي حالة استخدام الجهاز (AFFR) المعدل نجد تحسين كفاءة ازالة الTSS, NH3-N, BOD_5 and COD.

Abstract

A raw wastewater has been treated in wastewater treatment plant of Met Abo El-Kom city using attached growth systems. The treatment was accomplished using an Aerated Fixed Film Reactor (AFFR) with plastic plates or plastic plates with plastic mesh. The first reactor consisted of a number of biofilm carriers from fiber glass plates. Another modified (AFFAR) has been used by modifying the first one by attaching plastic mesh to enhance biofilm area. The system was run in the field for more than six months. Practically, the system consistsed of four stages as with bafflers at hydraulic loading rate (HLR) of 0.1 and 0.2 $m^3/m^2/d$.

The results showed under HLR= 0.1 $m^3/m^2/d$ for the first reactor has achieved a removal efficiency of 89%, 95%, 90% and 93% for COD, BOD_5, NH_3 and TSS respectively. However, the second modified reactor achieved high removal efficiency more than the first one because of the large biofilm area. The second reactor has achieved a removal efficiency of 94%, 98%, 95% and 97 for COD, BOD_5, NH_3 and TSS respectively.

The influent BOD_5 has been decreased from of 600 to 7 mg/l with removal percentage 98%. Removal of COD and SS was almost similar to that of BOD.

The initial COD and SS of 800 mg/l and 510 mg/l come down to 71 mg/l and 20 mg/l respectively. In addition, the present study illustrated that use of biofilm carrier (plastic plates) improve the growth of biomass above surface area of plates and have a relative large surface area in small volume. Results also indicated that better removal efficiency can be obtained in case of low hydraulic loading rate of 0.1$m^3/m^2/d$ especially for BOD_5 and COD. While in case of modified AFFR the effluent improved BOD_5, COD, NH_3 and TSS removal.

Keywords

Biofilm; Attached growth; Biofilm Carrier; Aerated fixed film reactor.

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Introduction:-

In Egypt there is an increasing need for low cost and small area methods for treating wastewater. Thus the idea of construction a cost-effective high efficiency and small area treatment facility is very demanding. Thus the idea of construction a cost effective combined attached-suspended activated sludge plant is very demanding and this done by employing growth of attached culture in aeration tank by using synthetic media. This media should be placed in a fully mixed plant aeration tank and have the ability to absorb and carry a great mass of microorganisms attached to the media.

There has been a growing interest in the application of biological fixed-film (attached growth) processes for the aerobic treatment of wastewaters. Stability and long retention of microorganisms in fixed-film processes proved to be advantageous in the treatment of various wastewaters (Antonie, 1976). Fixed-film processes such as the rotation biological contactors (RBC) have become popular in municipal wastewater treatment applications (Pike et al., 1982). In a recent development, the aerated submerged fixed-film (ASFF) system has been introduced (Hamoda and Abd-El-Bary, 1987). This is a multi-stage reactor employing totally-submerged, stationary-media plates for microbial attachment under diffused aeration conditions. Examination of reactor performance during the treatment of organic wastes under various loading condition has shown promising results due to the efficient oxygen transfer achieved in the reactor.

A number of models were used to describe the RBC process. Kornegay and Andrews (1968) proposed a model based on biological growth using Michaelis kinetics which neglects mass transfer resistance. Grieves (1972), however, has applied mass transfer resistance to the RBC process using both first-order and Michaelis kinetics for substrate utilization. Friedman et al., (1976) have employed two models to analyze RBC data, one of which is an empirical model assuming that substrate diffusion controls the overall reaction rate while the other is a simple first-order model.

A model which incorporates simultaneous oxygen and substrate transport with both liquid and biofilm resistances was developed and verified by Famularo et al., (1978). A design model that utilizes the total organic loading concept was presented by Kinacannon and Stover (1982).

A novel mixed culture reactor having attached and suspended culture in in a single unit, so the performance and design aspects of various were operating conditions. In addition increase the efficiency of the plant was observed. Biomass was maintained growing both in suspension and in biofilms onto small rough plastic particles (Artiga.P, Oyanedel.V, Garrldo.J.M, Mendez.R 2005). The results indicated that the highest removal efficiency was achieved at the internal recycling ratio as 400% of the influent flow rate which produced a superior effluent (Nguyen.D.D, Ngo.H.H, Yoon.Y.S 2014). Take advantage of the features suspended growth and attached growth.

