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# Effect of Nitrate Recycle Ratio on the Performance of Combined Cylindrical Anoxic/Aerobic Moving Bed Biofilm Reactor for Domestic Wastewater Treatment

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**ABSTRACT**
continuous up-flow moving bed biofilm reactor (MBBR) were used to treat 4m$^3$/d of domestic wastewater in Chongqing city at Southwest China .Both the anoxic and aerobic reactors were filled to 50 %( v/v) with Kaldnes (K1) biofilm carriers. After developing the biofilm on the carriers,the effect of nitrate recycle ratio on biological nutrients removal from domestic wastewater was investigated by operation of reactors under 3 different nitrate recycle ratios ranging from 50% to 150% (50%, 100%, and 150%) through changing the value of this parameter every one week. During this operation mode, the MBBRs was operated under the optimal value of gas/water ratio which equal to 7/1 and hydraulic retention time (HRT) equal to 6.2 hours. The experiment results showed that optimum value of the nitrate recycle ratio for simultaneous organic carbon and nutrients removal was equal to 100%. In this nitrate recycle ratio, the average removal efficiencies were 92.16 %, 98.84 %,71.23 % and 91 % for COD, $NH_4^+$-N,TN and TP respectively, while the average dissolved oxygen concentration (DO) in aerobic and anoxic MBBRs were 4.35 mg./L and 0.19 mg./L respectively .



# تاثير نسبة اعادة تدوير النترات على اداء مفاعل القواعد المتحركة الأسطوانيات لمتداخل لمعالجة مياه الصرف الصحي

**الكلمات المفتاحية**
نتروجين،نتريت،تفاعل

**الخلاصة**
تم استخدام مفاعل تجريبي ذو قواعد متحركة (**MBBR** ) بشكل اسطواني متداخل و تصريف علوي مستمر لمعالجة 4 م$^3$ / اليوم من مياه الصرف الصحي المنزلي لمدينة تشونغ تشنغ جنوب غرب الصين. المفاعل الرئيسي يتكون من تداخل مفاعل قواعد متحركة اسطواني ناقص التهوية (**Anoxic MBBR** ) مع مفاعل تهويه اسطواني ذو قواعد متحركة (**Aerobic MBBR** ) وبنسبة حجمية مساوية الى 16% . عملية المعالجة تخضع لمعايير الصنف (ب ) للمواصفة الصينية الخاصة بمعالجة مياه الصرف الصحي البلدية (**GB/T18918-2002**) . تم املاء كلا المفاعلين بنسبة حجمية مقدارها 50% من القواعد نوع (**K1**) الخاصة بالتصاق الحمئة النشطة وتكوين الاغشية الحيوية . تم تشغيل المفاعل الكلي بنظام النترجة التامه – نزع الناتروجين وبدون اعادة تدوير للحمئة النشطة مع عمليه اعادة تدوير داخلي مستمر من مفاعل التهوية (**Aerobic MBBR**) الى مفاعل نقص التهوية (**Anoxic MBBR** ) . بعد تكون الاغشية البايلوجية (**Biofilm**) على القواعد المتحركة تم دراسة تاثير نسبة النترات المعاد تدويرها على ازالة المغذيات (**Nutrients**) من مياه الصرف المنزلية عن طريق تشغيل المفاعل الكلي تحت ثلاثة قيم مختلفة لنسبة النترات المعاد تدويرها (50٪، 100٪، و 150٪) من خلال تغيير قيمة هذه النسبة بشكل اسبوعي . خلال وضعية التشغيل هذه تم تشغيل المفاعل الكلي تحت القيمة المثلى لنسبة الغاز/الماء والتي كانت تساوي 1/7 والقيمة المثلى لزمن البقاء الهيدروليكي والتي كانت تساوي 6.2 ساعة . نتائج الدراسة التجريبية أظهرت بأن القيمه المثلى لنسبة النترات المعاد تدويرها لغرض الازالة المشتركة اللكاربون العضوي والمغذيات كانت تساوي 100% . تحت هذه القيمة المثلى لنسبة النترات المعاد تدويرها كانت قيم الازالة الكلية للكاربون العضوي (**COD**)، الامونيا (**$NH_4^+$-N**) ، الناتروجين الكلي (**TN**) والفسفور الكلي (**TP**) مساوية ألى 92.16% ، 98.84%، 71.23% و 91% على التوالي بينما كانت قيم تراكيز الاوكسجين المذاب (**DO** ) في كل من مفاعل التهوية ومفاعل نقص االتهويه مساوية الى 4.35 ملغم/ لتر و 0.19 ملغم/ لتر على التوالي

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## 1-Introduction

Wastewater containing high levels of phosphorus and nitrogen cause several problems, such as eutrophication, oxygen consumption, and toxicity, when discharged into the environment. It is, therefore, necessary to remove such substances from wastewaters in order to reduce their harm to the environment.

