International Journal of Sciences: Basic and Applied Research (IJSBAR)

ISSN 2307-4531
(Print & Online)

http://gssrr.org/index.php?journal=JournalOfBasicAndApplied

Application of Hybrid System to Upgrade Existing Wastewater Treatment Plants: A Case Study

M. Raafat[a], O.D. El Monayeri[b], N. Amer[b]

[a] *Researcher, Faculty of Arab Academy for Science, Technology and Maritime Transport, Cairo, EGYPT.*

[b] *Assistant Professor of Sanitary and Environmental Engineering, Faculty of Arab Academy for Science , Technology and Maritime Transport, 1 Hay Shamal El Chouifat, Postal Code: 11477, New Cairo City, Cairo, EGYPT.*

[c] *Associate Professor, Faculty of Civil Engineering, Military Technical College, Cairo, EGYPT.*

[a]*Email: minabikhit100@hotmail.com*

[b]*Email: omonayeri@yahoo.com*

[c]*Email: nabil_amer63@yahoo.com*

Abstract

Upgrading of existing Wastewater Treatment Plants (WWTPs) has become indispensable especially in developing countries. The high growth rates, limited financial resources and land availability require stringent treated effluent quality in order to protect water resources. Hybrid systems could be considered as a suitable alternative. Balaks wastewater treatment plant (BWWTP), with an average designed capacity of 600,000 m^3/d, located in Egypt provides the material of this study. It is a conventional activated sludge treatment system which is expected to receive massive quantities of wastewater that would surpass its peak design capacity and consequently would fail to meet the allowable effluent limits. Subsequently, this research has focused on modeling and testing the use of either moving bed bio film reactor (MBBR) or integrated fixed film activated sludge (IFAS) in three different locations with respect to the installed surface aerators. BioWin, a software simulating program, was used to compare the performance of both systems. Results indicated that MBBR with polyethylene media acting as Bio film carrier possessed greater potential to be used as an ideal and efficient option for different flow rates ($Q_{inf.2013}$, $Q_{av\ 2037}$ and $Q_{Peak\ 2037}$).

---

* Corresponding author.

E-mail address: omonayeri@yahoo.com.

The MBBR removal efficiencies (RR) of COD, BOD_5 and TSS, in winter were 91.62%, 87.92% and 99.67%, respectively, while in summer, corresponding RR were 90.53%, 89.70% and 99.83%, respectively compared to IFAS system which achieved RRs of 91.62%, 88.26% and 98.34% in winter and 90.53%, 90.13% and 98.77% in summer. MBBR also achieved excellent removal of Ammonia in winter with residual value of 0.38mgN/l while in summer it was 0.99mgN/l, compared to IFAS system., in winter it was 19 mgN/l, while in summer it was 0.49 mg N/l. Concerning the number of aerators needed for maintaining a DO concentration of 2 mg/l, the results showed that in winter two aerators with hp 75 were sufficient, while in summer just one aerator was sufficient for the MBBR process. However, the number of aerators needed for IFAS process was 23 aerators in winter and 33 aerators in summer. The values of HRT in IFAS process achieved better results than MBBR; On the contrary the SRT achieved better results in MBBR than in IFAS. In conclusion, MBBR could be a preferable option for this study since a minimum number of aerators would be required and the media used is locally manufactured, thus the operating cost could be narrowed.

Keywords: Activated sludge ; Computer modeling ; Hybrid system ; IFAS ; MBBR ; Upgrading ; Wastewater treatment

1. Introduction

The rapid population growth rate as well as urbanization increases the need of efficient operating WWTPs. On the other hand, their expansion using conventional technologies may require a large area of land which could be impossible. Therefore, upgrading of the existing ones would be a promising alternative. New technologies were emerged in order to cope with the stricter effluent limits such as Moving Bed Biofilm Reactor (MBBR) and Integrated Fixed Film Activated Sludge (IFAS). These processes are designed to offer flexible solutions to a multitude of biological process upgrade applications such as nitrogen removal, increase in treatment capacity and wastewater reuse. The upgrade often consists of simply adding the biofilm media to the existing basins and can therefore be completed in a cost – effective and timely manner without major civil engineering requirements. Based on proprietary polyethylene biofilm carriers, the media technology provides a large internal surface area for the growth of micro-organisms.

Commonly, carrier material is incorporated into activated sludge basins and retained through various screen arrangements in the MBBR and IFAS processes. The conventional activated sludge (CAS) wastewater process scheme is virtually unchanged in both systems with primary sedimentation and secondary clarification. The foremost difference between the MBBR and IFAS systems is the presence of a return activated sludge stream that remains central to the IFAS process. In the MBBR process, biomass is retained in the bioreactor through attachment to suspended carrier material and retention of carrier material using sieves. MBBR system represents a different spectrum in advanced wastewater treatment. It is operated similarly to the activated sludge process with the addition of freely moving carrier media [7]. More specifically, in the MBBR process, biofilm grows attached on small carrier elements suspended in constant motion throughout the entire volume of the reactor and is constrained to the bioreactor through sieve arrangements at the reactor outlet [5]. Advantages of the MBBR over CAS process include better oxygen transfer, shorter Hydraulic Residence Time (HRT), higher organic loading rates, higher nitrification rate and larger surface area for mass transfer [11 & 19]. The idea of the MBBR is to combine the two different processes (attached and suspended biomass) by adding High Density Polyethylene (HDPE) carrier elements into the tank for biofilm attachment and growth. In these systems the biomass grows both as suspended flocs and as attached biofilm. In this way, the carrier elements allow a higher biomass concentration to be maintained in the reactor compared to a suspended growth process, such as activated sludge. This increases the biological treatment capacity for a given reactor volume. Furthermore, the increase of the overall sludge age in the system leads to a favorable environment for the growth of nitrifying bacteria [3]. Without the highly concentrated suspended bacterial population of activated sludge, the overall solids removal requirements are also reduced, allowing for the use of alternative technologies such as dissolved air flotation. In general the reactors are straightforward to install and maintain, requiring only a tank of adequate size and a bank of aerators. [8] proved that the treatment performance of MBBR is proportional to the installed biofilm surface area, so treatment upgrades can be performed by simply adding additional carriers to the same tank. [14] proved that MBBR can possess high organic loading rates at relatively short HRTs (in the range of 4 hrs), while producing consistently high quality effluent with respect to BOD, TN and TSS. According to [15] researchers have proven that MBBR possesses unique traits such as the high biomass, high COD loading, strong tolerance to loading impact, relatively smaller reactor and no sludge bulking problem. Wang et al., (2005) [10] recommended that the DO in the reactor should be kept higher than 2 mg/l for efficient COD removal. In their findings decreasing the DO from 2 to 1 mg/L decreased the COD removal efficiency by 13% indicating that DO became a limiting factor. On the other hand, increasing the DO from 2 to 6 mg/l increased the COD removal efficiency only by 5.8%. By modifying existing tanks, it is possible to implement IFAS into a WWTP without new construction, greatly decreasing the capital cost of the retrofit [4,16]. [18] noted that the IFAS process is also operated in the same way as CAS process by controlling DO and process SRT and requires the same amount of operator attention as a CAS process. According to [16], in many cases, an IFAS upgrade requires less aerobic volume, resulting in the creation of an anoxic zone preceding the aerobic zone with media to allow for more TN removal. By maintaining lower SRT and MLSS concentrations in the aeration basins, IFAS does not cause secondary clarifiers to become overloaded because the additional biomass remains in the IFAS tank [12, 17]. The different types of media used in the IFAS system include networks of string or rope that are suspended in the water (sometimes known as rope or ring lace systems), free-floating sponges and hard plastic media [17]. Each of those media has its advantages and disadvantages. One difference is the biomass retention on a string system or free-floating sponge and a hard plastic media.

