Eng. &Tech.Journal, Vol.33,Part (A), No.5, 2015

Advance Wastewater Treatment; Biological Removal of Eutrophic Nutrients

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Received on:7/1/2015 & Accepted on:7/5/2015

ABSTRACT

In this study, a lab scale different activated sludge configurations methods were used to treat a municipal wastewater from effluent of ;primary sedimentation tank of Al-Rustamiya wastewater treatment plant located near Baghdad city to remove organic load, nitrogen and phosphorus from the period of 15 July 2012 to 22 May 2013. Biological treatment systems were conventional activated sludge (CAS) , extended aeration , anaerobic-anoxic-aerobic(A2O) , anoxic-aerobic (MLE) and anaerobic –oxic(A/O). During the operation periods, the average removal efficiency of BOD_5, COD and TSS is 81.9, 77.7 and 85.8 respectively regardless of the fluctuation in influent quality. In addition the results show removal efficiency of ammonia, nitrate, nitrite and phosphorus with ranges (61-85.8), (34-81.7) , (35-81.4) (32.3-85.54) % respectively. The biological treatment systems produced high quality effluent which can achieve the Iraqi limitations of rivers maintenance for all measured parameters.

Keywords: Biological treatment, biological removal, conventional activated sludge (CAS) ,extended aeration , anaerobic-anoxic-aerobic (A2O), anoxic-aerobic (MLE) , anaerobic -oxic (A/O) .

المعالجة المتقدمة لمياه الصرف الصحي , الازالة البايولوجية لمغذيات الاثراء الغذائي

الخلاصة

في هذه الدراسة، على نطاق المختبر تم استخدام تشكيلات أنظمة معالجة حمأة منشطة مختلفة لمعالجة مياه الصرف الصحي البلدية والخارجة من حوض الترسيب الاولي لمحطة معالجة الرستمية الواقعة بالقرب من مدينة بغداد لازالة الاحمال العضوية,النتروجين والفسفور في الفترة من 5 يوليو 2012 الى 22 مايو 2013. انظمة

المعالجة البايولوجية هي الحماة المنشطة التقليدية , التهوية المطولة ,(اللاهوائي –هوائي محدد – هوائي) ,(هوائي محدد – هوائي) و (اللاهوائي - هوائي) .أثناء فترات العمل، فإن متوسط كفاءة الإزالة لكل من الاوكسجين المطلوب حيويا ، الاوكسجين المطلوب كيميائيا والمواد االعالقة الكلية هو 81.9، 77.7و 85.8 %على التوالي بغض النظر عن التذبذب في نوعية المياه الواردة .بالإضافة الى ان النتائج تظهر إزالة للأمونيا, النترات ,النتريت والفوسفور ضمن مدى(61- 85.8) ,(34-81.7) ,(35-81.4) و (32.3-85.54) %على التوالي.أن أنظمة المعالجة البيولوجية انتجت نوعية تصريف خارج بنوعية ممتازة والتي يمكن أن تحقق حدود المواصفات العراقية لصيانة الانهارو لجميع المعايير التي تم قياسها.

INTRODUCTION

Wastewater consists of both organic and inorganic substance including pathogenic microorganisms. Two important inorganic constituents in water are nitrogen and phosphorus [1], that if left untreated, cause detriment to the environment [2].

The various effects of eutrophication due to excessive nitrogen and phosphorus concentrations in the aquatic environment have been well documented. Algae and phytoplankton growth can be accelerated by higher concentrations of nutrients, leading to harmful algal blooms, hypoxia, and loss of submerged aquatic vegetation. In addition to stimulating eutrophication, nitrogen in the form of ammonia can exert a direct demand on dissolved oxygen (DO) and can be toxic to aquatic life. From a public health perspective, eutrophication may also cause risks to human health, resulting from consumption of shellfish contaminated with algal toxins or direct exposure to waterborne toxins. Eutrophication, in particular, can create problems if the water is used as a source of drinking water. For these reasons, it is important to eliminate nitrogen and phosphorus contamination of surface and ground water [3], [4] .

Several technologies and processes can remove nutrients in on-site domestic .Biological wastewater treatment processes harness the ability of microorganisms to break down and assimilate organic compounds .First, to reduction of watershed nitrogen inputs helps meet drinking-water quality standards for nitrate and nitrogen; and second , the reduction of both nitrogen and phosphorus helps protect the water quality of receiving surface and ground waters from eutrophication and the consequent loss in ecological ,commercial ,recreational and aesthetic uses of these waters [5].