Biofilm process was proved to be more reliablethan suspended systems for organic carbon and nitrogenremoval with no problems of suspended growthsystem. The most cost-effective nitrogen removalwill probably be achieved by using rather compact biofilm processes (Anthonisenetal.1976;Helmer et al.1999). Abiofilm process, which may be compact,is the one based on submerged biological filters.There are many reports concerning the possibility ofbiofilm process for treating wastewater, but the disadvantageof this system is the possibility of cloggingof the biofilm media (Chen et al.1995; Al-Ghusain et al.1994; Hallingand Jorgensen1993; Huang et al.1992; Rusten et al.1994, 1996 and 2000).

In the last years, the moving bed biofilm reactor (MBBR) was introduced as an alternative and successful method to treating different kinds of effluents under different conditions based on the biofilm principle that take advantage of both activated sludge process and conventional fixed film systems without theirs disadvantages(Andreottola et al.2002; Canziani et al.2006; Falletti and Conte 2007) .The first MBBR facility became operational in early 1990 in Norway and then this system developed in Europe and America. There are presently more than 400 large-scale wastewater treatment plants based on this process operation in 22 different countries all over the world(Maurer et al.2000).Reactor can be operated at very high load and the process is insensitive to load variations and other disturbances(Odegaard et al., 1994; Delenfort and Thulin, 1997). Unlike most biofilm reactors, the reactor volume in the MBBR is totally mixed and consequently there is no dead or unused space in the reactor. In addition, this system has a small head loss and there is no need for recycling of biomass or sludge(Xiao et al., 2007).

### Aim of The Study :

The aim of the present study was to evaluate the influence of nitrate recycle ratio on the performance of a continuous up- flow pilot scale combined cylindrical anoxic/aerobic MBBRs for biological nutrients removal from domestic wastewater by fully nitrification-denitrificationprocesses.

### Materials and Methods:
### Experimental set-up:

The experiments were conducted using two steel pilot scale MBBRs in nested form , including square primary settling tank (made of PVC 1m×1m×1m) ,an anoxic reactor (R1) (D=0.6 m and H=0.9m), an aerobic reactor (R2) (D=1.2m and H=2m) followed by a square final clarifier (made of PVC 1m×1m×1m). No sludge recycling was implemented. The anoxic MBBR (R1) was used to achieve the denitrification processes to provide the major portion of nitrate removal, while the aerobic MBBR (R2) was built to provide nitrification. A sketch of the pilot-scale moving bed biofilm reactors is shown in Figure (1) and some key parameters are listed in Table(1). Both anoxic and aerobic MBBRs were operated in an up-flow mode, Kaldnes (K1) media was used as a carrier in both reactors at a media fill ratio equal to 50%.

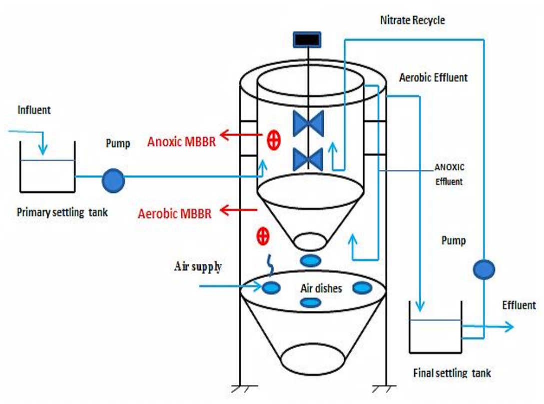


**Figure (1): Schematic diagram of pilot-scale MBBR system.**

**Table (1): Technical data and key parameters for the anoxic-aerobic MBBRs**

| Paramete | Anoxic MBBR(R1 | Aerobic MBBR(R2) |
|---|---|---|
| Effective Volume (m3) | 0.141 | 0.89 |
| Filling ratio with bio-carriers (%) | 50 | 50 |
| Specific biofilm surface area (m2/m3) | 250 | 250 |
| Total biofilm surface area (m2) | 35.25 | 222.5 |
| Flow rate (m3/day) | 4 | 4 |
| Flow direction | Up-flow | Up-flow |

The Kaldnes (K1) carrier elements are made of polyethylene (density 0.93 g/cm3) and shaped like small cylinders (about 25 mm in diameter and 10 mm long) with a cross inside to provide sites for active bacteria attachment in a suspended growth medium as shown in Figure (2).The effective specific growth area is 500 m2/m3 at 100% filling grade, Table (2) shows the characteristics of the Kaldnes (k1) media which was used in this study.