In this study a conventional wastewater treatment plant (BalaksWWTP), which needs upgrading was selected for this study. It is located in Shubra El Kheima. It was designed in 1970 to primarily treat industrial wastewater. It is started to operate in 1995 with an average capacity of 350,000 m^3/d and 525,000 m^3/d peak flow, while disposal of effluent was at Shebin El Kanater drain. Due to the growth of population in the city, BWWTP is now receiving a combination of both domestic and industrial wastewater with higher organic loads compared to the actual design criteria. Hence a secondary stage was needed and which started operation in 2005 to serve 2 million inhabitants according to Central Agency for Public Mobilization and Statistics. However, the population is expected to reach 3 million in 2037, so the capacity of the plant will be designed as 600,000 m^3/day average and 900,000 m^3/day peak. The unexpected increase in population as indicated from the records of the plant showed that the effluent quantity reached the maximum hydraulic designed loads, that means the effluent was estimated to reach 600,000 m^3/day in the year 2037 but actually by calculation it will reach approximately 820,000m^3/day average and 1,027,000m^3/day Peak. This could lead to an area which will include treated and untreated wastewater and that will reflect negatively on the environment and health of the people.

This research aims to examine the upgrade of BWWTP to provide better treatment efficiency and overcome most of the problems encountered with the increase in capacity. MBBR and IFAS systems were applied as alternative methods to test their performance in upgrading the plant via computer modeling. The simulation was implemented using BioWin 3.1 [5], a simulator software package in which the user can define and analyze the behavior of complex treatment plant configurations with single or multiple wastewater inputs.

2. Materials & Methods

To accomplish the required objectives for this research, two steps were done. The initial step required was to validate the activated sludge (AS) model with the experimental results measured in the laboratory. This was then followed by simulating the future expected flow rates to check on the final effluent quality in terms of COD, BOD_5, TSS, DO, NH4-N, NO3-N and pH and to determine if either MBBR or IFAS processes could provide better levels of treatment to expand the plant's treatment capacity without constructing additional aeration and sedimentation basins and with minimal additional cost.

The material used for experimentation was wastewater taken from different locations as shown in Figure 1 and measured according to Standard Methods, 1985. Those locations included the influent wastewater to be treated, the effluent wastewater from the primary sedimentation tanks (PST), the aeration tanks (AT), the return activated sludge (RAS) and the effluent WW from the final clarifier (FCT). The experimental measurements included COD, BOD_5, TSS, DO, NH_4-N, NO_3-N and pH to validate the result obtained from BioWin™ simulation. After the validation step, the existing plant was simulated with the designed future flow rate and the expected future flow rate relative to the rapid unexpected increase in population. Because of the failure to meet the effluent criteria, simulation was then done using MBBR once and IFAS another to examine the possibility of enhancing the treatment levels without needing to go for new construction. BWWTP consists of three batteries where each includes 4 PST with a volume of 5,000 m^3(3 operating and one standby), 1 AT with 50 surface aerators with a volume of 45,000 m^3(must not exceed 40) of 75 hp each, and 6 FCT with a volume of 5,000 m^3(4 operating and 2 standby). The primary and secondary sludge are pumped to El Berka WWTP. Figure 1 shows one battery for the existing plant with the location of samples taken before upgrading and which was used to build the computer model as illustrated in Figure 2.

Model validation was done in winter with wastewater temperature of 20°C and another time in summer with a temperature of 29°C.As shown in Table 1, according to the results obtained in February (winter) and August (summer) in 2013, the plant was simulated with a flow rate of (128,809 m^3/d in winter and 126,667 m^3/d in summer) per battery (actual operating conditions).Then the plant was simulated for the year 2037 with a flow rate of 200,000 m^3/d per battery (peak design value) and with a capacity of 300,000 m^3/d according to the expected future population.

