COMPARISON STUDY BETWEEN INTEGRATED FIXED FILM ACTIVATED SLUDGE (IFAS), MEMBRANE BIOREACTOR (MBR) AND CONVENTIONAL ACTIVATED SLUDGE (AS) PROCESSES

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ABSTRACT

Comparison study is required to evaluate the treatment efficiency of three alternative secondary treatment processes. These Processes are Integrated Fixed-film Activated Sludge (IFAS), Membrane Bioreactor (MBR) and Conventional Activated Sludge (AS). This study is required for a new wastewater treatment plant. The characteristics of the influent domestic wastewater for the proposed plant were measured. The influent wastewater is varied from low, medium and high concentrations. The treated effluent of the wastewater plant should be complied with the reuse regulations of the international standards for several purposed including non-restricted irrigation. The IFAS process has recently become popular for enhanced nitrification and denitrification in aerobic zones because it is an alternative to increasing the volume of treatment plant units to accomplish year round nitrification and nitrogen removal. The mathematical model is used to investigate the performance and treatment capability of the three proposed processes. The GPS-X (version 5.0) simulation program is used in this study to simulate the three treatment processes. The proposed plant model is consisted of three treatment stages. First stage is pretreatment unit (grit chamber). Second treatment stage is a rectangular primary clarifier. Third treatment stage is the secondary treatment units. The IFAS, AS and MBR processes are used as the three alternative secondary treatment units. It can be concluded from this results that, the treatment efficiency of the IFAS system based on BOD removal is ranged between 97.7 to 98.2 %, and based on TSS removal is ranged between 95.1 to 97.1 % for all cases of operation. Also, the treatment efficiency of the MBR system based on BOD removal is ranged between 98.1 to 99.4 %, and based on TKN removal is ranged between 97.9 to 99.1 % for all cases of operation.

Keywords: Integrated Fixed-film Activated Sludge; Membrane Bioreactor; GPS-X; Activated Sludge; Biological Treatment.

1. INTRODUCTION

The Integrated Fixed Film Activated Sludge (IFAS) process is comprised of a fixed film media free moving or stationary combined with activated sludge. By allowing the fixed film phase to retain biomass in the basin the IFAS process can be operated at low Solid Retention Time (SRT) and still achieve nitrification. By retaining biomass in the fixed film, the IFAS process can still achieve full nitrification because the nitrifiers in the basin can grow in the fixed film that has effective SRT controlled by the steady state sloughing of biomass from the media.

This is expected to be much longer than that required for nitrifier growth even at very cold temperatures. The addition of fixed film media to an existing activated sludge process effectively increases the biomass in the aeration basin without placing and additional load on the secondary clarifier. By maintaining a low SRT in the IFAS basin, the process has also been credited with better settling sludge with lower SVI compared with conventional activated sludge processes[1,2]. IFAS technology appears in many forms, and a variety of media is available to choose from. The different types of media include networks of string or rope that are suspended in the water, free floating sponges, and hard plastic media. Each of these media technologies has advantages and disadvantages. One difference is the biomass retention on a string system or free floating sponge and a hard plastic media [3,4].

The membrane bioreactor (MBR) concept is a combination of conventional biological wastewater treatment plant and membrane filtration. The concept is technically similar to that of a traditional wastewater treatment plant, except for the separation of activated sludge and treated wastewater. In an MBR installation this separation is not done by sedimentation in a secondary clarification tank, but by membrane filtration [5-8]. The high performance of membrane technology has been proven in recent years in a wide range of field, such as chemical industry, medical technology, drinking water treatment, biotechnology and environmental technology. The continuous development of membrane materials and membrane design on the one hand and the knowledge of operational management on the other hand have fostered the growth of membrane technology in wastewater treatment [9-12].

This study aims to investigate the performance and treatment efficiency of the IFAS, MBR and conventional AS by using simulation software. The modular program used in this study is GPS-X which is a modular, multi-purpose modeling environmental for the simulation of municipal and industrial wastewater treatment plants. GPS-X uses an advanced graphical user interface to facilitate dynamic modeling and simulation. GPS-X is also uses the most recent advances in process modeling, simulation technology, graphics and a host of productivity tools that simplify model construction, simulation and interpretation of results.