**Figure (2):Kaldnes (K1) carriers**.

The biofilm carrier elements are kept suspended in the water by air from the diffusers in the aerobic reactor and by means of propeller mixer in the anoxic reactor. The propeller mixer consist of central, 2-blade double stirrer of 25 cm diameter and with blades placed at 20 and 40 cm below top-water level, the stirrer speed was 100 rpm .The carrier elements are retained by means of small sized sieve(about 2mm opening). Aeration system consist of 4 fine bubble membrane diffuser ( 4 aeration dishes 220 mm in diameter ) distributed equally on the perimeter of the reactor which are fixed at the height 0.3 m from the bottom of the reactor. Aeration was achieved by using air compressor model ACO-818 (the largest aeration capacity of 300 L/min) connected with the main air distribution pipe (UPVC pipe 25mm in diameter) which connected each aeration dish with the other. The airflow to the reactor was measured by gas Rotameter(model LZB-10WB 5~45L/min) and regulated with a manual valve. Sampling ports were provided in each reactor by using DN10 UPVC pipes for sample collection in the top, middle, and bottom. The reactors were built in the DADUKOU wastewater treatment plant which is located in DADUKOU district in Chongqing city at Southwest China. The domestic wastewater reaching the primary settling tank from the preliminary treatment part in DADUKOU wastewater treatment plant (for the removal of rags, sticks, floatable, grit, and grease that may cause operational problems in the treatment process). Theprimary settling tank is to remove some of the suspended matter and organic material by settling ,(this method protects the pumps and pipes from clogging also improve subsequent biological treatment and keep stable water quality). The anoxic MBBR was continuously receiving the domestic wastewater from the primary settling tank in the start-up mode and from both the primary settling tank and the final clarifier inthe steady state mode by using magnetic circulation pumps model MP-30RZM with maximum capacity and maximum head equal to 15-17 (L/min) and 8-11(m) respectively. Both influent and effluent system pipes are made of unplasticised polyvinyl chloride (UPVC) with diameter equal to 20mm (DN20). The effluent system of the anoxic MBBR consist of 5 (DN20) UPVC pipes which carry the water to the aerobic MBBR by gravity. The influent and recycle flow was measured by a glass flow meter model LZB-15 (25-250 L/h) for influent flow and glass flow meter model LZB-25 (40-400 L/h) for recycle flow that can be regulated by controlling the manual valves (DN20).

**Table (2): The characteristics of the Kaldnes (k1) media**.

| Parameter | Value |
|---|---|
| Dimension (mm) | 25×10 |
| Surface area (m2/m3) | 500 |
| Filling ratio (%) | 15-65 |
| Density (g/cm3) | 0.93 |
| Number/m³ | 150,000 |
| Voidage (%) | 95 |
| Oxidation efficiency of BOD5 (g BOD5/m³.d) | 6000 |
| Hanging coefficient (g/carrier) | 1.3 |

Operating procedure:

The study was carried out using raw domestic wastewater supplied from the preliminary treatment part in DADUKOU wastewater treatment plant. The quality of wastewater resulting from the various daily uses in DADUKOU district at Chongqing city in China are given in Table (3).

Seeding sludge was obtained from DADUKOU municipal wastewater treatment plant. Firstly the collected sludge was screened with a sieve to remove coarse and inorganic particles, then was aerated for 2 days at room temperature. After that the sludge was mixed with wastewater by the ratio of 2/3 then filled 1/3 of the effective volume for the reactors by the mixed liquid. The reactors are ready for batch operation mode for 4 weeks. The batch operation was used as start-up for biofilm growth on the carrier elements. During the batch operation mode the mixed liquor (ML) was continuously aerated in the aerobic MBBR and mixed in the anoxic MBBR for 18 hours and then settled for 4 hours after that water discharge with drainage ratio of 100% for 2 hours. At the end of 4th week the pilot plant was operated under continuous operation mode at hydraulic retention time (HRT) of 6.2 hours, with nitrate recycle ratio equal to 100% and gas/water ratio equal to 7/1, getting prepared for main start-up .