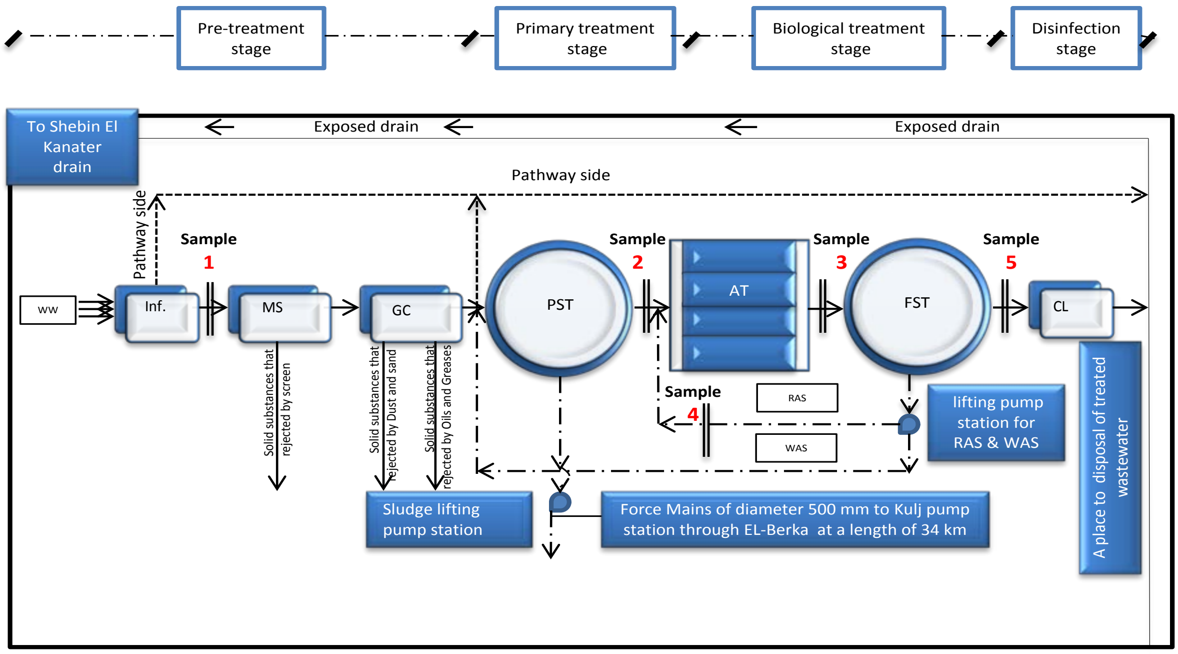


Figure 1: BWWTP process flow diagram illustrating the location of samples taken

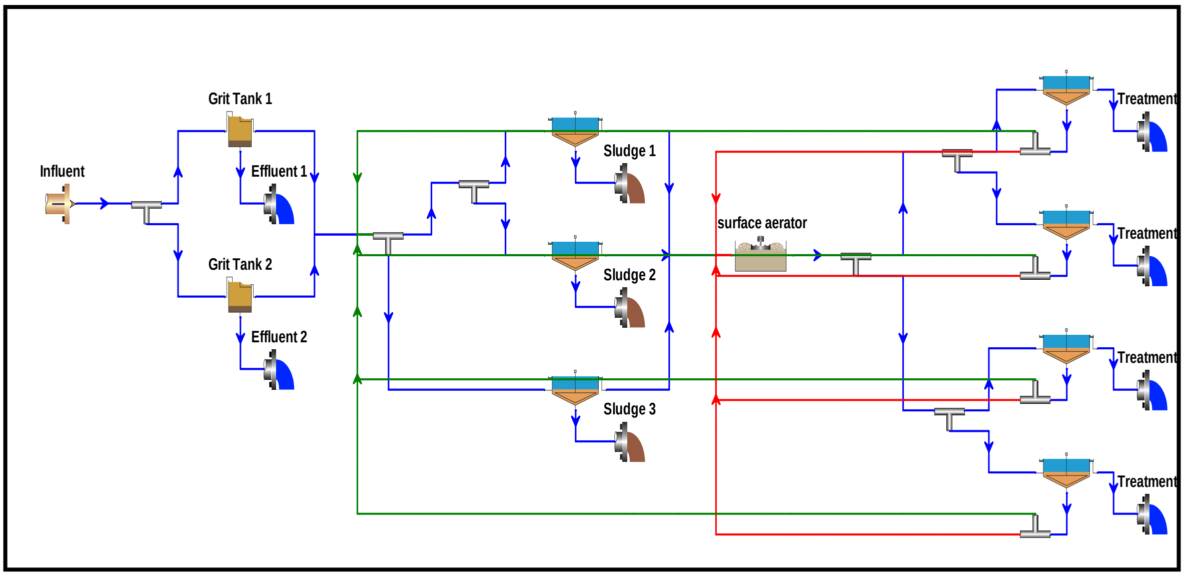


Figure 2: Case 1: CAS Process configuration in Biowin^{TM} model

The results showed that in 2037 BWWTP won't be working efficiently and won't meet the required effluent quality as shown in Table 2. Consequently, there will be a decisive need to extend the existing plant to handle the excess flow rate to comply with the required effluent wastewater quality; hence, MBBR and IFAS technologies were examined as alternative methods to overcome this crucial problem to avoid construction work due to economic concerns.

Table 1: Biowin Simulation in Winter and Summer (Model Validation)

Sample	Units	Actual		$Conventional_{2013}$		$Conventional_{2037}$		$Conventional_{2037}$	
		$Winter_{201}$	$Summer_{201}$	$Winter_{201}$	$Summer_{201}$	$Winter_{203}$	$Summer_{203}$	$Winter_{203}$	$Summer_{203}$
Influent									
Q per battery	**m^3/d**	**128,809**	**126,667**	**128,809**	**126,667**	**200,000**	**200,000**	**300,000**	**300,000**
COD	**mg/l**	**716**	**528**	**716**	**528**	**716**	**528**	**716**	**528**
BOD	**mg/l**	**298**	**233**	**298**	**233**	**298**	**233**	**298**	**233**
TSS	**mg/l**	**326**	**243**	**326**	**243**	**326**	**243**	**326**	**243**
NH4-N	**mgN/l**	**24**	**20**	**24**	**20**	**24**	**20**	**24**	**20**
NO3-N	**mgN/l**	**1.6**	**1.5**	**1.6**	**1.5**	**1.6**	**1.5**	**1.6**	**1.5**
Ph	**-**	**7.54**	**7.43**	**7.54**	**7.43**	**7.54**	**7.43**	**7.54**	**7.43**
Temp.	℃	**20**	**29**	**20**	**29**	**20**	**29**	**20**	**29**
Effluent Concentration from P.S.T									
COD	**mg/l**	**593**	**349**	**593**	**349**	**615**	**361**	**628**	**383**
BOD	**mg/l**	**278**	**152**	**268**	**153**	**280**	**160**	**287**	**173**
TSS	**mg/l**	**316**	**168**	**316**	**169**	**307**	**172**	**296**	**175**
pH	**-**	**7.27**	**7.29**	**7.55**	**7.45**	**7.55**	**7.45**	**7.55**	**7.45**
Effluent Concentration from A.T									
Volume	**m^3**	**45,000**	**45,000**	**45,000**	**45,000**	**45,000**	**45,000**	**45,000**	**45,000**
MLSS	**mg/l**	**2,689**	**1,309**	**1,944**	**899**	**2,029**	**929**	**1,897**	**796**
DO	**mg/l**	**2.10**	**2.10**	**2.10**	**2.10**	**2.38**	**2.28**	**2.17**	**2.24**
NH4-N	**mgN/l**	**-**	**-**	**15**	**12**	**19**	**17**	**20**	**17**
NO3-N	**mgN/l**	**-**	**-**	**4.00**	**-**	**2.08**	**-**	**1.76**	**-**
H.R.T	**hr**	**-**	**-**	**4.68**	**4.84**	**3.05**	**3.09**	**2.03**	**2.05**
pH	**-**	**-**	**-**	**7.7**	**7.71**	**7.7**	**7.71**	**7.69**	**7.7**
No. of aerators		**23**	**30**	**23**	**30**	**28**	**40**	**32**	**40**
Total Power	**kw**	**1,725**	**2,250**	**1,725**	**2,250**	**2,100**	**3,000**	**2,400**	**3,000**
T. O_2 uptake rate	**mgO/l/hr**	**-**	**-**	**27**	**22**	**32**	**28**	**37**	**28**
Effluent Concentration from F.S.T									
COD	**mg/l**	**59**	**47**	**59**	**48**	**80**	**57**	**102**	**68**
BOD	**mg/l**	**26**	**15**	**25**	**15**	**38**	**22**	**54**	**30**
TSS	**mg/l**	**32**	**16**	**32**	**17**	**33**	**17**	**31**	**15**
NH4-N	**mgN/l**	**15.00**	**11.80**	**15**	**12**	**19**	**17**	**20**	**17**
NO3-N	**mgN/l**	**4.00**	**-**	**4.00**	**-**	**2.08**	**-**	**1.76**	**-**
pH	**-**	**7.7**	**7.71**	**7.7**	**7.71**	**7.7**	**7.71**	**7.69**	**7.7**
Concentration of RAS									
COD	**mg/l**	**-**	**-**	**3,416**	**1,745**	**4,256**	**2,070**	**4,541**	**2,261**

