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EVALUATION RATE OF INTERNAL MIXED LIQUOR RECYCLING PUMP (IMLRP) FOR BIOLOGICAL NITROGEN REMOVAL FROM WASTEWATER

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ABSTRACT

Because nitrogen compounds such as ammonium, nitrite, and nitrate are toxic to aquatic species and cause eutrophication in natural water environments, the removal of total nitrogen from wastewater has become a worldwide emerging concern. Although activated sludge technology is old, it has proven to be effective in the removal of nitrogen compounds until now.

The objective of the studies of the pilot plant is used an internal mixed liquor recycling pump (IMLRP) with varied rates ranging from one to fifth of influent flow to optimize nitrogen component removal, similar to the recycle activated sludge (RAS) approach. There was also no clear value for the amount of recycled activated sludge (RAS) flow between, but it was an optional value ranging from 1 to 3. So these studies evaluated the economic rate of the internal mixed liquor pump.

The pilot plant consists of three tanks, the first and second tanks in a pilot plant are rectangular, while the third, which serves as the final sedimentation tank, is spherical with a conical bottom.

The arrangement of the pilot plant was as follows: the first tank was an anoxic tank, followed by an aeration tank (A.T), and a final sedimentation tank, using (IMLRP) rates ranging from (1–5) influent flow, an average dissolved oxygen (DO) of 2.5mg/l in the anoxic tank, temperature ranging from (18–21), and pH ranging from (6.5–8), the total nitrogen removal in this process with rate of (IMLRP) equal twice of influent flow and achieves 64.5% of total nitrogen removal.

Key Words: Nitrogen removal, internal mixed liquor pump (IMLRP), activated sludge, biological process.

INTRODUCTION

Nitrogenous substances have long been known to have negative impacts on aquatic habitats. Nitrogenous chemicals can deplete dissolved oxygen in receiving waters, are poisonous to fish, and hence reduce stream and lake productivity, as well as pose a public health risk. To protect the quality of receiving water, many wastewaters treatment facility discharge licenses are being updated to include limits on the discharge of certain nitrogen compounds. To meet these permit limits, the biological processes of nitrification and denitrification are extensively used. The process of converting ammonia to nitrite and then to nitrate is known as nitrification.

Denitrification produces gaseous nitrogen from nitrite and nitrate **(Nicholas, 1996 ; Jeyanayagam, 2005 and Xueming, 2017)**

The commonly used nitrification-denitrification based wastewater treatment technologies include the oxidation ditch (Fig. 1.B), which is usually equipped with aerators to provide aeration, circulation and achieve simultaneous nitrification-denitrification in the same bioreactor through a spatial dissolved oxygen (DO) gradient, and the sequencing batch reactor (SBR), Fig. 1.C, which creates aerobic and anoxic conditions in the same bioreactor through temporal separation. For designing and operating the bioreactors, sludge retention time (SRT) and aeration are two parameters of key importance. Compared with heterotrophic bacteria, autotrophic nitrifying bacteria (i.e., AOB and NOB) grow slowly, so a proper SRT should be considered to maintain those microorganisms in the systems to ensure high nitrification efficiencies and hence better total nitrogen (TN) removal. Aeration is the main treatment in WWTPs performing the conventional nitrification-denitrification process and must be controlled to provide enough oxygen supply for nitrification while avoiding unnecessary energy consumption **(Zhao *et al.*, 1999 ; de Kreuk, *et al.*, 2005 and Jetten, *et al.*, 2009)**.