At the end of 5th week the pilot plant was operated under continuous operation mode at 3 different nitrate recycleratios(50%, 100%, and 150%) with hydraulic retention time (HRT) equal to 6.2 hours and gas/water ratio equal to 7/1 During this operation mode the temperature average values in both anoxic and aerobic MBBRs were 30.40C and 30.70C respectively, the average value of the total mixed liquor suspended solids concentration ( MLSS Total ) in both anoxic and aerobic reactors equal to 2968 mg/L and 3219 mg/L respectively, while pH average values were 7.34 and 7.25 respectively. The average dissolved oxygen concentration (DO) in aerobic MBBR was 4.35 mg/L ,while in anoxic MBBR was 0.12 mg/L at 50 % nitrate recycle ratio , 0.19 mg/L at 100 % nitrate recycle ratio , and 0.28 mg/L at 150 % nitrate recycle ratio.

**Table (3): Characteristics of the domestic wastewater from DADUKOU district at Chongqing city in China.**

| Parameter | COD (mg/L) | NH4+-N (mg/L) | TN (mg/L) | TP (mg/L) | pH |
|---|---|---|---|---|---|
| Value | 76.5-430 | 24.31-70.8 | 28-74.5 | 1.88-8.27 | 6.8-7.58 |

**Sampling and analysis:**

Samples were collected from influent and effluent of MBBRs. The analytical techniques used in this study were performed according to the standard methods described in (Water and wastewater monitoring and analysis methods -fourth edition, 2002). Temperature, Dissolved oxygen (DO) and pH were measured in each reactor by using Multi parameter Meter (HACH sensionTM156). The dissolved oxygen(DO) was tested three times every day in both anoxic and aerobic MBBRs, in the anoxic MBBR the DO was tested in the top, middle, and the bottom of the reactor then the average value was used, while in the aerobic MBBR the DO was tested in four points at middle of reactor according to the locations of the aeration dishes then the average value was used. Both the pH and the temperature was tested three times every day in the two reactors and the tests was done in the middle of the reactors. The samples of COD, ammonium nitrogen (NH4+-N), total nitrogen (TN) and total phosphorous (TP) were measured on alternate days by using HACH DR5000UV Spectrophotometer. The assessment of the total suspended solids concentration (TSS) on the fixed biomass elements was performed as follows: the attached biomass was removed from 10 bio-carriers by putting them in a flask with demineralized water that was placed in an ultrasound bath for 45 minutes. After that the bio-carriers were rinsed with demineralized water and then the mixed liquid was filtered through 0.45 μm fiber filter and dried at 105ºC and weighed. Because of the variability of carriers dimension, the obtained value was referred to the total measured surface of the 10 bio-carriers. TSS was assessed through the total surface in one cubic meter of reactor (Andreottola et al., 2000 a&b;Jahren et al., 2002; Helness, 2007).

**Results and Discussion:**

In this research an experimental study to evaluate the application of fully nitrification/denitrification processes in a continuous up-flow combined anoxic/aerobic system for the removal of organic carbon and nutrients from domestic wastewater in Chongqing city at Southwest China .The treatment must be satisfactory to meet with grade B of discharge standard of pollutants for municipal wastewater treatment plant in China (GB/T18918-2002) shown in Table(4). Operation and performance data are presented in Table (5) and shown in Figure (3) to Figure (10).

**Table (4): Discharge standard of pollutants for municipal wastewater treatment plant (GB/T18918-2002).**

| Parameter | COD (mg/L) | BOD5 (mg/L) | NH4+-N (mg/L) | TN (mg/L) | PO43-P (mg/L) |
|---|---|---|---|---|---|
| Grade A | 50 | 10 | 5 | 15 | 0.5 |
| Grade B | 60 | 20 | 8 | 20 | 1 |

The anoxic MBBR was designed to achieve the denitrification process, while the aerobic MBBR was designed to achieve the nitrification process. The denitrification processis a very important process for nitrogen removal by utilizing nitrite and nitrate as electron acceptors.When the nitrification rate in the aerobic MBBR increases more nitrateenters the anoxic MBBR and as a result more denitrificationand subsequently more COD removal is achieved. In the anoxic MBBR some of the phosphate is removedby denitrifying phosphate-accumulating bacteria (DNPAO) which uses nitrate as an electronacceptor and consumes some of the biodegradable organic matter,there must also be sufficient ammonium available for phosphate denitrification. Here the anoxic MBBR consumes a part ofthe biodegradable organic matter (COD) in order to remove nitrate and phosphate. Thus, reducing the pollutants loading rate in the aerobic MBBR and increases theoverall efficiency of the treatment process.In the aerobic MBBR the dissolved oxygen was consumed by a competition between heterotrophic (COD removal) ,autotrophic(nitrification) and phosphate-accumulating organisms (PAO) ,while the biodegradable organic matter (COD) was consumed by a competition between heterotrophic and phosphate-accumulating organisms(Metcalf and Eddy, 2003).