BOD	**mg/l**	**-**	**-**	**970**	**400**	**1,323**	**592**	**1,488**	**813**
2^{ndry} sludge	**mg/l**	**4,144**	**1,952**	**4,145**	**1,953**	**4,387**	**2,041**	**4,102**	**1,720**
S.R.T	**day**	**-**	**-**	**5.90**	**5.72**	**3.99**	**3.66**	**2.62**	**2.22**
RAS	**m^3/d**	**-**	**-**	**23,348**	**22,880**	**35,862**	**35,250**	**53,793**	**52,875**
WAS	**m^3/d**	**-**	**-**	**3,489**	**2,542**	**4,752**	**4,054**	**7,128**	**7,931**

Table 2: Required Quality of Treated Effluent for Disposal to Surface Water According to the Egyptian Code of Practice

Sample	Units	Allowable values to dispose to surface water	Allowable values for reuse
COD	**mg/l**	**80**	**40**
BOD	**mg/l**	**60**	**20**
TSS	**mg/l**	**50**	**20**
NH4-N	**mgN/l**	**-**	**-**
NO3-N	**mgN/l**	**-**	**-**
pH		**6-9**	**6 - 9**

Figures 3 and 4 illustrate modeling the existing operating plant with the aeration being installed with MBBR units and IFAS system respectively for the excess flow rate. Three scenarios were considered in this research as presented in Table 1 showing the change in flow rate, the number of aerators required to maintain the levels of DO at a minimum level of 2.0 mg/l in the aeration tanks, and the ratios of RAS & WAS for each case. The tested RAS ratios were 0.4, 0.475, 0.55, 0.625 and 0.7 (limit ranged from 0.4 to 0.7). The third and last scenario investigated the effect of change in the WAS from the final clarifier (which included 0.08, 0.0975, 0.115, 0.135 and 0.15 as the limit ranged from 0.08 to 0.15).

Figure 3 illustrates the simulation of the plant using MBBR being installed in the aeration tanks with the operating conditions mentioned in Table 1 above. The tank had a volume of 45,000 m^3 and similar to the attached growth method, the tank was divided into two compartments in which the MBBR was placed in 1/3 of the tank (25-50% or reactor volume is filled by the packing material, [12]. The carrier elements were used to provide an active biofilm surface area of approximately 850m^2.m^3 in each zone (locally manufactured). This process was also selected as it doesn't require the recirculation of activated sludge from the final clarifier which is used to precipitate sloughed solids; hence it is a promising process for upgrading the existing plant and helps in reducing the solids loading on the operating clarifiers [1,2].

Figure 4 demonstrates the simulation of the plant using IFAS following the same strategy used to test for MBBR. Carrier elements were used as an active biofilm media with an approximate specific surface area of375m^2/m^3in each zone (the specific surface area provided by Ringlace® is: 120 – 500 m^2/m^3 of tank volume, [13]. The simulation operating conditions are again presented in Table 1.