Recently Biofilm with ASP is widely used to enhance the performance of treatment (Fouad.M, Bhargava.R, 2005). The overall BOD percentage removal efficiencies were consistently above 94.0% at all HRTs including the 2 hours while the COD percentage removal efficiencies ranged between 65.7–76 %.(Al-Sharekh.H.A, Hamoda.M.F 2001).

Effect of hydraulic loadings and influent 2, 4-dichlorophenol concentration on 2,4-dichlorophenol removal were discussed and showed maximum organic removal at hydraulic loads of 0.024 and 0.046 m3.m-2.d-1. Also, a correlation plot between 2, 4 CP applied and 2, 4 CP removed was presented (Radwan.K.H, Ramanujam. T.K 1997). The system also showed an achievement in terms of low trans-membrane pressure (TMP) development rate (Nguyen. T.T, Ngo. H.H, Guo. W 2013). Therefore, an ASFF process showed that it was feasible to treat high oily wastewater in order to meet the discharge standards Izanloo.H, Mesdaghinia.A.R, Nabizadeh.R, Nasseri. S, Naddafi.K, Mahvi.A.H, Nazmara.S (2006).

It has been found that these processes were able to remove nitrogen content almost completely and simultaneously, the removal of organic matter (expressed as BOD5 and COD), color and turbidity were sufficiently achieved (Loukidou.M.X, Zouboulis.A.I, 2001). Treatments of Wastewater Using Aerated Fixed Film Reactor (AFFR) system process are combining fixed-film and suspended activated sludge process.

The main objectives of the present study is to use the Aerated Fixed Film Reactor and the modified aerated fixed film reactor to treat the domestic wastewaters under varying hydraulic loading rates.

Materials and Methods

The AFFR in the present study was a pilot model and consists of two identical reactors made of plastic plates. Each reactor had a net liquid volume of 168L and was divided into four zones (equal-size compartments) in series as shown in Fig.(1).

There were 10 plastic plates in each zone providing a surface area of 2.1 m^2 per zone for microbial attachment and for the second reactor the plates were modified by attaching plastic mesh sheet to enhance biofilm area. The AFFR trough was made of plastic plates and was divided into four equal volume chambers by constructing baffles which have openings (2cm*2cm) at the top to hydraulically inter-connect the consecutive chambers.

Sufficient compressed air were introduced, at a regulated rate through different placed at the bottom of each compartment so as to create rising air bubbles in the spaces between plates and maintain dissolved oxygen levels of about 80% saturation.