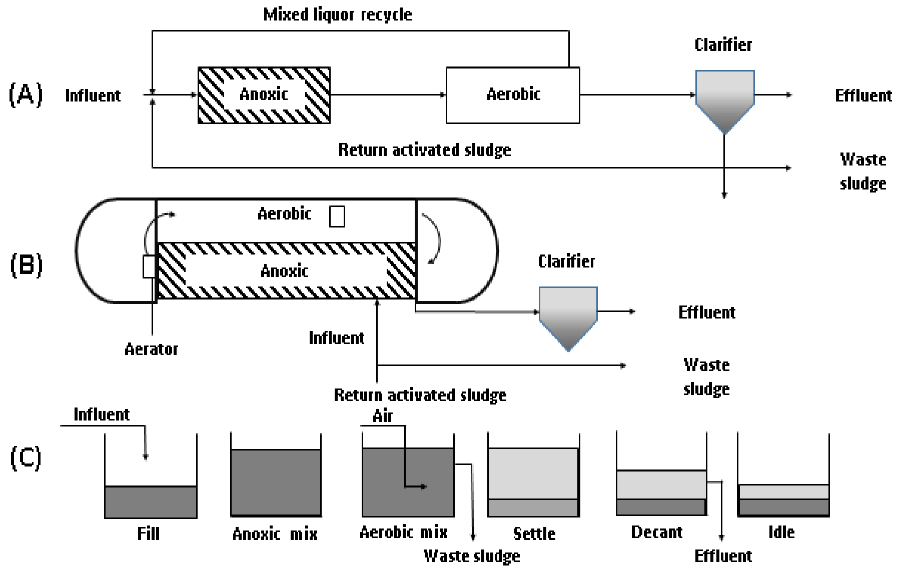

Fig. (1): Schematic Diagrams of (A) Modified Ludzack-Ettinger Configuration; (B) Oxidation Ditch Configuration; and (C) SBR Configuration [**Jeyanayagam, 2005**].

MATERIALS AND METHODS

1. Pilot plant location

The experimental work was carried out as shown in Fig.2 at Quhafa wastewater treatment Plant located in El-Fayoum Governorate, Egypt.

Fig. (2): A: Layout of Quhafa WWTP B: Location of Pilot Plant

2. Regional condition

The climate in this region is defined as subtropical with an average temperature of 18 °C in winter and 32 °C in summer. The physical and chemical characteristics of influent and effluent wastewater in Quhafa WWTP over the entire experimental period are shown in Table 1.

Table 1: Physical and Chemical Characteristics of Influent and Effluent of Wastewater in Quhafa WWTP

Parameter / Month	°C		pH		TN		DO	NH_4		NO_2	
	In	Out	In	Out	In	Out	Out	In	Out	In	Out
Jan.	18	17.5	7.6	7.5	31.50	18.7	2.4	13.4	8.50	0.1	ND
Feb.	18.7	18.7	7.4	7.3	33.15	17.80	2.1	16.4	11	0.1	ND
Mar.	19.7	19.2	7.2	7	32.5	19	2.6	14.5	9.1	0.1	0.1
Apr.	24	23	7.8	7.6	30.90	14.5	3.1	13.8	8.5	0.1	ND
May	28	26	7.2	7.1	31.45	16.4	3.4	14.2	9.45	0.1	ND
June	30.7	30.1	7.3	7.6	32.8	18.5	5.2	15.2	9.80	0.1	ND
July	31.7	30.7	7.7	8	33	22.5	5	13.7	10.2	0.1	ND
Aug.	31.2	31	7.8	8.1	27.4	31.4	4.9	15.2	15.6	0.1	0.1
Sep.	30	29.6	7.7	7.8	27.6	17	4.9	17.8	8.8	0.1	0.8
Oct.	28.8	28.7	7.4	7.5	32.25	19.3	5.5	18.6	10.1	0.1	0.3
Nov.	24.3	24.6	7.5	7.6	33.78	19.8	5.3	22.1	14.3	0.1	0.1
Dec.	20.1	19.8	7.4	7.5	31.6	19.4	6.1	21.9	10.2	0.1	0.1
Avg.	25.4	23.2	7.5	7.6	31.49	19.5	4.2	15.4	10.15	0.1	0.125

3. Description of pilot plant and parameters

The influent raw wastewater will be collected after primary treatment (inlets, screens, oil & grease separators and grit chamber) in Quhafa WWTP, and then will be received to pilot plant by using a submersible pump (about 2 HP) to delivered raw wastewater to an elevated polyethylene tank with a volume of 1000 liters located at the roof of the pilot plant room to feed the model with raw wastewater, as shown in Fig. 3. The model consists of three tanks, the first and second tanks are rectangular and the third is circular with conical bottom, description of pilot plant as follows.

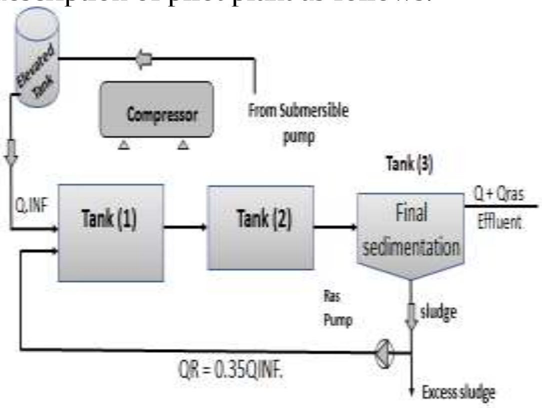

Fig. (3): Schematic diagram of pilot plant

4. description for pilot plant

In this phase of the experiment observing is shown in Fig. 4 the sequence of process consists of an anoxic tank followed by an aeration tank and then to a final sedimentation tank. In this phase the system provided with internal mixed liquor recycle pump which located at the effluent of the second tank with rate ranged from QIMLRP = (1-5) QINF.