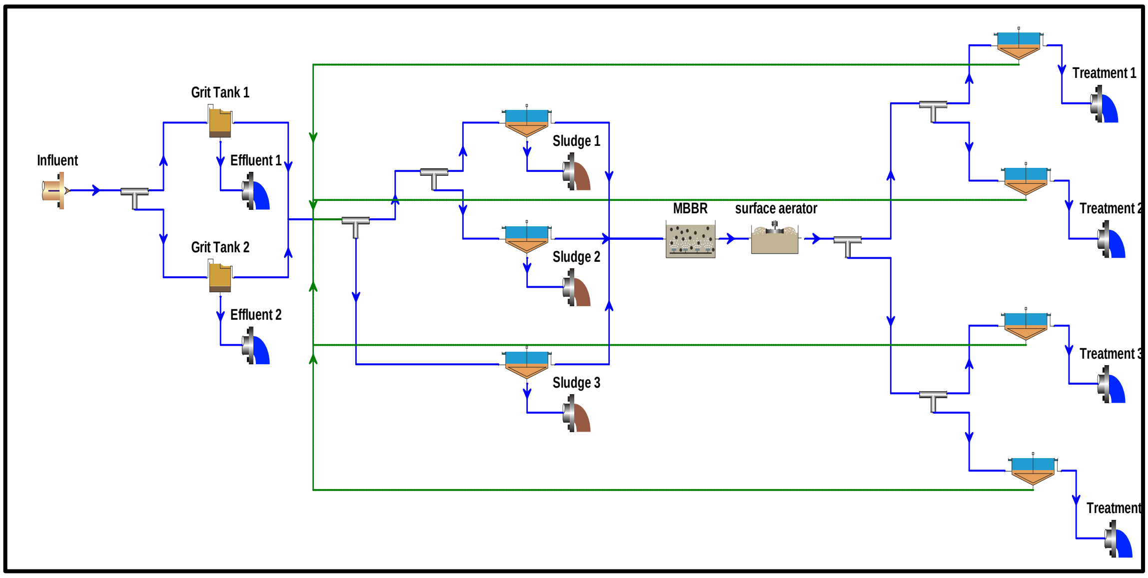


Figure 3:Case 2: MBBR Process configuration in Biowin^{TM} model

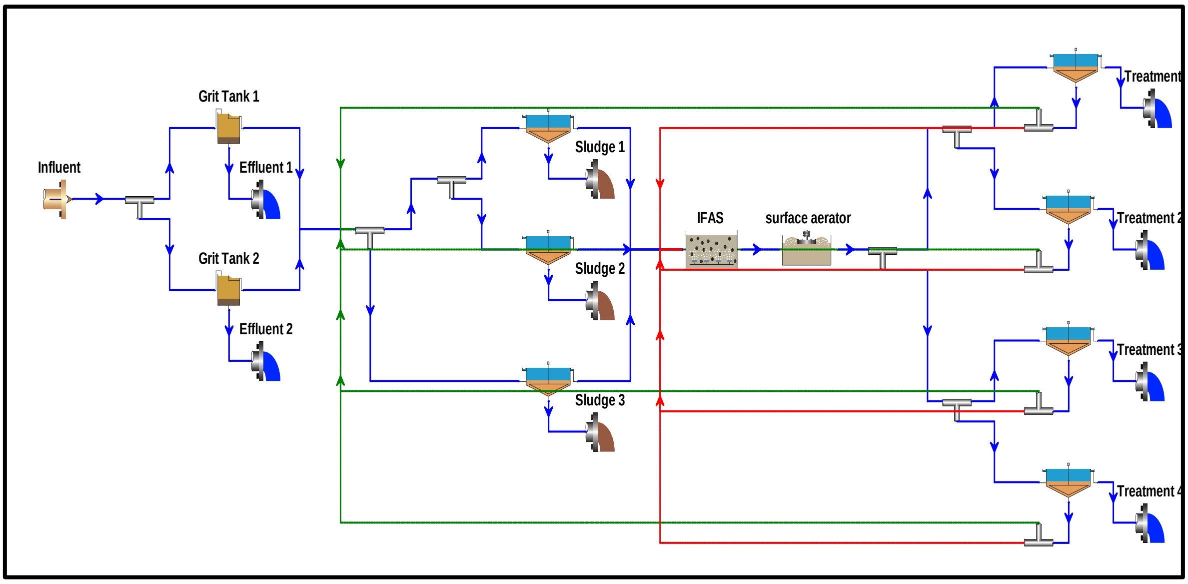


Figure 4: Case 3: IFAS Process configuration in Biowin^{TM} model

3. Results and Analysis

This section shall demonstrate the efficiency of the plant subjected to different flow rates mentioned above under three operating processes namely, CAS, MBBR, and IFAS. The removal efficiencies were determined for BOD_5, COD, TSS and ammonia in addition to the corresponding values of HRT and SRT. On the other hand, MBBR and IFAS processes were tested in three locations as to surface aerators (before, in between and after the surface aerator) to achieve the best results as will be shown in the following set of figures and tables.

3.1 Case 1: Operating the plant under actual flow rate in 2013

All three processes have achieved high removal rates for the tested organic loads as illustrated in Figure 5. Accordingly, the processes were able to withstand the variation of the influent quality. As a result of the two seasons shown below in each case, CAS removals in winter were 91.76%, 91.61% and 90.18% while, in summer were91.10%, 93.56% and 93.00% for COD, BOD_5, and TSS respectively. MBBR and IFAS were placed in the three locations as to the surface aerator as shown in Table 3 (Location 1: before ,Location 2: in between and Location 3: after).As for MBBR removals in winter were 96.09%, 95.30% and 99.64% for Location 1, 96.09%, 95.30% and 99.66% for Location 2 and 94.83%, 93.29% and 99.68% for Location 3 while, in summer were 93.94%, 95.28% and 99.84%.for Location 1, 93.75%, 94.85% and 99.84% for Location 2 and 92.99%, 93.56%and 99.84% for Location 3. On the other hand, IFAS removals in winter were 96.51%, 96.64% and 97.96% for Location 1, 97.21%, 97.78% and 98.03% for Location 2 and 96.65%, 96.96% and 98.05% for Location 3while, in summer were 93.56%, 94.85% and 98.90% for Location 1, 93.56%, 95.28% and 98.91% for Location 2 and 93.75%, 95.28% and 98.90% for Location 3.

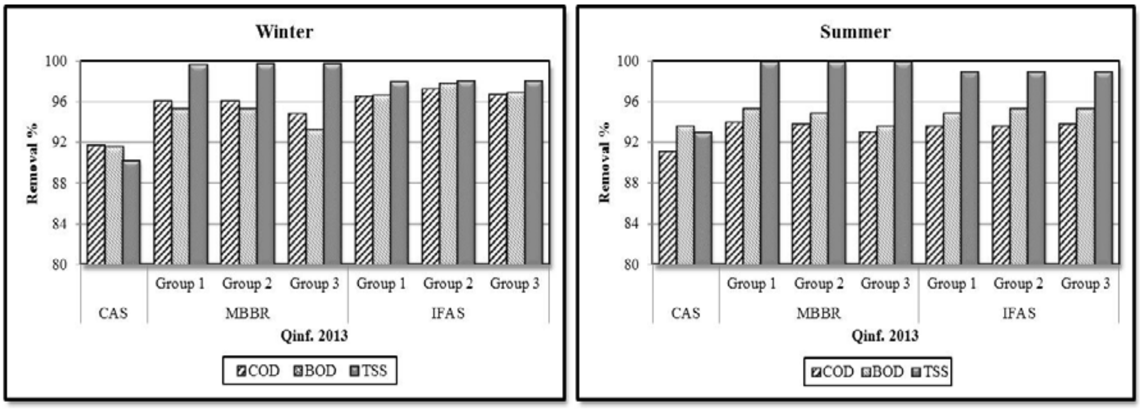


Figure 5: Efficiency removals % pertaining to CAS, MBBR and IFAS in 2013

HRT and SRT values presented in Table 3 were within the allowable limits as required in the Egyptian code (4-8 hr& 5-15 days respectively). As for the best location for MBBR or IFAS, it is noticed that, in Location 1, MBBR achieved better removals of COD, BOD_5, and TSS in both seasons. Moreover, it achieved the highest RR for Ammonia with the least number of aerators and thus would consume the least amount of energy compared to locations 2 and 3. The IFAS system achieved results in location 2 for the removals of COD, BOD_5, TSS and Ammonia but the required number of aerators were much higher compared to the MBBR system, Hence will have a high electrical consumption rate.