**Table (5): Reactors performance in COD ,NH 4 +-N, TN and TP removal at different Nitrate recycle ratio in steady state operation mode.**

| Nitrate Recycle Ratio % | COD | | | NH4 + -N | | | TN | | | TP | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | INF. (mg/L) | EFF. (mg/L) | R. (%) | INF. (mg/L) | EFF. (mg/L) | R . (%) | INF. (mg/L) | EFF. (mg/L) | R. ( %) | INF. (mg/L) | EFF. (mg/L) | R. ( %) |
| 50 | 355.60 | 33.80 | 90.49 | 45.30 | 3.60 | 92.05 | 49.40 | 26.44 | 46.48 | 3.42 | 0.92 | 73.08 |
| 50 | 244.70 | 38.20 | 84.39 | 39.18 | 3.11 | 92.06 | 44.70 | 25.61 | 42.71 | 3.66 | 0.95 | 74.06 |
| 50 | 190.32 | 46.70 | 75.46 | 62.20 | 3.70 | 94.05 | 68.33 | 31.38 | 54.08 | 4.93 | 0.96 | 80.53 |
| 50 | 268.90 | 39.80 | 85.20 | 25.61 | 2.65 | 89.65 | 33.18 | 19.75 | 40.48 | 2.61 | 0.87 | 66.70 |
| 100 | 369.40 | 15.70 | 95.75 | 31.38 | 0.40 | 98.72 | 35.38 | 12.41 | 64.92 | 2.86 | 0.22 | 92.30 |
| 100 | 347.50 | 16.80 | 95.17 | 50.80 | 0.67 | 98.68 | 56.67 | 15.38 | 72.86 | 4.44 | 0.31 | 93.02 |
| 100 | 150.00 | 20.40 | 86.40 | 43.28 | 0.54 | 98.76 | 45.11 | 13.83 | 69.34 | 2.83 | 0.36 | 87.29 |
| 100 | 202.50 | 17.60 | 91.31 | 43.31 | 0.34 | 99.21 | 48.92 | 14.49 | 70.38 | 3.37 | 0.29 | 91.39 |
| 150 | 317.00 | 44.80 | 85.87 | 27.60 | 5.10 | 81.52 | 34.11 | 21.68 | 36.44 | 4.66 | 0.46 | 90.13 |
| 150 | 142.80 | 25.00 | 82.49 | 58.40 | 7.90 | 86.47 | 62.27 | 27.61 | 55.66 | 2.94 | 0.86 | 70.75 |
| 150 | 237.40 | 38.30 | 83.87 | 46.10 | 6.31 | 86.31 | 48.16 | 23.33 | 51.56 | 3.79 | 0.57 | 84.96 |
| 150 | 407.10 | 48.71 | 88.03 | 39.80 | 6.67 | 83.24 | 40.52 | 20.83 | 48.59 | 3.47 | 0.72 | 79.25 |

INF. = Total Influent EFF. = Total Effluent R. = Total Removal Efficiency

**①COD Removal at Different Nitrate Recycle Ratio**

Total COD concentrations of influent, effluent, and total removal efficiency versus nitrate recycle ratio are shown in Figure (3)and Table (5), while the average performance of the MBBRs in COD removal are shown in Figure (4).The daily concentration of COD in the feed were ranging from 150 mg/L to 407.1 mg/L (Average =269.43 and SD=89.14), while the total effluent COD concentrations steadily decreased to the range 14.9 mg/L to 46.7 mg/L(Average =24.7 and SD=11.47). As nitrate recycle ratio was increased from 50 % to 150 %, the average total effluent COD concentrations decreased from 39.63 mg/L (SD= 5.36) to 16.84 mg/L (SD= 1.89), while the average total removal efficiency increased from 83.89 % (SD= 6.23) to 93.15% (SD= 2.6). The results illustrated that the nitrate recycle ratio in range 50 % to 150 % did not significantly affect COD removal efficiencies and the total effluent COD concentration could meet with grade A of discharge standard of pollutants for municipal wastewater treatment plant in China (GB/T18918-2002) (50 mg/L).