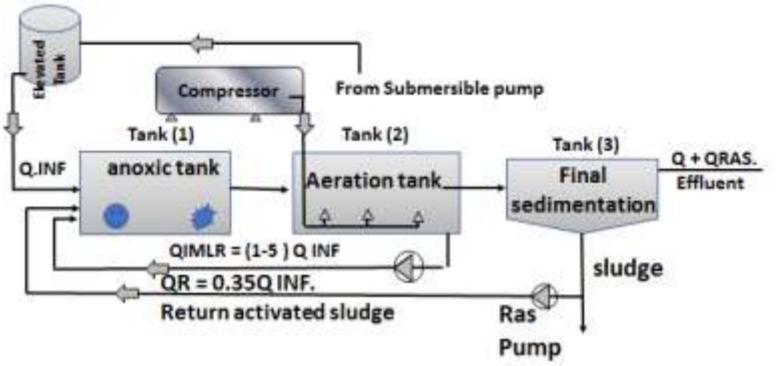

Fig. (4): Phase 3 Schematic Diagram Q(IMLRP)= (1-5) Qinf. (Anoxic Tank, Aeration Tanks and Final Sedimentation Tank)

5. Samples Collection

The influent and effluent samples were collected from raw line and treated line plus samples from a specific location throw the process. DO and pH were also measured using portable instruments for processes as well as nitrogen removal efficiency evaluation. The samples were collected from the pilot plant two times per week along with the experimental work of this pilot plant. The analysis of samples was conducted in HBRC laboratory according to American standard methods for examination of wastewater as follows: -

- **Temperature, pH and DO**

Measured at site of pilot plant by multi-parameter analyzer Horriba.

- **Total nitrogen (TN)**

Measured in HBRC laboratory by using Millipore (Elix) UV-Milli-Q Advantage A 10 System.

RESULTS AND DISCUSSION

The operating variables rate of the (IMLRP) process were studied in a pilot plant technique to determine the optimum conditions of the economical rate of (IMLR) pump in the process to achieve maximum removal efficiency.

The experimental works in this unit were operated with a continuous flow rate of raw wastewater with a different rate of (IMLRP) pump average ambient temperature of 17 ^{o}C. The pilot plant was operated at this stage for about 16 weeks.

- **Total nitrogen and ammonium ions removal**

The target of this stage was to obtain the max removal efficiency of nitrogen by using different rats of (IMLRP) ranged from QIMLRP = (1-5) QINF

From Figures (5, 6) overall removal efficiencies of total nitrogen and ammonium ions. It can be seen that the removal efficiency increases when increase rate of return recirculation pump gradually from QIMLRP=1 QINF. Up to QIMLRP=2 QINF. And efficiency was 42% and 64.5% respectively but when the rate increases to be equal three, four or five times from influent flow, the removal efficiency decreased to be 30%, 25% and, 15% respectively.