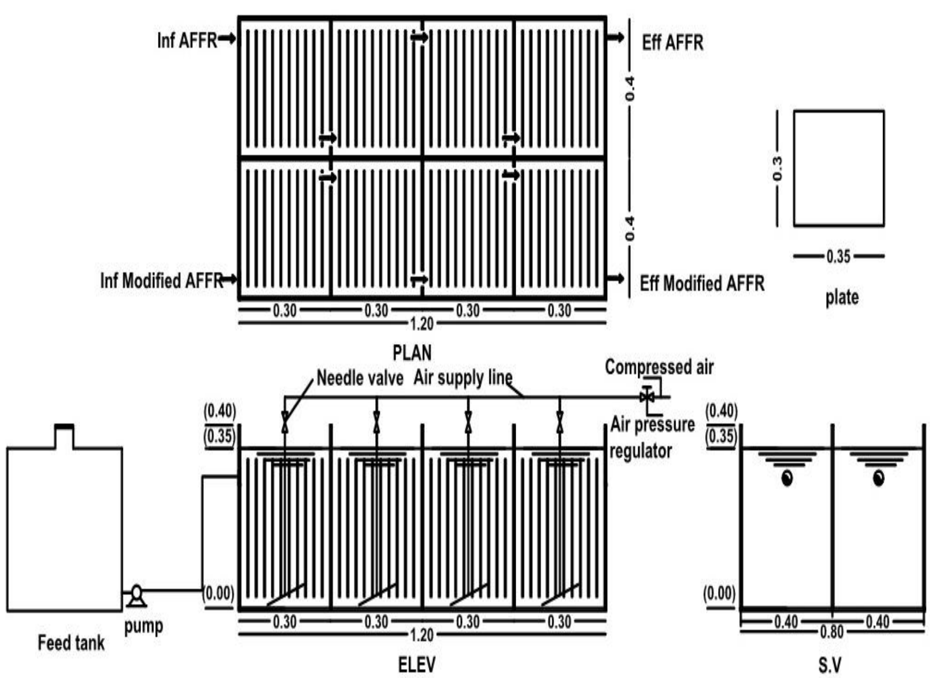

Fig (1) schematic diagram of AFFR`s reactors

The reactor operated in a continuous flow system in the experimental setup.

The pilot treatment plant used was installed at the site of Met Abu El-Kom wastewater treatment, which is situated at about 24 km east Monofia city on the Sheben El Kom - Tala road. This wastewater treatment plant is located about 2 km away from the village in the south direction.

The raw wastewaters were pumped with two hydraulic loading rates of 0.1 and $0.2m^3/m^2/d$.

Biomass growth occurs on the media plates for both reactors at the same time. During the continuous operation of the AFFR`s, the thickness and possibly the configuration of the biomass is constantly changing. As the biomass becomes thicker sloughing by hydraulic shear increases.

Therefore, each experimental run was conducted and monitored until a steady state was reached. After words, steady state was maintained for a minimum of 2 weeks, during which the influent and effluent from both reactors were analyzed.

The experimental parameters measured were COD, BOD_5, TSS, NH_3-N, DO and TDS. Analyses were conducted using the methods given in APHA standards methods (1998).

Wastewaters parameters COD, BOD_5, TSS and NH_3-N in table (1) were measured as average value for the following periods.

Table (1) Characteristics of Raw Wastewaters

Parameters	13-4 to 13-5-2014	15-5 to 15-6-2014	17-6 to 17-7-2014	20-7 to 20-8-2014
COD, mg/l	820	803	844	837
BOD_5 mg/l	590	580	606	606
TSS, Mg/l	482	460	450	448
NH_3-N, mg/l	13.9	12.7	14.25	14.25

The pilot plant was operated using domestic wastewater with variable organic strength. The type of wastewater fed to the pilot plant is raw domestic wastewater. Operation of the pilot plant was first started by adding seed microorganisms from Met Abu El-Kom wastewater treatment plant. Raw wastewater was taken from the distribution chamber after screen and grit removal. After adding microorganisms the pilot plant with H.L.R of 0.1 $m^3/m^2/d$ to reach to steady state and then increased to 0.2 $m^3/m^2/d$. The first retention time was 4.8 hours cross-ponding a discharge of $0.84m^3/d$ (HLR=0.1m/d). The second retention time was 2.4 hours cross-ponding a discharge of $1.68m^3/d$ (HLR=0.2m/d).

Fig.(2-a) shows the operational condition of the first reactor and Fig.(2-b) shows the operational condition of the modified reactor.

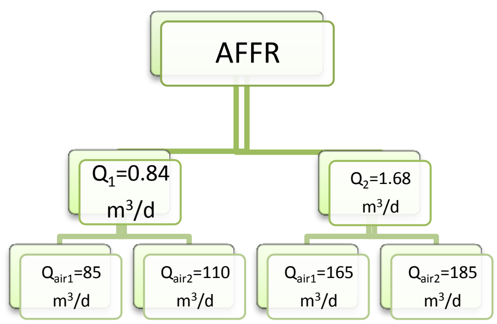

Figure (2-a) Flow Chart of Operational Conditions for AFFR

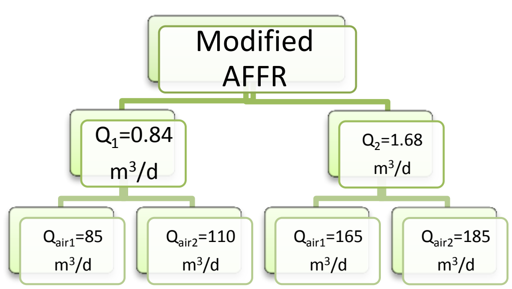

Figure (2-b) Flow Chart of Operational Conditions for Modified AFFR

After the attached biomass had reached the maximum growth and the system completing the start-up phase reaching the steady state. The pilot plant was operated and tested under different discharge raw wastewater and air flow. The operation of the pilot plant was tested for about four months with two HLR`s and air flows for each reactor.