Wastewater treatment falls into three categorized processes known as primary, secondary or tertiary (also considered ‘advanced’ wastewater) treatment [6]; [7]. Advanced treatment technologies can be extensions of conventional secondary biological treatment to further stabilize oxygen-demanding substances in the wastewater, or to remove nitrogen and phosphorus [8].

Tertiary treatment can involve the reduction of nutrients (phosphorus or nitrogen compounds) to protect waters from eutrophication caused by excessive nutrient inputs from treatment plants [9]; [10].Nitrogen in the form of ammonia is removed by using the BNR process of nitrification and denitrification in the wastewater treatment plant [11]. The nitrification process oxidizes ammonia initially to nitrite (NO_2) and then subsequently with further oxidized to nitrate (NO_3). Nitrosomonas and Nitrobacter are examples of autotrophic bacterial species that can carry out such conversions [12]. In the denitrification process, nitrite or nitrate is used as electron receiver for the oxidation of organic carbon and is converted to nitrogen gas; this process takes place under anoxic conditions. [13]; [14].

A biological phosphorus removal process utilizes bacterial capabilities for their capability to take up phosphorus as they grow in the system. This process is considered the enhanced biological phosphorus removal (EBPR). The bacteria responsible for this, are categorized as phosphate-accumulating organisms (PAOs) [6]; [7].In anaerobic conditions of low DO concentrations, PAOs convert readily available organic matter like volatile fatty acids (VFAs) to carbon compounds for storage which is considered as polyhydroxyalkanoates (PHA) specifically polyhydroxybutyrate (PHB). The result of this, is an initial release of phosphorus from the cells [15] ; [11]; [16]]. In the aerobic zones of high DO concentrations, the previously stored carbon is used by PAOs for biomass growth and polyphosphate (poly-P) formation [11]; [17].

Material and Methods

Laboratory –scale experiments

The experimental setup consisted of elevated tank, storage tank, aerobic bioreactor, aeration system and settling tank. Figure (1) shows the schematic diagram of the laboratory -scale experimental work. A photograph of this system is shown in photograph (1). Elevated tank (60*60*60) cm about 190 cm above the ground; for storage wastewater came from primary sedimentation tank effluent of Rustamia WWTP with mixer (WP-100M with Q max. 3000L/hr and H max. 0.5) to avoid wastewater from settle .This tank supply the wastewater by gravity to another storage tank (flow-level stabilization) of 15 L and 95 cm height .The 15L tank is provided with a float in order to supply constant level-flow to the reactor under 15cm from the second tank. The flow passes to aeration tank. This tank contains 4 nozzles of 15 and 20 mm at the bottom.15 mm inlet to allow effluent water came from aeration tank to inter the settling tank and 15 mm outlet with weir to allow effluent water came from settling tank to exit smoothly, another nozzle of 15 mm at the bottom for sludge wasting.

Then the aerated wastewater (mixed liquor) flows to secondary settling tank consist of plastic cylindrical tank height 18 cm and 13 cm dia. with conical bottom to collect the settling sludge with 10 cm height. The 20 mm nozzle in the bottom of conical base fixed with small pump (AWP 107-10, 12V with Q 2400 ml/min) to return the activated sludge collected in the tank to bioreactor. The purpose of this tank was to separate solid from mixed liquor to provide a clear effluent water with allowable limits of suspended solids and colloidal particles.

Aerobic condition was maintained by coarse bubbling ambient air into the bioreactor at a rate to maintained DO concentration of approximately 4 ± 0.5 mg/L. The aeration system consists of electrical air pumps, air supply tube and porous diffusing tubes. The electrical air pumps (RS-510 with 200 L/hour) is used to supply air. The 10 mm air supply feasible tube were connected from the compressor to the diffusing tube. The diffusing tube (with 110 holes, Ø 1 mm) was positioned at the bottom of the reactor. Thus, the coarse bubbles to provide all necessary aeration for biological activity of microorganism because microorganism needs to suitable conditions for growth and increasing. From these conditions provide complete mixing and sufficient dissolved oxygen to degradable and oxidation the organic materials in wastewater.