Table 3: Comparison between CAS, IFAS, and MBBR for the flow rate received in 2013

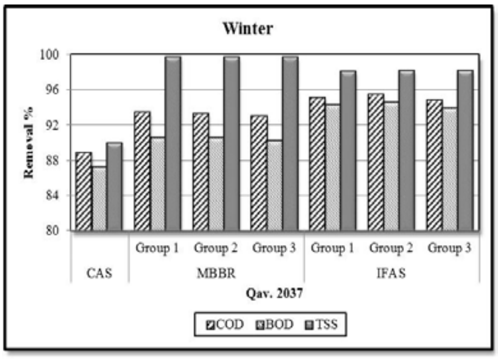
Case 1		CAS		MBBR						IFAS					
				Location 1		Location 2		Location 3		Location 1		Location 2		Location 3	
				Before the surface aerator		In between the surface aerator		After the surface aerator		Before the surface aerator		In betweenthe surface aerator		After the surface aerator	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S
COD (mg/l)	**Inlet**	716	528	716	528	716	528	716	528	716	528	716	528	716	528
	Outlet	59	47	28	32	28	33	37	37	25	34	20	34	24	33
BOD (mg/l)	**Inlet**	298	233	298	233	298	233	298	233	298	233	298	233	298	233
	Outlet	25	15	14	11	14	12	20	15	10	12	6.61	11	9.05	11
TSS (mg/l)	**Inlet**	326	243	326	243	326	243	326	243	326	243	326	243	326	243
	Outlet	32	17	1.17	0.40	1.11	0.40	1.04	0.40	6.64	2.67	6.42	2.66	6.35	2.67
NH4-N (mgN/l)	**Inlet**	24	20	24	20	24	20	24	20	24	20	24	20	24	20
	Outlet	15	12	0.12	0.08	0.22	0.12	0.60	0.31	1.12	0.21	0.33	0.19	0.73	0.35
NO3-N (mgN/l)	**Inlet**	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50
	Outlet	4.00	-	23	-	22	-	21	-	21	-	22	-	21	-
HRT (hr)		4.68	4.84	6.93	7.17	6.94	7.16	6.93	7.17	4.52	4.63	4.52	4.62	4.52	4.63
SRT (day)		5.90	5.72	3.22	3.20	3.06	3.11	3.17	3.20	4.33	4.22	3.76	3.72	4.29	4.23
No# of aerator		23	30	2	1	5	4	8	9	13	11	19	21	21	23

3.2 Case 2: Operating the plant under the average expected flow rate in 2037

For this simulation, it was noticed that CAS RR in winter decreased to 88.83%, 87.25% and 89.88% while in summer, the RR decreased to 89.20%, 90.56% and 93.00%. This could be referred to the increase in the influent flow rate which would consequently decrease the performance and level of treatment. Moreover, the system failed to maintain the allowable limits for HRT and SRT as shown in Table 4. As for the MBBR process the RR realized in winter were 93.44%, 90.60% and 99.66% for Location 1, 93.30%, 90.60% and 99.67% for Location 2 and 93.02%, 90.27% and 99.68% for Location 3 while, in summer were 92.80%, 93.56% and 99.83% for Location 1, 92.61%, 93.13% and 99.83% for Location 2 and 92.05%, 91.85% and 99.83% for Location 3. The SRT achieved was 2 days and this complies with the findings of [9] who also used BioWin in increasing the capacity of an existing plant without adding new basins.

IFAS removals in winter for COD, BOD_5 and TSS were 95.11%, 94.30% and 98.10%for Location 1, 95.39%, 94.63% and 98.16% for Location 2 and 94.83%, 93.96% and 98.17% for Location 3 while, in summer were

91.29%, 91.42% and 98.84% for Location 1, 90.91%, 90.99% and 98.84% for Location 2 and 91.29%, 91.42% and 98.84% for Location 3. The results are shown in **Figure 6** below.



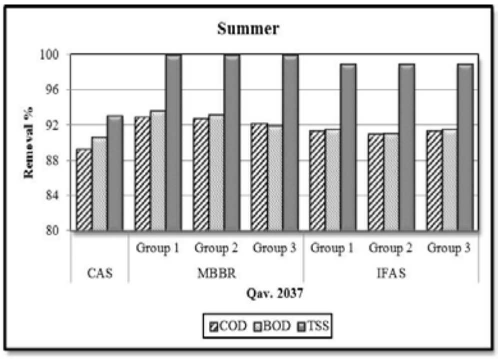


Figure 6: Efficiency removals % pertaining to CAS, MBBR and IFAS concerningaverage in 2037

Table 4: Comparison between CAS, MBBR, and IFAS for the average expected flowrate in 2037

Case		**CAS**		**MBBR**						**IFAS**					
				Location 1		Location 2		Location 3		Location 1		Location 2		Location 3	
				Before the surface aerator		In betweenthe surface aerator		After the surface aerator		Before the surface aerator		In between the surface aerator		After the surface aerator	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S
COD (mg/l)	**Inlet**	716	528	716	528	716	528	716	528	716	528	716	528	716	528
	Outlet	80	57	47	38	48	39	50	42	35	46	33	48	37	46
BOD (mg/l)	**Inlet**	298	233	298	233	298	233	298	233	298	233	298	233	298	233
	Outlet	38	22	28	15	28	16	29	19	17	20	16	21	18	20
TSS (mg/l)	**Inlet**	326	243	326	243	326	243	326	243	326	243	326	243	326	243
	Outlet	33	17	1.12	0.41	1.09	0.42	1.03	0.42	6.18	2.82	6.00	2.81	5.95	2.81
NH4-N (mgN/l)	**Inlet**	24	20	24	20	24	20	24	20	24	20	24	20	24	20
	Outlet	19	17	0.21	0.11	0.35	0.18	0.66	0.52	1.06	0.34	0.27	0.34	0.81	0.71
NO3-N (mgN/l)	**Inlet**	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50
	Outlet	2.08	-	23	-	23	-	22	-	3.08	-	22	-	21	-
HRT (hr)		3.05	3.09	4.47	4.56	4.48	4.56	4.47	4.56	2.91	2.94	2.90	2.94	2.91	2.94
SRT (day)		3.99	3.66	2.07	2.03	1.97	1.97	2.03	2.03	2.76	2.70	2.41	2.37	2.74	2.70
No# of aerator		28	40	2	1	4	6	8	9	13	16	23	28	25	32

Concerning HRT and SRT couldn't reach the value as shown in Table 4. Similar to the previous case, in Location 1, the MBBR process required the least number of aerators and thus would consume the least amount ofenergy during operation. While in Location 2, the IFAS process achieved good results removing of COD, BOD_5, TSS and Ammonia except no# of aerators which attained better results in Location 1.