Aerated Fixed Film Reactor (AFFR) systems, which use integrated-growth support surface such as Perspex and plastic mesh media offer potential cost-effective solutions. Aerated Fixed Film Reactor (AFFR) reactor can be used for some different applications such as increasing the efficiency of nutrient removal, new wastewater treatment plant (WWTP) construction and also upgrading the existing WWTP, not only for increasing the capacity of BOD removal, but also removal of the nutrients.

Results and Discussion

1. Startup Results

Long-term experimental run were made for about 4 months to examine the system performance under varied hydraulic loading rate and compressed air flows.

At the beginning the HLR of 0.1 m/d was used for about one month to reach a steady state condition and the flow rate of air was 85m^3/d. Fig.(3) show the startup results for COD, BOD_5, TSS and NH_3-N for both reactors.

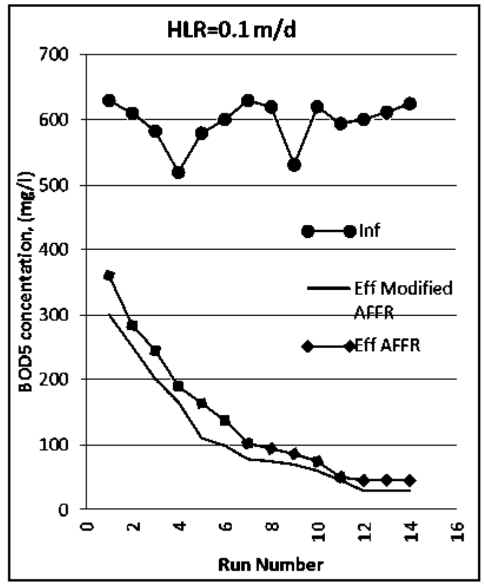

Fig (3-a) Start up results for BOD_5 removal

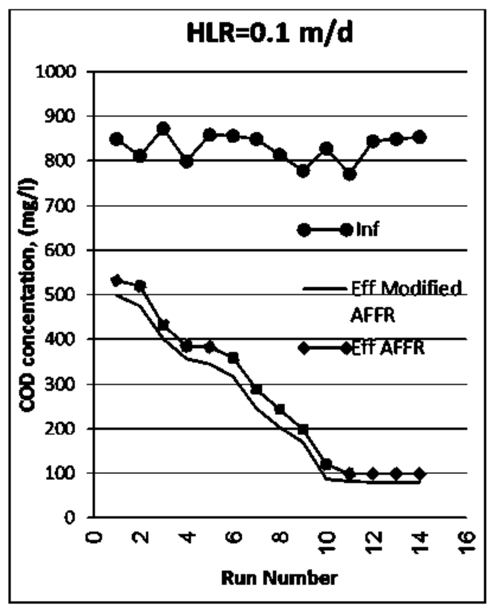

Fig (3-b) Start up results for COD Removal

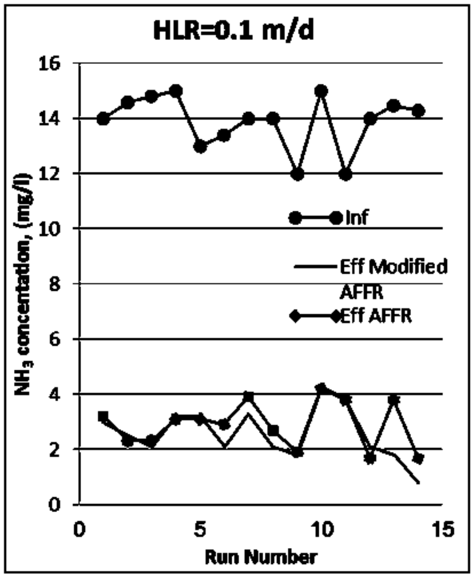

Fig (3-c) Start up results for NH_3-N Removal

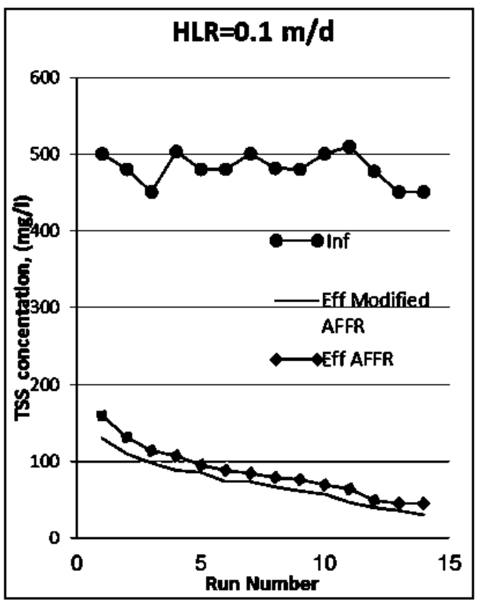

Fig (3-d) Start up results for TSS Removal