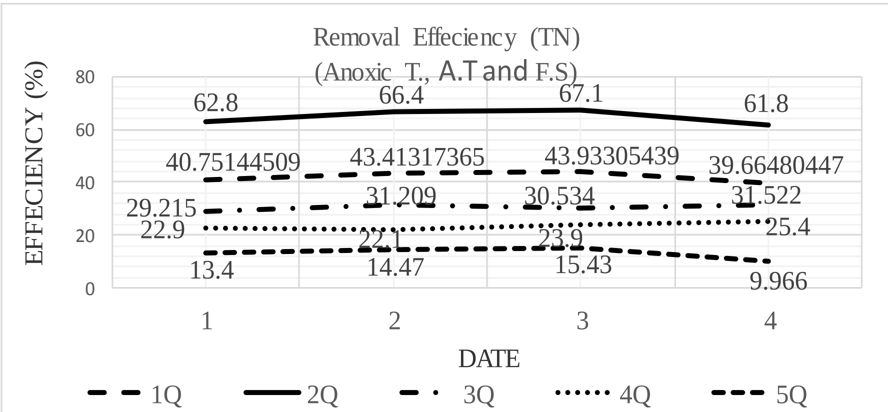

Fig. (5): Overall efficiency of TN

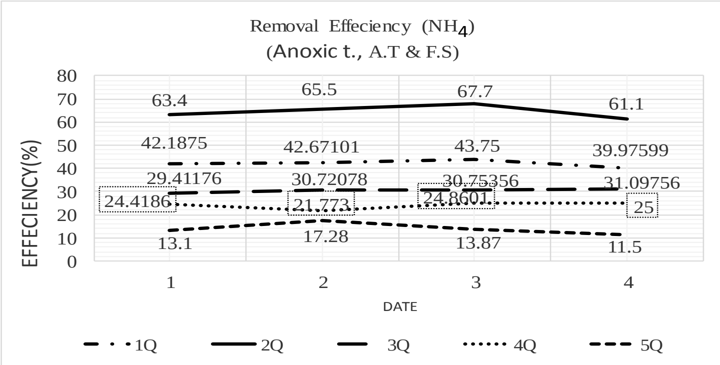

Fig. (6): Overall efficiency of NH_4

Table 2: Influent & Effluent of (TN & NH_4)

Q=1Q							
TN				**NH_4**			
DATE	**INFLUENT**	**EFLUENT**	**%**	**DATE**	**INFLUENT**	**EFLUENT**	**%**
13-3-2019	**34.6**	**21**	**40.8**	**13-3-2019**	**16**	**9.25**	**42.2**
14-3-2019	**33.4**	**19**	**43.4**	**14-3-2019**	**15.35**	**8.8**	**42.7**
19-3-2019	**23.9**	**13**	**43.9**	**19-3-2019**	**11.2**	**6.3**	**43.8**
20-3-2019	**35.8**	**22**	**39.7**	**20-3-2019**	**16.66**	**10**	**40**
AVERAGE	**31.9**	**19**	**41.9**	**AVERAGE**	**14.803**	**8.5875**	**42.1**
Q=2Q							
TN				**NH_4**			
DATE	**INFLUENT**	**EFFLUENT**	**%**	**DATE**	**INFLUENT**	**EFFLUENT**	**%**
26/2/2019	**32.3**	**12**	**62.8**	**26/2/2019**	**15.03**	**5.5**	**63.4**
27/2/2019	**26.8**	**9**	**66.4**	**27/2/2019**	**12.45**	**4.3**	**65.5**
6/3/2019	**37.2**	**12**	**67.1**	**6/3/2019**	**17.3**	**5.58**	**67.7**
7/3/2019	**34.3**	**13**	**61.8**	**7/3/2019**	**15.95**	**6.21**	**61.1**
AVERAGE	**32.7**	**12**	**64.5**	**AVERAGE**	**15.183**	**5.3975**	**64.4**
Q=3Q							
TN				**NH_4**			
DATE	**INFLUENT**	**EFFLUENT**	**%**	**DATE**	**INFLUENT**	**EFFLUENT**	**%**
12/2/2019	**31.1**	**22**	**29.2**	**12/2/2019**	**14.45**	**10.2**	**29.4**
13/2/2019	**30.8**	**21**	**31.2**	**13/2/2019**	**14.29**	**9.9**	**30.7**
20/2/2019	**31.7**	**22**	**30.5**	**20/2/2019**	**14.73**	**10.2**	**30.8**
21/2/2019	**35.3**	**24**	**31.5**	**21/2/2019**	**16.4**	**11.3**	**31.1**
AVERAGE	**32.2**	**22**	**30.6**	**AVERAGE**	**14.968**	**10.4**	**30.5**
Q=4Q							
TN				**NH_4**			
DATE	**INFLUENT**	**EFFLUENT**	**%**	**DATE**	**INFLUENT**	**EFFLUENT**	**%**
2/1/2019	**29.6**	**23**	**22.9**	**2/1/2019**	**13.76**	**10.4**	**24.4**
3/1/2019	**30.3**	**24**	**22.1**	**3/1/2019**	**14.1**	**11.03**	**21.8**
9/1/2019	**30.8**	**23**	**23.9**	**9/1/2019**	**12.51**	**9.4**	**24.9**
10/1/2019	**31.1**	**23**	**25.4**	**10/1/2019**	**10.8**	**8.1**	**25**
AVERAGE	**30.4**	**23**	**23.6**	**AVERAGE**	**12.793**	**9.7325**	**24**
Q=5Q							
TN				**NH_4**			
DATE	**INFLUENT**	**EFLUENT**	**%**	**DATE**	**INFLUENT**	**EFFLUENT**	**%**
18-12-2018	**32.1**	**28**	**13.4**	**18-12-2018**	**14.96**	**13**	**13.1**
19-12-2018	**31.9**	**27**	**14.5**	**19-12-2018**	**14.87**	**12.3**	**17.3**
25-12-2018	**31.1**	**26**	**15.4**	**25-12-2018**	**14.28**	**12.3**	**13.9**
26-12-2018	**29.1**	**26**	**9.97**	**26-12-2018**	**13.22**	**11.7**	**11.5**
AVERAGE	**31.1**	**27**	**13.3**	**AVERAGE**	**14.333**	**12.325**	**13.9**