2. MATERIALS AND METHOD

2.1 Mathematical Model Configuration

The GPS-X (version 5.0) simulation program was used in this study to simulate the proposed plant model. The GPS-X is a modular, multi-purpose modeling environmental for the simulation of municipal and industrial wastewater treatment plants. Figure 1 shows the general layout of Integrated Fixed-film Activated Sludge (IFAS), Conventional Activated Sludge (AS) and Membrane Bioreactor (MBR) mathematical model.

The influent wastewater flow rate for the mathematical model is 45,000 m^3/d. The mathematical model was used to investigate the performance of the three systems. The proposed plant model is consisted of three stages. First treatment stage is pretreatment unit. The pretreatment is a grit chamber unit. Second treatment stage is a rectangular primary clarifier. Third treatment stage is the secondary treatment units. Three secondary treatment units are proposed in the mathematical model. The three flow splitter is followed the primary treatment. Each path of the secondary treatment has one third of the total influent flow rate. First path of secondary treatment unit is a conventional activated sludge tank with final circular clarifier. Second path of secondary treatment is an anaerobic and anoxic-aerobic integrated fixed-film activated sludge with a final circular clarifier. Third path of secondary treatment is a membrane bioreactor tank unit. The model has the ability to optimize the kinetic parameters of the biological reactions for the proposed model. After the model optimization, three different cases of operations are run. The concentrations of the influent wastewater are used to run the proposed mathematical model. The influent of case 1, case 2 and case 3 are low, medium and high concentrations respectively.

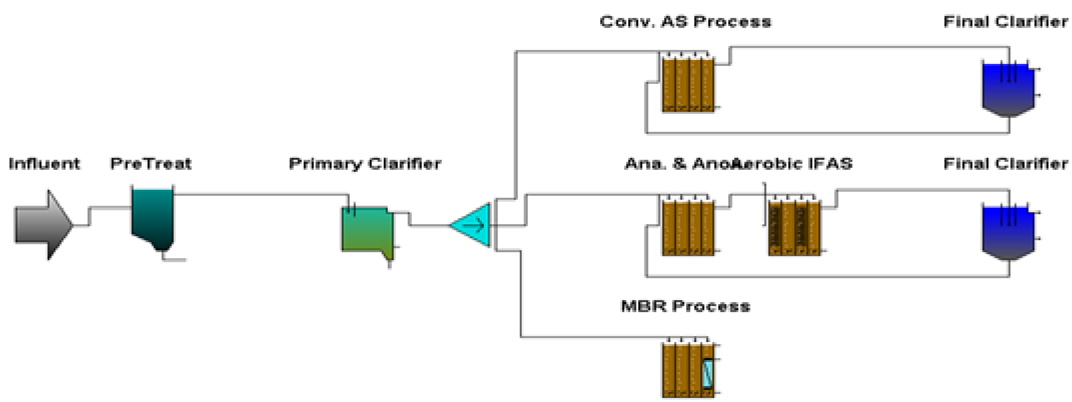

Figure 1 General layout of IFAS, AS and MBR mathematical model.

2.2 Influent Characteristics and Cases of Operation.

The proposed mathematical plant model was run by using three scenarios (cases of operation). Table 1 shows the influent raw wastewater characteristics for each case of operation. First case of operation (case 1) was run with low influent concentrations. The total SS, BOD_5 and TKN for case 1 were 180, 225 and 25 mg/l respectively. Second case of operation (case 2) was run with medium influent concentrations. The total SS, BOD_5 and TKN for case 2 were 250, 300 and 35 mg/l respectively. Third case of operation (case 3) was run with high influent concentrations. The total SS, BOD_5 and TKN for case 3 were 375, 450 and 50 mg/l respectively. The influent flow rate for all cases of operation of the plant models was constant along the running time. All cases run for 10 days of operation.

Table 1 Influent raw wastewater characteristics

Parameter	Case 1 Low concentrations	Case 2 Medium concentrations	Case 3 High concentrations	Units
Total SS	180	250	375	[g/m3]
Volatile SS	135	188	281	[g/m3]
Total inorganic SS	45	62.5	93.8	[g/m3]
Total BOD5	225	300	450	[gO2/m3]
Total COD	408	548	807	[gCOD/m3]
TKN	25	35	50	[gN/m3]

Table 2 shows the wastewater characteristics after the primary treatment. The total SS, BOD_5 and TKN for the primary treated wastewater of case 1 were 56.2, 137 and 19.9 mg/l respectively. The total SS, BOD_5 and TKN for the primary treated wastewater of case 2 were 71.3, 176 and 27.4 mg/l respectively. The total SS, BOD_5 and TKN for the primary treated wastewater of case 3 were 195, 328 and 42.9 mg/l respectively. The TSS removal efficiencies for the primary treatment for case 1, case 2 and case 3 are 68.8, 71.5 and 48.0 % respectively. The BOD removal efficiencies for the primary treatment for case 1, case 2 and case 3 are 45.2, 41.3 and 27.1 % respectively. The TKN removal efficiencies for the primary treatment for case 1, case 2 and case 3 are 20.4, 21.7 and 14.2 % respectively.