From Fig.(3-a) and Fig.(3-b), it was observed that effluent of BOD_5 and COD reached for AFFR 45 and 99 mg/l respectively whereas for modified AFFR, the BOD_5 and COD reached to 30 and 90 mg/l respectively.

From Fig. (3-c), at average influent NH_3-N of 14 mg/l, the effluent NH_3-N reached for AFFR to 1.7 mg/l and for modified AFFR reached to 0.8 mg/l.

Finally, Fig.(3-d) gives the results of TSS removal; it was observed that at average influent TSS of 482 mg/l. The effluent TSS reached for AFFR to 45 mg/l and for modified AFFR reached to 30 mg/l.

2. Performance of reactors at HLR=0.1m/d:-

After reaching to steady state, the results for COD, BOD_5, TSS and NH_3-N were obtained.

From Fig.(4-a) and Fig.(4-b), it was observed that effluent of BOD_5 and COD reached for AFFR 29 and 87 mg/l respectively whereas for modified AFFR, the BOD_5 and COD reached to 7 and 71 mg/l respectively.

From Fig.(4-c), at average influent NH_3-N of about 14 mg/l the effluent NH_3-N reached for AFFR to 2.5 mg/l and from modified AFFR reached to 0.8 mg/l.

Finally, Fig.(4-d) gives the results of TSS removal; it was observed that at average influent TSS of 450 mg/l, the effluent TSS reached for AFFR to 35 mg/l and for modified AFFR reached to 20 mg/l.