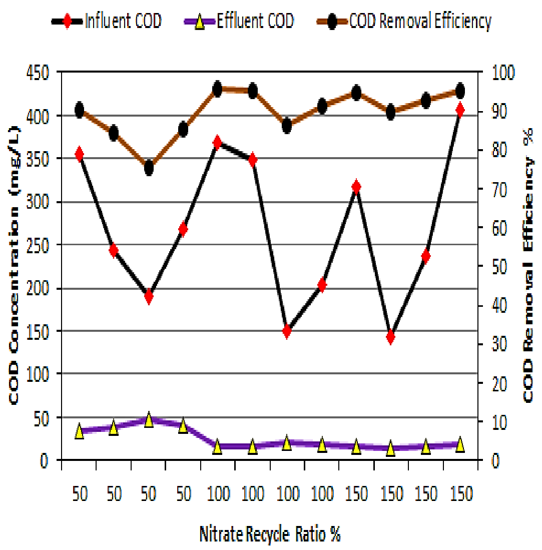


**Figure (3): Profile of COD concentration and removal efficiency variations versus Nitrate recycle ratio.**

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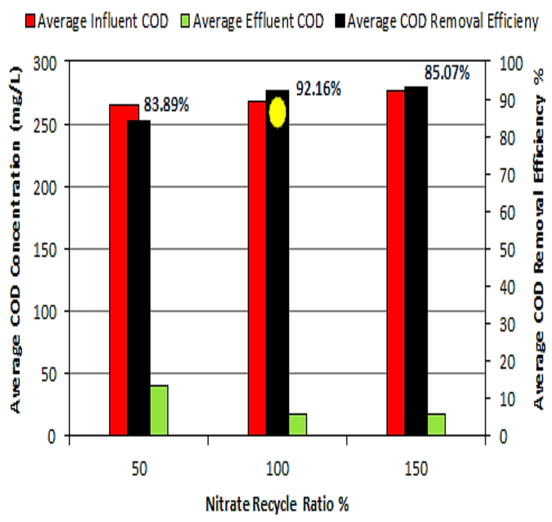



**Figure (4): Profile of average COD concentration and average removal efficiency variations versus Nitrate recycle ratio.**

**②Ammonium ($NH_4^+$-N) Removal at Different Nitrate Recycle Ratio**

Total ammonium concentrations of influent, effluent, and total removal efficiency versus nitrate recycle ratio are shown in Figure (5) and Table (5) , while the average performance of the MBBRs in ammonium removal are shown in Figure (6) . It seems that the daily fluctuations of $NH_4^+$-N concentration in the feed were ranging from 25.61 mg/L to 62.2 mg/L (Average = 42.75 and SD= 11.2), while the total effluent $NH_4^+$-N concentrations decreased to the range 0.34 mg/L to 7.9 mg/L ( Average = 3.41 and SD = 2.65) . As nitrate recycle ratio was increased from 50 % to 100 % , the average total effluent $NH_4^+$-N concentrations decreased from 3.27 mg/L (SD= 0.48) to 0.49 mg/L (SD= 0.15), while the average total removal efficiency increased from 91.95 % (SD= 1.8) to 98.84 % (SD= 0.25) .When the nitrate recycle ratio was increased from 100 % to 150 % the average total removal efficiency decreased to 84.39 % (SD= 2.42) , while the average total effluent ammonium concentration increased to 6.5 mg/L (SD = 1.15) , this value could comply with grade B of discharge standard of pollutants for municipal wastewater treatment plant in China (GB/T18918-2002) (8 mg/L). Finally the nitrate recycle ratio in range 50 % to 150 % did not significantly affect $NH_4^+$-N removal efficiencies.