Table 2 Wastewater characteristics after the primary treatment

Parameter	Case 1 Low concentrations	Case 2 Medium concentrations	Case 3 High concentrations	Units
Total SS	56.2	71.3	195	[g/m3]
Volatile SS	47.4	58.1	155	[g/m3]
Total inorganic SS	8.78	13.2	40.5	[g/m3]
Total BOD5	137	176	328	[gO2/m3]
Total COD	246	309	573	[gCOD/m3]
TKN	19.9	27.4	42.9	[gN/m3]

2.3 Model Operation Conditions

2.3.1 The operation conditions of the conventional AS process were as follows:

- Total plug flow aeration tank reactors volume = 6500 m^3.
- Average influent flow rate = 15000 m^3/d.
- Return sludge flow rate = 12000 m^3/d.
- Waste sludge flow rate = 205 m^3/d.
- Hydraulic retention time for the aeration tank (HRT) = 9.18 hr.
- Mixed Liquor Suspended Solids (MLSS) = 1720 mg/l.
- For the circular settling tank: Area = 804 m^2, Tank depth = 5.5 m, Tank volume = 4422 m^3.
- Hydraulic retention time for the settling tank (HRT) = 3.95 hr.

2.3.2 The operation conditions of the MBR process were as follows:

- Numbers of reactors = 3, total reactors volume = 4000 m^3.
- Average flow rate = 15000 m^3/d.
- Hydraulic retention time (HRT) = 6.4 hr.
- Mixed Liquor Suspended Solids (MLSS) = 7190 mg/l.
- Membrane pore size = 1.0 µm.
- Total membrane surface area = 4000 m^2.
- Transmembrane pressure = 0.1 bar.
- Cross air flow = 19000 m^3/d.
- Frequency of backwash = 15 min, duration of backwash = 30 sec, backwash flow = 2000 m^3/d.
- Frequency of chemical cleaning = 6.0 months.

2.3.3 The operation conditions of the IFAS process were as follows:

- Number of reactors = 3 (two anaerobic-anoxic tanks + one IFAS tank), total reactors volume = 4900 m^3.
- Average flow rate = 15000 m^3/d.
- Hydraulic retention time (HRT) = 4.45 hr.
- Mixed Liquor Suspended Solids (MLSS) = 1610 mg/l.
- Return sludge flow rate = 12000 m^3/d.
- Waste sludge flow rate = 205 m^3/d.
- For the circular settling tank: Area = 804 m^2, Tank depth = 5.5 m, Tank volume = 4422 m^3.
- Hydraulic retention time for the settling tank (HRT) = 3.95 hr.
- Number of biofilm layers = 6, specific surface of media = 500 1/m^3.

3. RESULTS AND DISCUSSION

3.1 Case 1 of operation.

Table 3 shows the summary of results for case 1 of operation for the AS, IFAS and MBR systems. The case 1 is the low influent concentration operation phase for the three systems. Figure 2 shows the effluent concentration for the AS, IFAS and MBR systems for case 1 of operation. The effluent biochemical oxygen demand BOD for the AS, IFAS and MBR systems are 5.3, 5.17 and 1.64 mg/l respectively. The effluent Suspended solids SS for the AS, IFAS and MBR systems are 8.9, 8.83 and 0.07 mg/l respectively. The effluent ammonia nitrogen NH_3 for the AS, IFAS and MBR systems are 0.47, 0.39 and 0.32 mg/l respectively. The results of case 1 of operation show that, the treatment efficiency of the MBR system higher than the IFAS and AS systems. Also, the efficiency of both AS and IFAS systems is approximately the same.