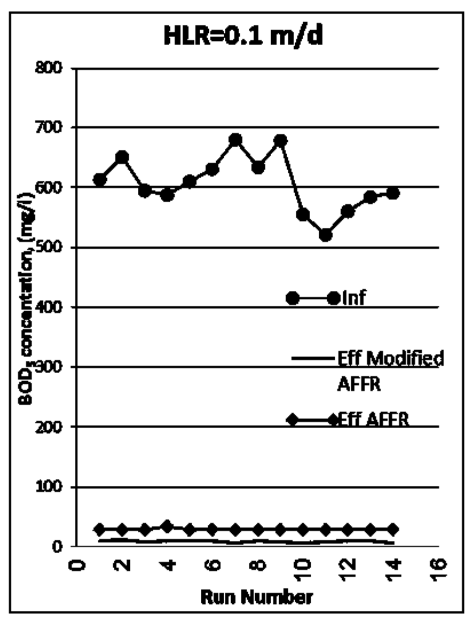

Fig (4-a) BOD_5 removal

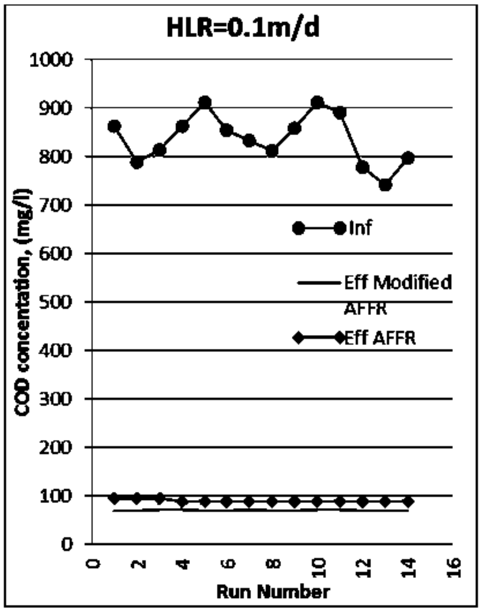

Fig (4-b) COD Removal

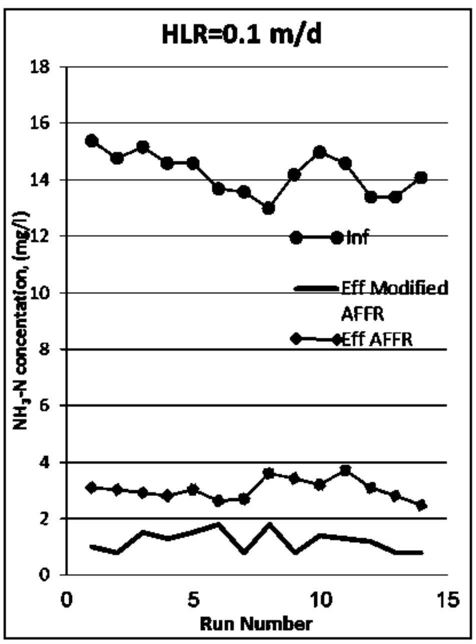

Fig (4-c) NH_3-N Removal

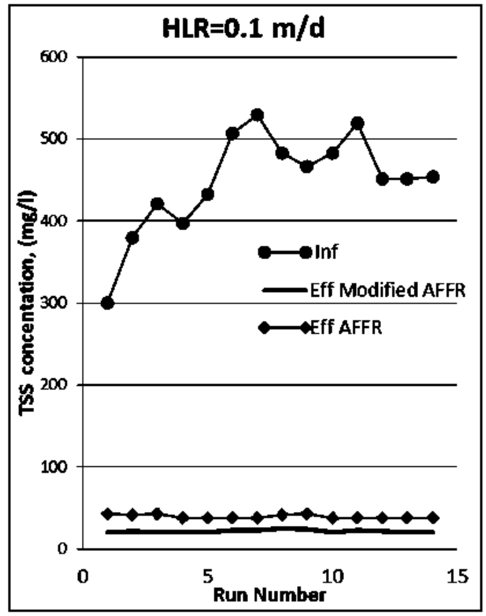

Fig (4-d) TSS Removal

3. Performance of reactors at HLR=0.2 m/d:-

After reaching to steady state, the results for COD, BOD_5, TSS and NH_3-N were obtained

From Fig.(5-a) and Fig.(5-b), it was observed that effluent of BOD_5 and COD reached for AFFR at HLR= 0.2 m/d 37 and 102 mg/l respectively whereas for modified AFFR, the BOD_5 and COD reached to 22 and 80 mg/l respectively.

From Fig.(5-c), at average influent NH_3-N of about 14 mg/l, the effluent NH_3-N reached for AFFR to 3.0 mg/l and for modified AFFR reached to 1.2 mg/l.

Finally, Fig.(5-d) gives the results of TSS removal; it was observed that at average influent TSS of 450 mg/l, the effluent TSS reached for AFFR to 43 mg/l and for modified AFFR reached to 26 mg/l.