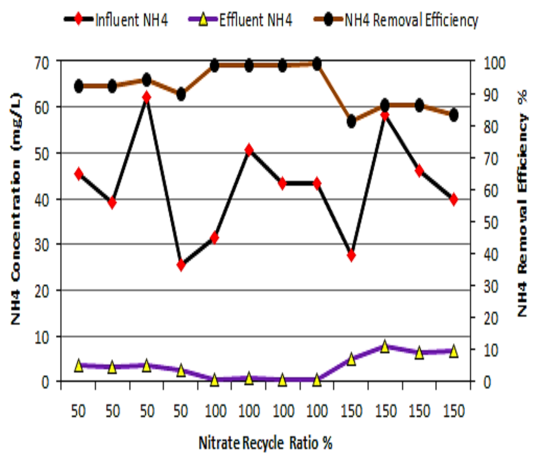



**Figure (5): Profile of $NH_4^+$-N concentration and removal efficiency variations versus Nitrate recycle ratio.**

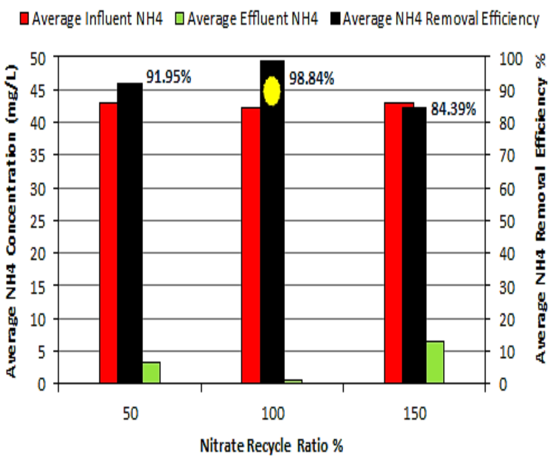



**Figure (6): Profile of average $NH_4^+$-N concentration and average removal efficiency variations versus Nitrate recycle ratio.**

**③Total Nitrogen (TN) Removal at Different Nitrate Recycle Ratio**

The profile of TN concentration and removal efficiency variations versus nitrate recycle ratio are shown in Figure (7) and Table (5) , while the average performance of the MBBRs in TN removal are shown in Figure (8) .As illustrated in Figures (7&8), the nitrate recycle ratio in range 50 % to 150 % significantly affect TN removal efficiencies. As nitrate recycle ratio was increased from 50 % to 100 %, the average total effluent TN concentrations decreased from 25.8 mg/L (SD= 4.77) to 13.25 mg/L (SD= 1.72), while the average total removal efficiency increased from 45.93 % (SD= 5.97) to 71.23 % (SD= 2.09). As nitrate recycle ratio was increased from 100 % to 150 %, the average total effluent TN concentrations increased to 23.11 mg/L (SD=4.92), while the average total removal efficiency decreased to 49.6 % (SD= 2.33) because this reduced the hydraulic retention time in the anoxic MBBR and increased the DO concentration in this reactor,this inhibitsdenitrification. Only the average total effluent TN at nitrate recycle ratio of 100 % could meet with grade B of discharge standard of pollutants for municipal wastewater treatment plant in China (GB/T18918-2002) (20 mg/L).

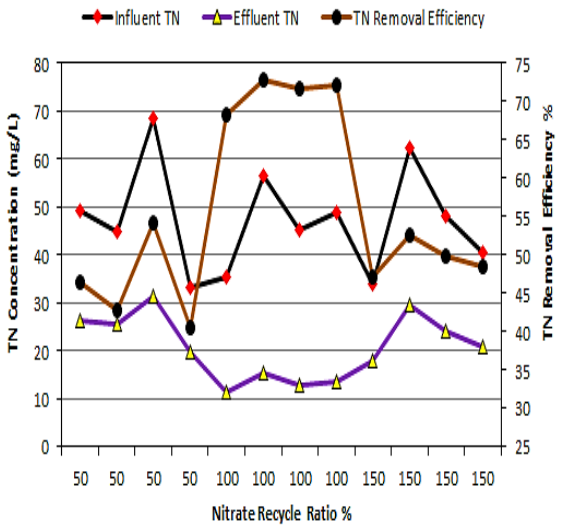



**Figure (7): Profile of TN concentration and removal efficiency variations versus Nitrate recycle ratio.**

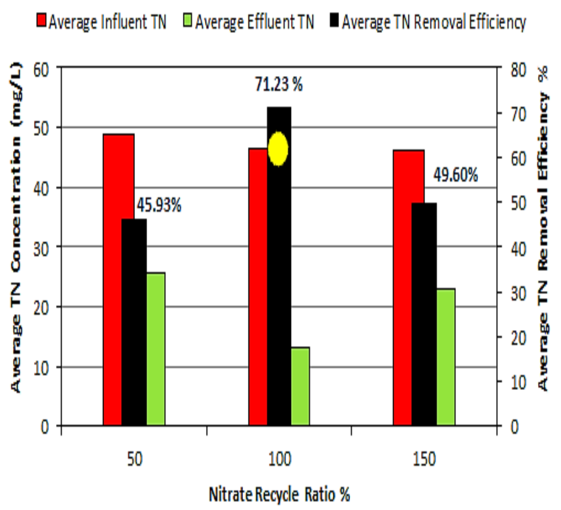



**Figure (8): Profile of average TN concentration and average removal efficiency variations versus Nitrate recycle ratio.**