Returning sludge system different return sludge ratios can be taken with constant temperatures. The return sludge system consist of small pumps (AWP 107-10, 12V with Q 2400 ml/min) fixed conical bottom in the settling tank and its controlled by electrical controllers system worked automatically through number of timers according to required return ratio for each run.

The bioreactor which has an overall working volume of 30 L is made of glass with dimensions of (50*30*25) cm, and weir above 20 cm from the base of tank to control effluent aerated wastewater to settling tank. The reactor contained 2 nozzles of Ø15 mm each, one at the top to feed wastewater and the other in the weir to at discharge effluent treated water to settling tank. The purpose of this reactor is to provide suitable conditions (free elemental oxygen is present) for nitrification and denitrification process and to enhanced phosphorus uptake by PAOs. For each experimental bioreactor divided to many part according to the conditions and requirements of the system to ensure the removal. Municipal wastewater obtained from the settling basin effluent of Rustumia 3rd extension wastewater treatment plant. The characteristics of the influent wastewater used for this study are presented in table (1).

Table (1): characteristics of the influent wastewater used for this study

Parameters	Unites	Range	Average
Biochemical oxygen demand (BOD)	mg/L	69-280	194.45
Chemical oxygen demand (COD)	mg/L	168-468	331.09
Orthophosphate PO_4-P	mg/L	10.7-38.5	28.417
Ammonia NH_3-N	mg/L	18-119.61	65.66
Nitrate NO_3-N	mg/L	1.26-191.52	3. 166
Nitrite NO_2-N	mg/L	8.4-32	20.33
Total suspended solid TSS	mg/L	98-485	257.9
pH		6.8-7.7	7.1

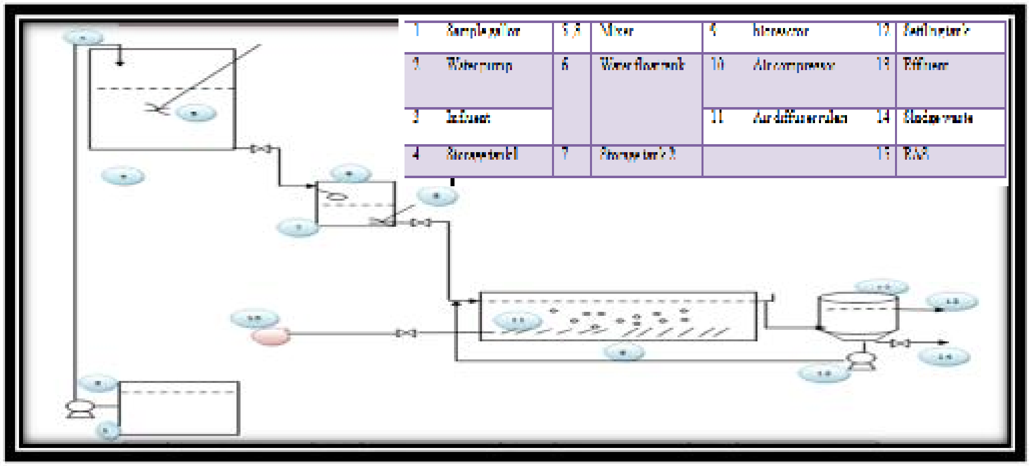
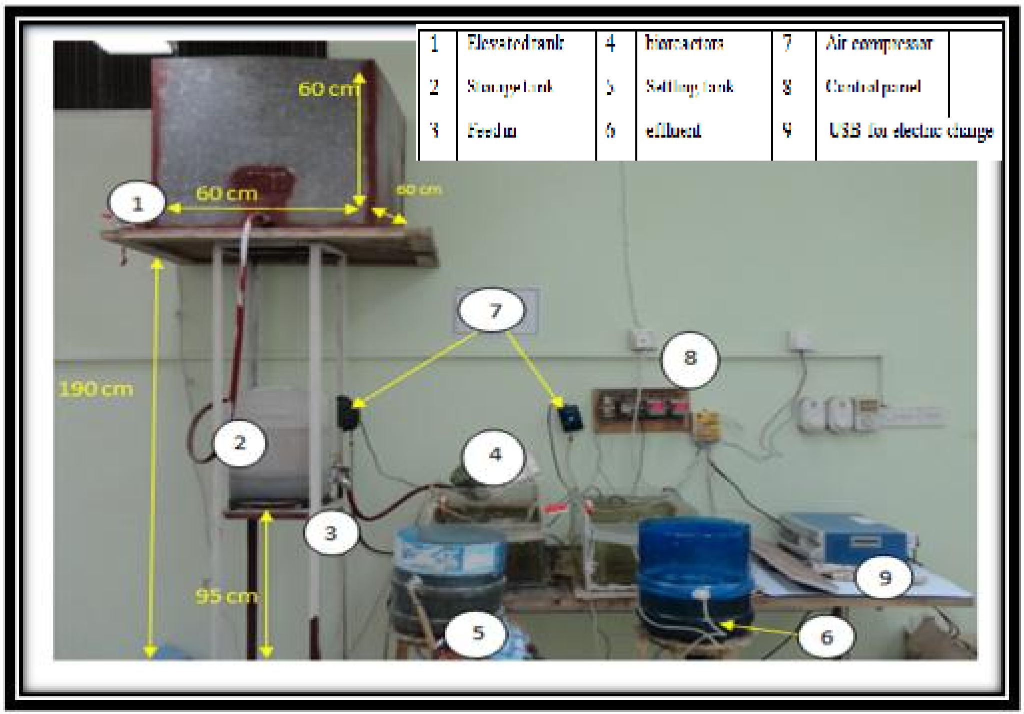