Table 3 Summary of results for case 1 of operation for the AS, IFAS and MBR systems

Treatment System	MLSS [g/m3]	Aeration power [kw]	Effluent SS [g/m3]	Effluent BOD [g/m3]	Effluent Ammonia Nitrogen [g/m3]	Waste sludge flow rate [m3/d]
AS system	1720	60.6	8.9	5.3	0.468	205
IFAS system	1600	86.3	8.83	5.17	0.394	180
MBR system	7190	80.1	0.072	1.74	0.316	110

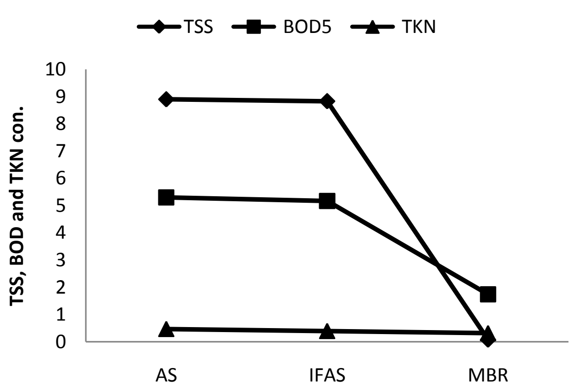

Figure 2 Effluent concentrations for the AS, IFAS and MBR systems for case 1.

3.2 Case 2 of operation.

Table 4 shows the summary of results for case 2 of operation for the AS, IFAS and MBR systems. The case 2 is the medium influent concentration operation phase for the three systems. Figure 3 shows the effluent concentration for the AS, IFAS and MBR systems for case 2 of operation. The effluent biochemical oxygen demand BOD for the AS, IFAS and MBR systems are 5.18, 5.42 and 1.7 mg/l respectively. The effluent

Suspended solids SS for the AS, IFAS and MBR systems are 9.32, 9.31 and 0.1 mg/l respectively. The effluent ammonia nitrogen NH_3 for the AS, IFAS and MBR systems are 0.46, 0.46 and 0.33 mg/l respectively. . The results of case 2 of operation show that, the treatment efficiency of the MBR system higher than the IFAS and AS systems. Also, the efficiency of both AS and IFAS systems is approximately the same.

Table 4 Summary of results for case 2 of operation for the AS, IFAS and MBR systems

Treatment System	MLSS [g/m3]	Aeration power [kw]	Effluent SS [g/m3]	Effluent BOD [g/m3]	Effluent Ammonia Nitrogen [g/m3]	Waste sludge flow rate [m3/d]
AS system	2370	80.7	9.32	5.18	0.455	205
IFAS system	2350	105	9.31	5.42	0.456	180
MBR system	9710	98.9	0.0972	1.7	0.325	110

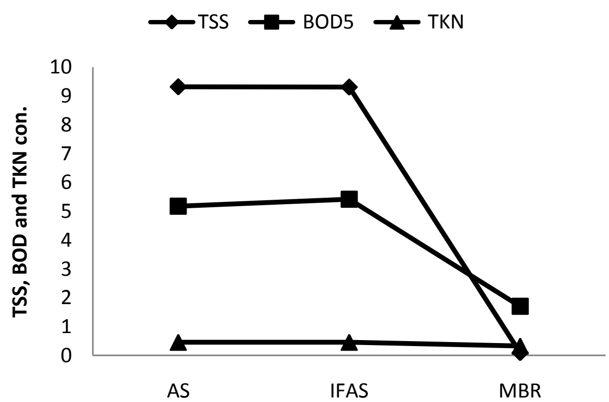

Figure 3 Effluent concentrations for the AS, IFAS and MBR systems for case 2.

3.3 Case 3 of operation.

Table 5 shows the summary of results for case 3 of operation for the AS, IFAS and MBR systems. The case 3 is the high influent concentration operation phase for the three systems. Figure 4 shows the effluent concentration for the AS, IFAS and MBR systems for case 3 of operation. The effluent biochemical oxygen demand BOD for the AS, IFAS and MBR systems are 12.2, 9.35 and 8.51 mg/l respectively. The effluent Suspended solids SS for the AS, IFAS and MBR systems are 31.7, 10.74 and 0.31 mg/l respectively. . The effluent ammonia nitrogen NH_3 for the AS, IFAS and MBR systems are 0.48, 1.39 and 1.05 mg/l respectively. The results of case 3 of operation show that, the treatment efficiency of the MBR and IFAS systems higher than the AS systems. Also, the efficiency of both MBR and IFAS systems is approximately the same. It can be concluded form these results, the MBR and IFAS systems have a good ability to treat the high influent wastewater concentrations.