3.3 Case 3: Operating the plant under the peak flow rate expected in 2037

As illustrated in Figure 7, results obtained from this simulation showed a continuous decline in CAS removals in winter to 85.75%, 81.88% and 90.49% while in summer, were 87.12%, 87.12% and 93.83% for the same organic parameters measured respectively. In winter, the MBBR process resulted in RR of 91.62%, 87.92% and 99.67% for Location 1, 91.34%, 87.25% and 99.68% for Location 2 and 90.78% , 86.24% and 99.69% for Location 3 while, in summer were 90.53%, 89.70% and 99.83% for Location 1, 90.15%, 89.27 and 99.83% for Location 2 and 89.77%, 88.41 and 99.83% for Location 3. In winter, IFAS system achieved RRs of 91.34%, 87.92% and 98.21% for Location 1, 91.62%, 88.26% and 98.34% for Location 2 and 91.06%, 87.25% and 98.36% for Location 3 while, in summer 90.72%, 90.56% and 98.77% for Location 1, 90.53%, 90.13% and 98.77% for Location 2 and 90.53%, 90.13% and 98.77% for Location 3.

For HRT and SRT didn't achieve this value as shown in Table 5. Similar to the previous case, in Location 1, the MBBR process still achieved the required least number of aerators and thus would consume the least amount of energy during operation. On the other hand, the IFAS process didn't achieve good results for Ammonia and Nitrate in the three Locations which may be due to less diffusion.

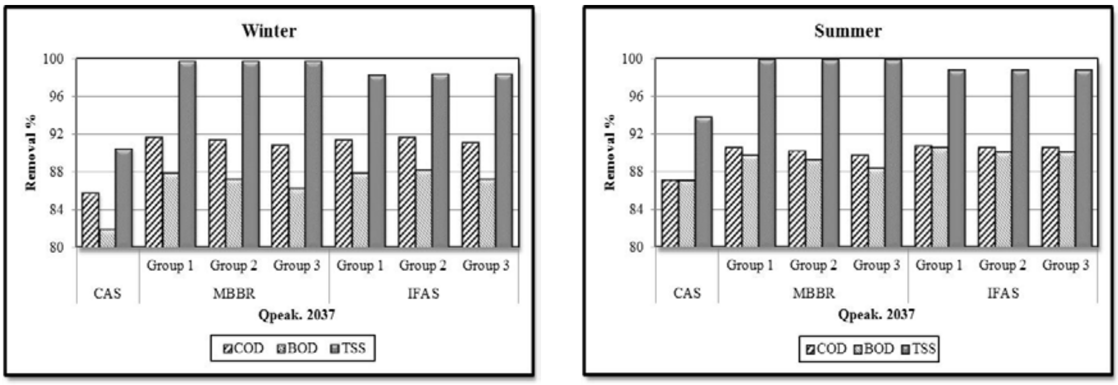


Figure 7: Efficiency removals % pertaining to CAS, MBBR and IFAS concerning Peak in 2037

The simulating scenarios and consequent results revealed that the operational efficiency of BWWTP could be downgraded if it continues to operate with the prevailing conditions for the average and peak flowrates of 2037. For $Q_{avg\ 2037}$, results indicated that HRT couldn't attain the limits required by the Egyptian code (4 to 8 hr); the model recorded 3.05 hr in winter and 3.09 hr in summer. Moreover, concerning SRT, the Egyptian code stated the limits from 5 to 15 day while the model recorded 3.99 days in winter and 3.66 days in summer. In addition, in summer the number of aerators reached the maximum. Concerning the organic loads, in winter, COD reached the limit according to the Egyptian code (80 mg/l), thus any increase in the influent would most probably result in a higher effluent concentration and this would violate the regulations not only for surface water disposal but for reuse as well. The same operating problems pertained for the peak flow rate in 2037 in case no changes are done to the existing situation. On reviewing the results, it is notable that MBBR achieved better removals of COD, BOD_5 and TSS in the three locations of the media inside the aeration tank; however a higher removal ratio of ammonia nitrogen was achieved in location 1 for the media compared to locations 2 and 3. As for the IFAS system, similar to the MBBR, the media in the three locations achieved high removal ratios for the organic loads yet it failed to achieve better removal for ammonia nitrogen in winter. MBBR achieved better results in the number of operating aerators required to maintain DO levels above 2 mg/l and SRT compared to IFAS.

Table 5: Comparison between CAS, MBBR, and IFAS for Peak flowrate in 2037

Case 3		**CAS**		**MBBR**						**IFAS**					
				Location 1 Before the surface aerator		Location 2 In between the surface aerator		Location 3 After the surface aerator		Location 1 Before the surface aerator		Location 2 In between the surface aerator		Location 3 After the surface aerator	
		W	S	W	S	W	S	W	S	W	S	W	S	W	S
COD (mg/l)	**Inlet**	716	528	716	528	716	528	716	528	716	528	716	528	716	528
	Outlet	102	68	60	50	62	52	66	54	62	49	60	50	64	50
BOD (mg/l)	**Inlet**	298	233	298	233	298	233	298	233	298	233	298	233	298	233
	Outlet	54	30	36	24	38	25	41	27	36	22	35	23	38	23
TSS (mg/l)	**Inlet**	326	243	326	243	326	243	326	243	326	243	326	243	326	243
	Outlet	31	15	1.06	0.42	1.04	0.41	1.01	0.41	5.82	2.98	5.42	2.99	5.36	2.99
NH4-N (mgN/l)	**Inlet**	24	20	24	20	24	20	24	20	24	20	24	20	24	20
	Outlet	20	17	0.38	0.99	0.57	1.36	0.93	1.88	20	0.87	19	0.49	19	1.06
NO3-N (mgN/l)	**Inlet**	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50	1.60	1.50
	Outlet	1.76	-	23	-	22	-	22	-	1.74	-	1.82	-	1.84	-
HRT (hr)		2.03	2.03	2.95	3.01	2.94	3.00	2.95	3.01	1.94	1.96	1.94	1.96	1.94	1.96
SRT (day)		2.62	2.22	1.38	1.35	1.31	1.31	1.35	1.35	1.83	1.82	1,59	1.59	1.80	1.82
No# of aerator		32	40	2	1	4	6	7	8	14	18	23	33	26	37