Figure (1) A schematic diagram of the biological system

Operational Parameters and Conditions

Operational parameters of lab-scale experiment include of hydrogen ion concentration (pH) and temperature, pH of the mixed liquor was continuously measured in order to be kept within the range of 6.8 - 8 by the addition of either a 1% HCL solution or a 20 g/L Na_2CO_3 solution when needed, while the temp. of the mixed liquor was continuously measured in order to be kept within the range of (20 – 40) °C . The operation condition are flow rate 30L/day with hydraulic retention time(HRT)equal 24 hours.



Photograph (1) biological system

Analytical Methods

Biochemical Oxygen Demand (BOD_5) is measured using the (WTW Oxidirect control system).Chemical Oxygen Demand (COD)is measured photometrically after sample digested in a (Thermoreactor ET 108) for two hours at 150 °C, cooled then measured using lovibond checkitdirect COD vario .

Dissolved oxygen (DO) concentration and pH is measured using DO Meter (Lovibond senso direct oxi 200) and Portable meter for field measurements of pH (Hanna Instruments HI9811-5). While ammonia, nitrate, nitrite and phosphorus using (multipara meter bench photometer HANNA C99) .Each analytical parameter was analyzed once or twice a week, the samples collected from the sampling port were analyzed on the same days, two hour after sampling.

Results and Discussion

Organic matter removal

Despite of the fluctuation in the influent BOD_5 and COD the average removal efficiencies of BOD_5 and COD for Conventional Activated Sludge (CAS) ,Extended Aeration with RAS =1 , Extended Aeration with RAS =1.5, (Anaerobic-Anoxic-Aerobic) A2O, (Anoxic-Aerobic) MLE and (Anaerobic -Oxic) A/O were 65.9 %, 71.5%, 78.81% ,91.28 %,90.8% and 93.5% respectively as shown in figures (2),and (3). The major part of influent organic matter was consumed during the anoxic periods ,as indicated by low effluent BOD_5 and COD concentration.

Nitrogen removal

The influents of ammonia during experimental was varied between 18 -119.61mg/L , and the average removal efficiencies of NH_3 for conventional activated sludge (CAS), extended aeration with RAS =1, extended aeration with RAS =1.5, anaerobic-anoxic-aerobic (A2O), anoxic-aerobic(MLE) and anaerobic –oxic(A/O) were 61 %, 73.59% , 80.22%, 85.83% , 72..8% and 82.18 % respectively as shown in figure (4) .This is an agreement with previous studies for [18] , [19] ,[20] they found that nitrate is the major constituent of effluent total nitrogen indicating good nitrification for ammonia removal in the A2O system. This is may be explained by that the denitrifying PAOs are known as being able to reduce nitrate together with the absorption of phosphorus ,while utilizing the accumulated substrate as an electron donor. This process is reported to perform slower than ‘‘conventional’’ heterotrophic denitrification as being suggested by [21].