Table 5 Summary of results for case 3 of operation for the AS, IFAS and MBR systems

Treatment System	MLSS [g/m3]	Aeration power [kw]	Effluent SS [g/m3]	Effluent BOD [g/m3]	Effluent Ammonia Nitrogen [g/m3]	Waste sludge flow rate [m3/d]
AS system	5090	141	31.7	12.2	0.48	205
IFAS system	4056	105	10.74	9.35	1.39	180
MBR system	30500	98.9	0.31	8.51	1.05	110

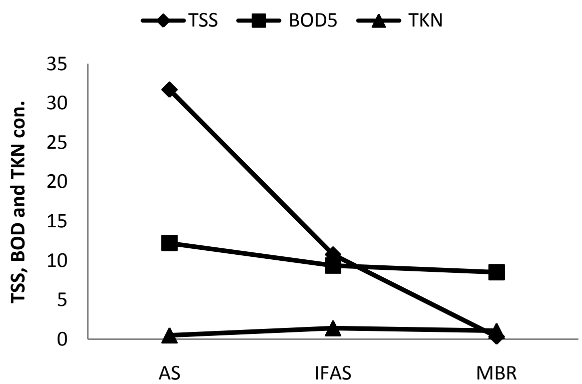

Figure 4 Effluent concentrations for the AS, IFAS and MBR systems for case 3.

3.4 Performance of the Activated Sludge (AS) system.

Table 6 shows the performance of the Activated Sludge AS wastewater treatment plant model. Figure 5 shows the efficiency of total suspended solids TSS, BOD and TKN removal for the Activated Sludge system for all cases of operation. The suspended solid removal for the activated sludge process are 95.06%, 96.27% and 91.55 % for case 1, case 2 and case 3 of operation respectively. The BOD removal for the activated sludge process are 97.64%, 98.27% and 97.29 % for case 1, case 2 and case 3 of operation respectively. The TKN removal for the activated sludge process are 98.13%, 98.70% and 99.10 % for case 1, case 2 and case 3 of operation respectively. It can be concluded from these results, the suspended solids removal decreased due to the organic shock loads.

Table 6 Performance of the AS wastewater treatment plant model.

Parameter	Case 1 Low con.			Case 2 Medium con.			Case 3 High con.		
	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %
TSS	180	8.9	95.06%	250	9.32	96.27%	375	31.7	91.55%
BOD5	225	5.3	97.64%	300	5.18	98.27%	450	12.2	97.29%
TKN	25	0.468	98.13%	35	0.455	98.70%	50	0.48	99.10%

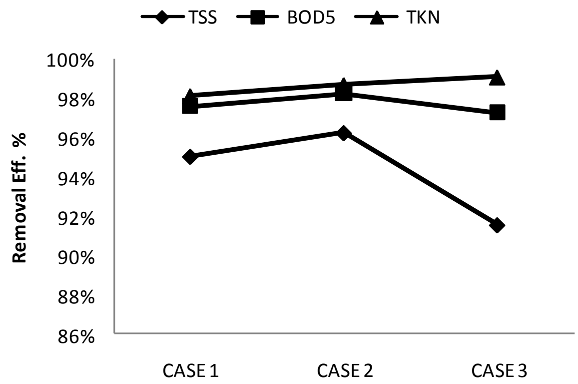

Figure 5 Efficiency of TSS, BOD and TKN removal for Activated Sludge system.

3.5 Performance of the Integrated Fixed-film Activated Sludge (IFAS) system.

Table 7 shows the performance of the Integrated Fixed Activated Sludge IFAS wastewater treatment plant model. Figure 6 shows the efficiency of total suspended solids TSS, BOD and TKN removal for the IFAS system for all cases of operation. The suspended solid removal for the IFAS process are 95.09%, 96.28% and 97.14 % for case 1, case 2 and case 3 of operation respectively. The BOD removal for the activated sludge process are 97.70%, 98.19% and 97.92 % for case 1, case 2 and case 3 of operation respectively. The TKN removal for the activated sludge process are 98.42%, 98.70% and 97.22 % for case 1, case 2 and case 3 of operation respectively. It can be concluded from these results, the TKN removal decreased due to the organic shock loads.

Table 7 Performance of the IFAS wastewater treatment plant model.