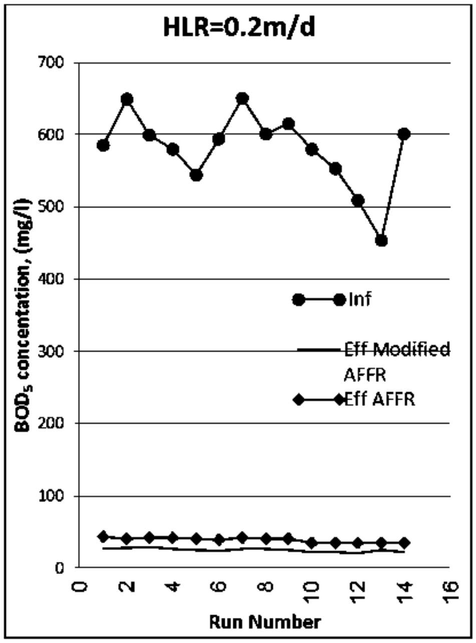

Fig (5-a) BOD_5 removal

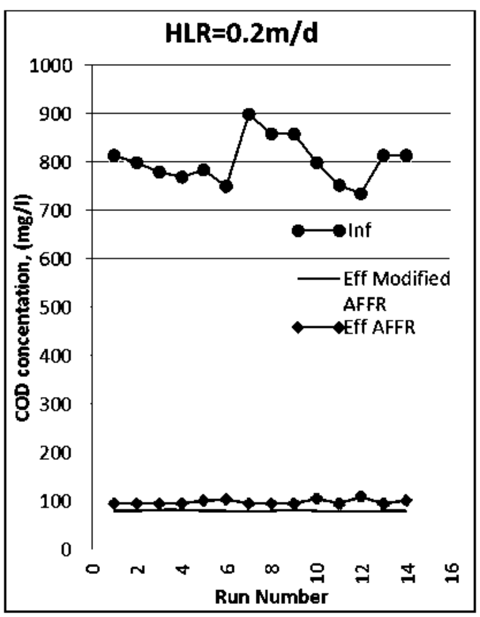

Fig (5-b) COD Removal

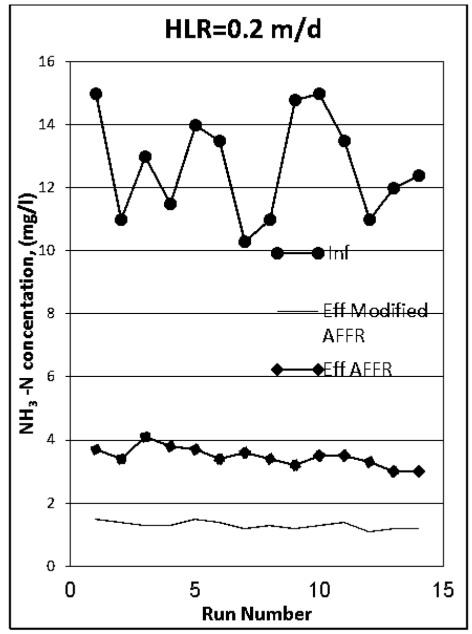

Fig (5-c) NH_3-N Removal

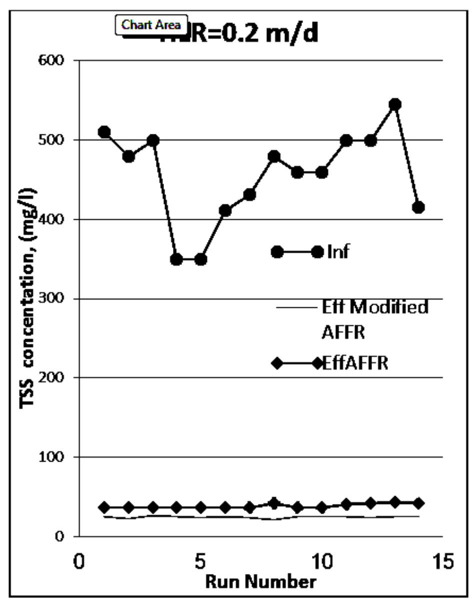

Fig (5-d) TSS Removal

It was reported that application of the present's system has a great significance mainly at different discharge (water flow) and air flow. At HLR=0.1 m/d the results showed that AFFR reactor has achieved a removal efficiency of 89%, 95%, 90%, and 93 for COD, BOD_5, NH_3-N and TSS respectively. However, the modified AFFR reactor achieved high removal efficiency more than AFFR reactor because of the large biofilm area. Similarly at HLR=0.1 m/d the modified AFFR has achieved a removal efficiency of 94%, 98%, 95%, and 97% for COD, BOD_5, NH_3-N and TSS respectively. In operation, it was also reported that application of mixed culture has great significance mainly at different discharge (wastewater flow) and air flow, resulting in relative high removal efficiency of pollutants. The influent BOD_5 has been decreased from of 600 to 7 mg/l with removal percentage 99%. Removal of COD and TSS was almost similar to that of BOD initial COD and TSS of 800 mg/l and 460 mg/l comedown to 71 mg/l and 20 mg/l respectively. In addition, the present study illustrated that use of biofilm carrier (plastic plates) was easy for growth the biomass above surface area and have a relative large surface area in small volume. Results also indicated that better removal efficiency can be obtained in case of low HLR especially for BOD_5 and COD. While in case of media plastic plates with mesh the effluent improved BOD_5, COD, NH_3-N, and TSS removal.