While the influents nitrate during experimental was varied between (1.26-191.52) mg/L , and the average removal efficiencies of NO_3 for conventional activated sludge (CAS) ,extended aeration with RAS =1 , extended aeration with RAS =1.5, anaerobic-anoxic-aerobic,(A2O) , anoxic-aerobic (MLE) and anaerobic -oxic (A/O) were 35.9 %, 55.74% , 56.73%, 76.68% , 81.76% and 33.97 % respectively as shown in figure (5). Figure (6) presents the average removal efficiencies of NO_2 for conventional activated sludge (CAS) ,extended aeration with RAS =1 , extended aeration with RAS =1.5, anaerobic-anoxic-aerobic,(A2O) , anoxic-aerobic (MLE) and anaerobic -oxic (A/O) were 34.95 %, 44.08% , 45.89%, 77.25% , 81.4% and 36.88 % respectively .This indicates that the acclimation ability of nitrifying bacteria (nitrosomonas bacteria)was increased with the time in the aerobic zone which is convert amonia to nitrite .Also decreasing in nitrite effluent concentration indicate to denitrification bacteria in anoxic zone convert amount of effluent nitrate and nitrite to nitrogen gas.

Phosphorus removal

The concentration of influents of phosphorus during experimental was varied between 10.7-38.5 mg/L , and the average removal efficiencies of PO_4-P for conventional activated sludge (CAS), extended aeration with RAS =1, extended aeration with RAS =1.5, anaerobic-anoxic-aerobic,(A2O), anoxic-aerobic (MLE) and anaerobic -oxic (A/O) were 44.43 %, 32.36% , 33.4%, 71.64% , 62.74% and 85.54 % respectively as shown in figure (7).

Its clearly increase of phosphorus removal efficiency and decreasing phosphorus effluent concentration with time,bacause in fully aerobic conditions if the aerobic phase is prolonged; phosphate release may take place. The reason for this can be the carbon store in the cells becomes depleted before the sludge reaches the end of the aerobic zone, and degradation of polyphosphates results in the beginning of a new carbon store build-up [22]; [23].

Satisfaction the effluent from different systems with the environmental limitations:

To find out the compliance of effluent quality from experiments system results with the discharge environmental limitations. The measured parameters were compared with the maximum permessible concentrations according to the Iraqi limitations of rivers maintenance from pollution no. 25, 1967 (ILRM no. 25, 1967).Table (2) presents the comparison of effluent from each system with these limitations.

Table (2) Comparison the effluent of CAS, Extended Aeration, A2O, MLE and A/O systems with Iraqi limits

parameters	ILRM no. 25, 1967	CAS	Extended Aeration (RAS=1)	Extended Aeration (RAS=1.5)	A2O	MLE	A/O
BOD_5 (mg/L)	< 40	76	50.4	36.20	17.2	13.25	18.625
COD(mg/L)	< 100	127.4	105.4	74.4	36.75	46.937	47.75
NH_3 (mg/L)	…….	7.936	4.044	5.487	3.81	8.6335	5.5837
NO_3 (mg/L)	50	28.21	24.95	27.46	17.216	12.17	44.4287
PO_4 (mg/L)	3	11.478	14.954	14.159	5.79	7.2987	2.8075
TSS (mg/L)	60	…….	……..	58.22	30.44	26.875	27.625

CONCLUSION:

From the previous results, it can be concluded that MLE system gave the higher removal efficiencies of BOD_5, NO_3 and NO_2 and A2O system gave the higher removal efficiency of COD, TSS and NH_3.While the higher removal efficiency of PO_4 was from A/O system and the lower removal efficiency of PO_4 from extended aeration system with RAS=1, 1.5.