**④Total Phosphorus (TP) Removal at Different Nitrate Recycle Ratio**

Total TP concentrations of influent, effluent, and total removal efficiency versus nitrate recycle ratio are shown in Figure (9) and Table (5) , while the average performance of the MBBRs in TP removal are shown in Figure (10).The daily concentration of TP in the feed were ranging from 2.61 mg/L to 4.93 mg/L (Average =3.58 and SD= 0.76), while the total effluent TP concentrations decreased to the range 0.22 mg/L to 0.96 mg/L(Average =0.62 and SD=0.29). As nitrate recycle ratio was increased from 50 % to 100 %, the average total effluent TP concentrations decreased from 0.93 mg/L (SD= 0.04) to 0.3 mg/L (SD= 0.06), while the average total removal efficiency increased from 73.59 % (SD= 5.66) to 91 % (SD= 2.56). As nitrate recycle ratio was increased from 100 % to 150 %, the average total effluent TP concentrations increased to 0.65 mg/L (SD= 0.17), while the average total removal efficiency decreased to 81.27 % (SD= 8.3). The results illustrated that the nitrate recycle ratio in range 50 % to 150 % did not significantly affect TP removal efficiencies and the total effluent TP concentration at nitrate recycle ratio of 100 % could meet with grade A of discharge standard of pollutants for municipal wastewater treatment plant in China (GB/T18918-2002) (0.5 mg/L), while at nitrate recycle ratio of 50 % and 150 % the average total effluent TP could meet with grade B of this standard (1 mg/L).

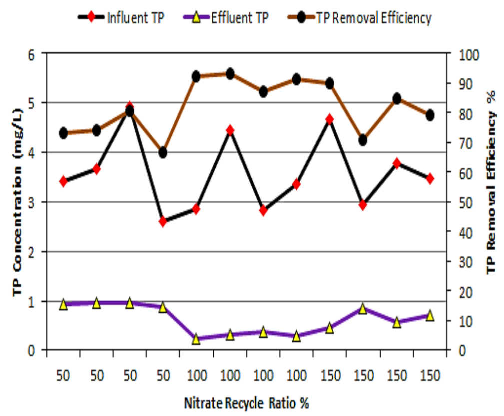



**Figure (9): Profile of TP concentration and removal efficiency variations versus Nitrate recycle ratio.**

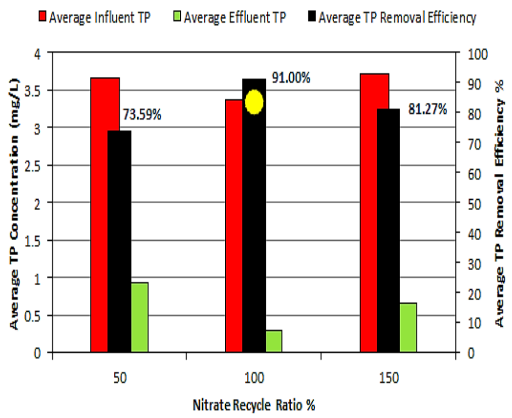
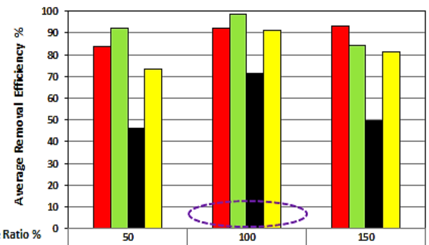



**Figure (10): Profile of average TP concentration and average removal efficiency variations versus Nitrate recycle ratio.**

CONCLUSION:

The results showed that the nitrate recycle ratio in range 50 % to 150 % did not significantly affect COD, $NH_4^+$-N, and TP removal efficiencies,while the average total effluent of TN concentrations could not meet with grade B of discharge standard of pollutants for municipal wastewater treatment plant in China (GB/T18918-2002) at nitrate recycle ratio of 50 %, and 150 %,while could meet with grade A of this standard at nitrate recycle ratio of 100 %.Finally we can conclude that the nitrate recycle ratio of 100 % is optimal for simultaneous organics and nutrients removal. Average total removal efficiency of COD, $NH_4^+$-N, TN, and TP versus nitrate recycle ratio are shown in Figure (11).




| Nitrate Recycle Ratio % | 50 | 100 | 150 |
|---|---|---|---|
| Average COD Removal Efficiency | 83.89 | 92.16 | 93.15 |
| Average NH4 Removal Efficiency | 91.95 | 98.84 | 84.39 |
| Average TN Removal Efficiency | 45.93 | 71.23 | 49.60 |
| Average TP Removal Efficiency | 73.59 | 91.00 | 81.27 |

**Figure (11): Average Total Removal Efficiency of COD,$NH_4^+$-N,TN and TP versus Nitrate recycle ratio.**

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