4. Variations of TDS for both reactors

From Fig. (6-a) and Fig.(6-b) TDS value of effluent modified AFFR increased and more than TDS of effluent of AFFR and influent of both reactors.

The TDS value increased for effluent for both reactors compared with influent TDS because of biological conversion in reactors.

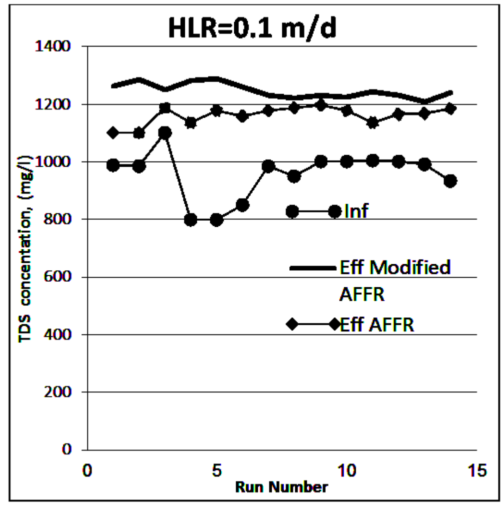

Fig (6-a) Influent and Effluent of TDS for both reactors (HLR=0.1m/d)

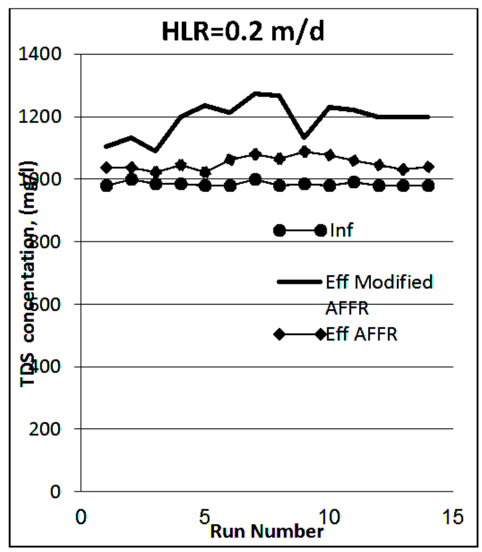

Fig (6-b) Influent and Effluent of TDS for both reactors (HLR=0.2m/d)

General discussion

In this study a mixed culture reactor with attached and suspended culture was fabricated and operated to remove organic matter and nutrients.

This study focus on enhancement of the efficiency and economy of wastewater treatment in conventional activated sludge processes by modification of activated sludge process by applying mixed culture in the aeration tanks of activated sludge process.

This type of installation will effectively improve the performance of an existing suspended growth system to handle higher organic load without increasing the size of the reactor. Thus, it will save the cost of reconstruction as well as the land area.

Conclusions

This study has considered both reactors (AFFR and modified AFFR) and investigated the ability of rectors to treat domestic wastewater. Based on results the following conclusions were obtained:-

1. The AFFR and modified AFFR successfully treated domestic wastewaters of high strength with average BOD_5 and COD 600mg/l and 800mg/l respectively.
2. The percentage removal of COD at HLR=0.1 m/d by AFFR varied from 85% to 89% and for modified AFFR varied from 91% to 94% whereas at HLR= 0.2 m/d the percentage removal of COD decreased.
3. The modified AFFR gives better performance compared AFFR.
4. Both AFFR and modified AFFR are successfully for removal NH_3-N to low concentration up to 1.0 mg/l.

Nomenclature

COD	chemical oxygen demand	mg/L
BOD_5	Biological oxygen demand	µs/cm
DO	Dissolved oxygen	$m^3/m^2\cdot hr$
NH_3-N	Ammonia Nitrogen	
TDS	total dissolved solids	mg/L
TSS	total suspended solids	mg/ L

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