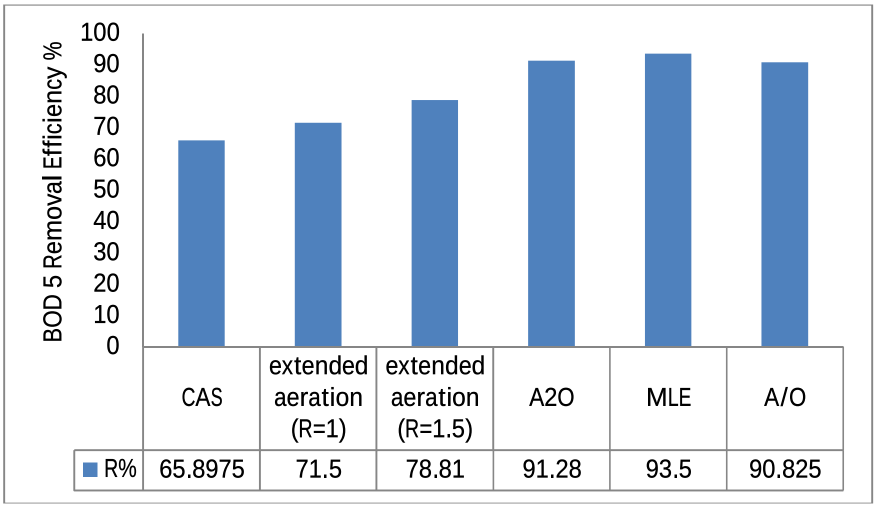


Figure (2) BOD$_5$ removal efficiency for different systems

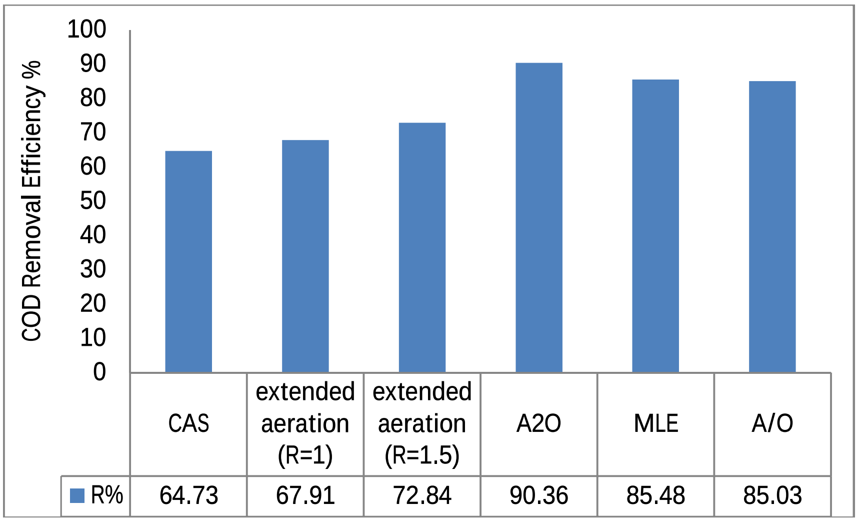


Figure (3): COD removal efficiency for different systems

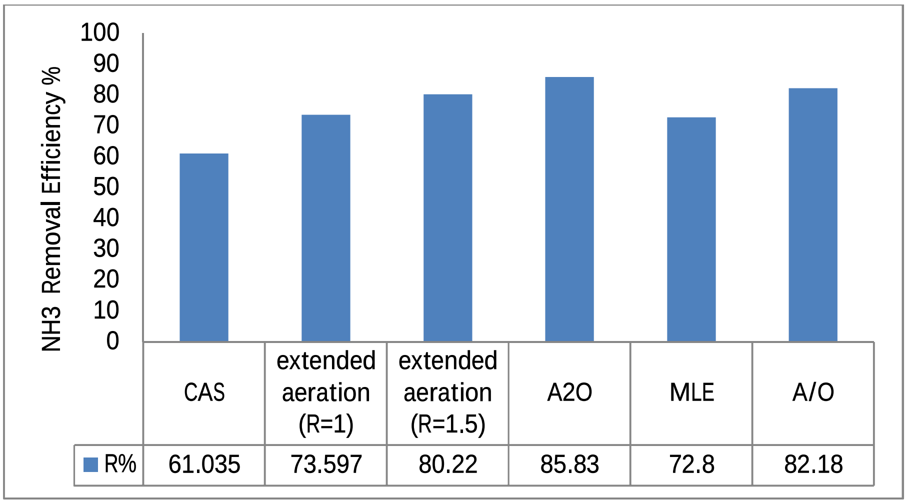


Figure (4) :NH$_3$ removal efficiency for different systems