	Case 1 Low con.			Case 2 Medium con.			Case 3 High con.		
Parameter	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %
TSS	180	8.83	95.09%	250	9.31	96.28%	375	10.74	97.14%
BOD5	225	5.17	97.70%	300	5.42	98.19%	450	9.35	97.92%
TKN	25	0.394	98.42%	35	0.456	98.70%	50	1.39	97.22%

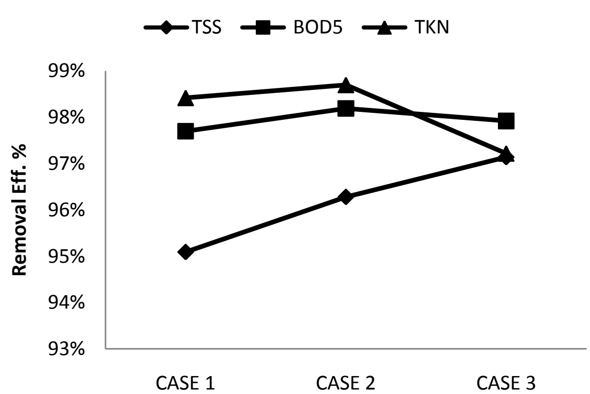

Figure 6 Efficiency of TSS, BOD and TKN removal for IFAS system.

3.6 Performance of the Membrane Bioreactor (MBR) system.

Table 8 shows the performance of the Membrane Bioreactor MBR wastewater treatment plant model. Figure 7 shows the efficiency of total suspended solids TSS, BOD and TKN removal for the MBR system for all cases of operation. The suspended solid removal for the MBR process are 99.96%, 99.96% and 99.92 % for case 1, case 2 and case 3 of operation respectively. The BOD removal for the MBR process are 99.22%, 99.43% and 98.11 % for case 1, case 2 and case 3 of operation respectively. The TKN removal for the MBR process are 98.74%, 99.07% and 97.90 % for case 1, case 2 and case 3 of operation respectively. It can be concluded from these results, the BOD and TKN removal decreased due to the organic shock loads.

Table 8 Performance of the MBR wastewater treatment plant model.

Parameter	Case 1 Low con.			Case 2 Medium con.			Case 3 High con.		
	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %	Influent [g/m3]	Effluent [g/m3]	Removal Eff. %
TSS	180	0.072	99.96%	250	0.0972	99.96%	375	0.31	99.92%
BOD5	225	1.74	99.22%	300	1.7	99.43%	450	8.51	98.11%
TKN	25	0.316	98.74%	35	0.325	99.07%	50	1.05	97.90%

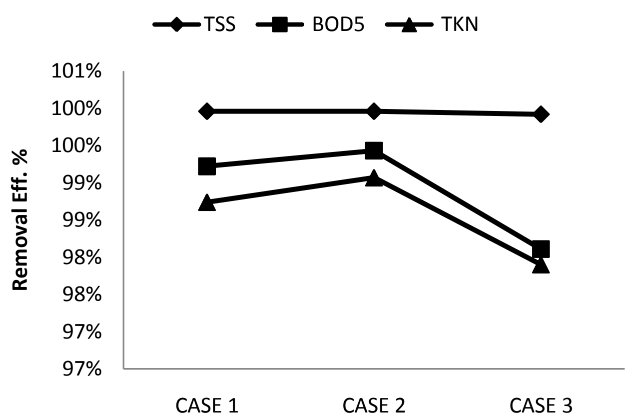

Figure 7 Efficiency of TSS, BOD and TKN removal for MBR system.

4. CONCLUSIONS

Based on the results obtained from this study, the following points are concluded:

- The treatment efficiency of the AS system based on BOD removal is ranged between 96.3 to 97.3 %, and based on TSS removal is ranged between 91.6 to 96.3 % for all cases of operation.

- The treatment efficiency of the IFAS system based on BOD removal is ranged between 97.7 to 98.2 %, and based on TSS removal is ranged between 95.1 to 97.1 % for all cases of operation.
- The treatment efficiency of the MBR system based on BOD removal is ranged between 98.1 to 99.4 %, and based on TKN removal is ranged between 97.9 to 99.1 % for all cases of operation.
- The MBR system has a good ability to receive the organic shock load of operation without a big loss of the treatment efficiency.
- The IFAS system has a high treatment efficiency and good ability to receive the organic chock loads.
- The AS system has a sensitive ability due to the organic shock load of operation

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