4. Conclusion

To sum up, comparing between MBBR & IFAS, the MBBR system would be favored in upgrading the operating performance of BWWTP for several reasons. This study may be helpful to check the possibility that the hybrid process (MBBR in this case) can be used as an ideal and efficient option for upgrading wastewater plants as:

1. MBBR achieved high removal efficiencies for the different organic loads COD, BOD_5 and TSS.
2. MBBR was able to withstand the variation in the influent flow interims of quality and quantity.
3. MBBR achieved excellent removal for soluble Ammonia.
4. Minimum no# of aerators were required to achieve the allowable DO limits.
5. This process could have a lower operating cost as no return activated sludge is required compared to IFAS process.
6. MBBR achieves short sludge age compared to IFAS.
7. Preferable to choose Location 1 (before the surface aerators) as its location achieved best results for MBBR.

In conclusion, MBBR could be a promising solution to upgrade BWWTP specially that the media is locally manufactured, and minimum number of aerators would be required (power saving) thus would facilitate the operation and maintenance phase and would be less expensive compared to the IFAS modules which would have to be imported specially with the tight financial resources availability.

References

[1] B. Rusten, B. G. HellstÖm, F. HellstÖm, O. Sehested, E. Skjelfoss, and B. Svendsen (2000) " *Pilot Testing and Preliminary Design of Moving Bed Biofilm Reactors for Nitrogen Removal at the FREVAR Wastewater Treatment Plant*" Water Science and Technology Vol. 41 p.13.

[2] B. Rusten, M. McCoy, R. Proctor and J. G. Siljuden (1998) "*The Innovative Biofilm Moving Bed Biofilm Reactor / Solids Contact Reaeration Process for Secondary Treatment of Municipal Wastewater*." Water Environment Research, Vol. 67, page 1083.

[3] C.W. Randall, and D. Sen, (1996). "F*ull-scale evaluation of an integrated fixed-film activated sludge (IFAS) process for enhanced nitrogen removal"*. Water Sci. Technol., 33: 155-162.

[4] D. Ross, W.Fernandes, T. Briggs, N. Kim, G. Booth, D. Neely, J.Welp, "*Integrated Fixed Film Activated Sludge (IFAS) At The Lakeview WWTP: The Real Implementation Issues*." Proceedings of the 77th WEFTEC- National Conference of the Water Environment Federation.New Orleans, LA, October 2-6, 2004.

[5] EnviroSim Associates, Ltd., User Manual for BioWin 3.0, EnviroSim Associates, Ltd., Hamilton, Canada, 2008

[6] G. Mannina, and G. Viviani, (2009). "*Hybrid moving bed biofilm reactors: an effective solution for upgrading a large wastewater treatment plant.*" Water Science and Technology, 60 (5), 1103-1116.

[7] H. Odegaard, 2006. "*Innovations in wastewater treatment: The moving bed bioreactor*." Water Sci.Technol, 53: 17-33.

[8] H. Odegaard, B. Gisvold and J. Strickland, (2000). "*The influence of carrier size and shape in the moving bed biofilm process."* Water Sci. Technol., 41: 383391.

[9] J.A. Davis, K. Harrison, and B. Shields. "*Compact Technology: Increasing Treatment Capacity without Building More Basins*." Florida Water Resources Journal, page: 24-29, July 2009.

[10] J.X. Wang, S.Q. Xia, L. Chen, J. F. Zhao, N. J. Renault, and J. M. Chovelon. 2005. "*Nutrients removal from municipal wastewater by chemical precipitation in a moving bed biofilm reactor"*. Process Biochemistry 41, (4): 824-828.

[11] K. Sombatsompop, C. Visvanathan and R. Ben Aim (2006) "*Evaluation of bio fouling phenomenon in suspended and attached growth membrane bioreactor systems*," Desalination, 201: 138-149.

[12] K. Yerrell, M. Gobbie, P. Dold, R. Jones, L. Sickerdick, "*Full-Scale Demonstration Of A Free Moving Media IFAS Process For Enhancing Nitrification Performance.*" Proceedings of the 74th WEFTEC-National Conference of the Water Environment Federation. Atlanta, GA, October 13-17, 2001.

[13] Metcalf & Eddy, Inc. "*Wastewater Engineering: Treatment, Disposal, and Reuse*." 3rd Edition. McGraw-Hill, New York, P.1661. 2005.

[14] R.M. Ahl, T. Leiknes and H. Odegaard, 2006. "*Tracking particle size distributions in a moving bed biofilm membrane reactor for treatment of municipal wastewater*." Water Science. Technology., 53: 33-42.

[15] S. Chen, D. Sun, and J.S. Chung, (2008). "*Simultaneous removal of COD and ammonium from landfill leachate using an anaerobic–aerobic moving-bed biofilm reactor system.*" Waste Manage. 28: 339346.

[16] S. Hubbell, C. McDowell, "*Cold Temperature BNR Using Integrated Fixed-Film Activated Sludge (IFAS) Hybrid Technology*." Proceedings of the 76th WEFTEC- National Conference of the Water Environment Federation. Los Angeles, CA, October 12-15, 2003.

[17] S. Hubbell, D. Krichten,"*Demonstration And Full Scale Results Of A Plant Upgrade For BNR Using Integrated Fixed-Film Activated Sludge (IFAS) Technology."* Proceedings of the 77 WEFTEC- National Conference of the Water Environment Federation. New Orleans, LA, October 2-6, 2004.

[18] T. Johnson, J. McQuarrie, A. Shaw "*Integrated Fixed-Film Activated Sludge (IFAS): The New Choice for Nitrogen Removal Upgrades In The United States.*" Proceedings of the 77 WEFTEC- National Conference of the Water Environment Federation. New Orleans, LA, October 2-6, 2004.

[19] Y.J. Chan, M.F. Chong, C.L. Law and D.G. Hassell, 2009. "*A review on anaerobic-aerobic treatment of industrial and municipal wastewater*." Chem. Eng. J.,155: 1-18.