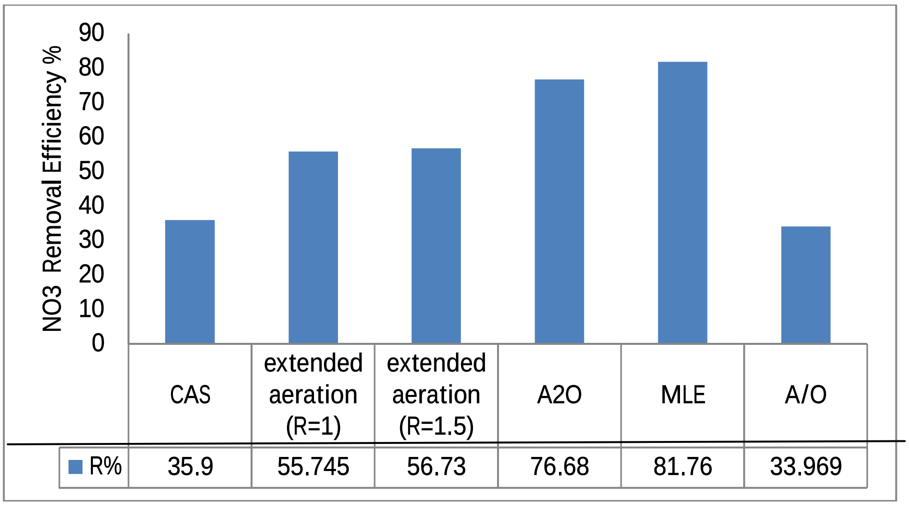


Figure (5) NO$_3$ removal efficiency for different systems

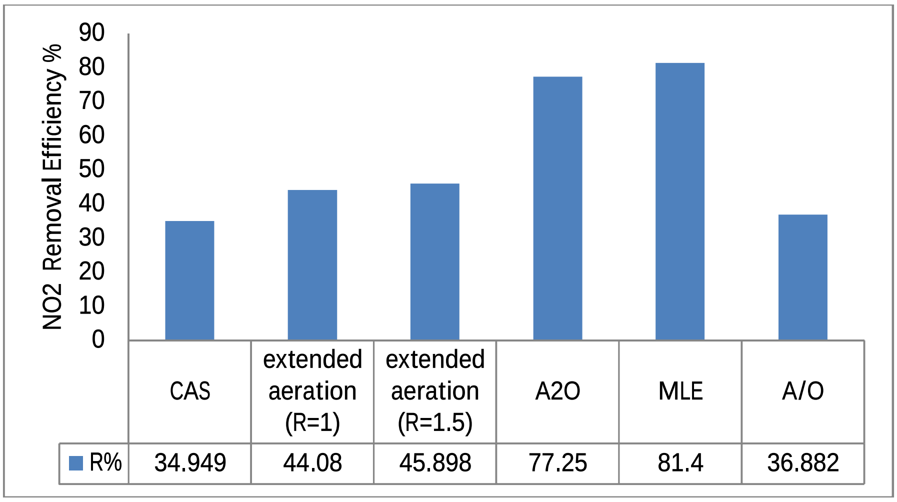


Figure (6) NO_2 removal efficiency for different systems

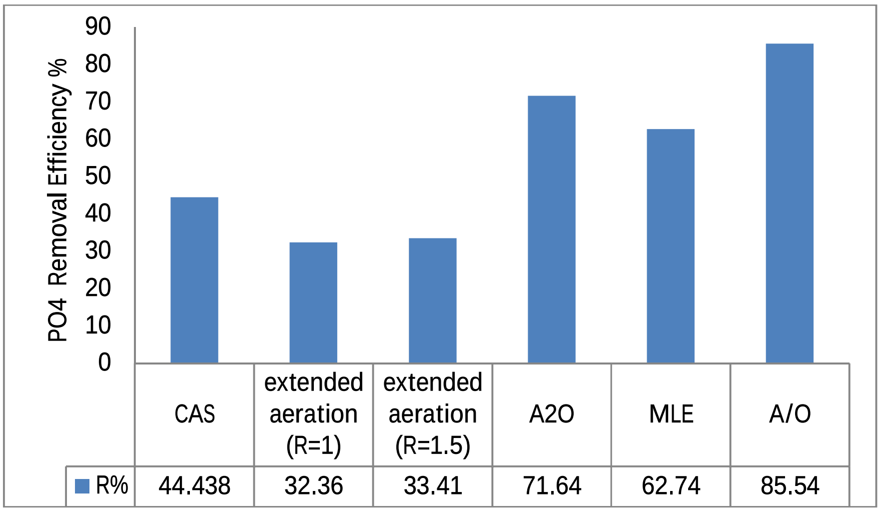


Figure (7) PO_4 removal efficiency for systems

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