CONCLUSION

Using internal mixed liquor recycle pump in biological phase in activated sludge process, like RAS pump, return activated sludge from final sedimentation tank to the influent tank of biological phase **(Pochana, & Keller1999 ; Bernat & Wojnowska-Baryla 2007 ; Chiu, *et al.*, 2007 and Sun, *et al.*, 2010).** So, when using recycling pump to be returned flow (water and sludge) to the system, this flow rich in microbial activated and adapted nitrification/denitrification bacteria which mixed again with the raw wastewater and take its time to complete nitrification/denitrification in special conditions of DO in aeration tank not less than 2.5 mg/l, DO equal or less than 0.5 mg/l in an anoxic tank. Temperature was about 20ºC and more with an average pH ranged from 6.5 up to 8 in pilot plant.

The arrangements of this pilot plant, (anoxic tank, aeration tank, and F.S.T), from experimental, it was found that the efficiency increase gradually till QIMLR=2QINF., and achieve max efficiency due to increase the anaerobic bacteria content in the anoxic tank. Also, decrease the oxygen content in an anoxic tank, the bacteria will react or use the ammonia and nitrate as food in absence of oxygen. This improved the efficiency removal for nitrogen (ammonia and nitrate). However, when QIMLRP= (3-5) QINF increase, the efficiency decreases. This may be due to dilution and total count of anaerobic bacteria was lower.

So, the most effective removal of nitrogen occurs in case of process anoxic tank followed by aeration tank and finally sedimentation tank which achieve 64.5% of total nitrogen removal with using internal mixed liquor pump of rate equal twice of influent flow rate.

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تقييم معدل التصرف لطلمبة أعادة المياه (IMLRP) لازالة النتيروجين بيولوجيا من مياه الصرف الصحي

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تعد مركبات النيتروجين مثل الأمونيوم والنتريت والنترات بمياه الصرف الصحي من اكثر الملوثات السامة للمياه سواء المياه السطحية أو المياه الأرضية وتتسبب في زيادة المغذيات في بيئات المياه الطبيعية ، لذا فقد أصبح إزالة النيتروجين الكلي من مياه الصرف الصحي مصدر قلق في جميع أنحاء العالم وعلى الرغم من أن تقنية الحمأة المنشطة قديمة ، إلا أنها أثبتت فعاليتها في إزالة مركبات النيتروجين حتى الآن لذا فهذه الدراسه تهدف الى تحديد افضل معدل تصرف لطلمبة اعادة المياه للوصول الى اعلى كفاءة ازاله لمركبات النيتروجين .

والغرض من النموذج المعملي هو تحديد افضل معدل او تصرف باستخدام طلمبة تدوير المياه (IMLP) لازالة النيتروجين من مياه الصرف ، حيث تم تغيير معدل تصرف الطلمبة من (1 وحتي 5) اضعاف معدل او تصرف معدل المياه الخام الداخلة بالنموذج وتعد هذه التقنية مماثله تماما لطلمبة اعادة الحمأه (RAS) والتي تستخدم في المعالجة البيولوجية بالحمأه المنشطة الا ان معدل تصرف الحمأه يؤخذ من (1–3) دون تحديد القيمة المثلي .

ويتكون االنموذج المعملى من ثلاثة خزانات من الصلب المعزول والخزانان الاول والثاني مستطيل الشكل اما الخزان الثالث فهو دائري وينتهي بشكل مخروطى بالقاع وهذا الخزان يستخدم كخزان ترسيب.

وتم ترتيب النموذج ليكون الخزان الاول غير مهوى والخزان الثانى بنظام تهويه اما الخزان الثالث فهو خزان الترسييب والنموذج مزود بطلمبه لاعاده المياه من الخزان الثانى الى الخزان الاول بمعدل تصرف من (1 – 5) اضعاف تصرف المياه الداخله للنموذج ، وكانت قيمة الاكسجين الذائب بالخزان الاول الغير مهوى حوالى 2.5 مجم / ل ، اما درجة الحراره بالنموذج تتراوح ما بين (18 – 21) درجه مئويه وكذلك فان الاس الهيدروجينى بالنموذج يتراوح ما بين (6.5 – 8) ، واظهرت النتائج ان اعلى نسبة ازاله لمركبات النتيروجين هى 64.5 % فى حالة استخدام طلمبة اعادة المياه بتصرف يساوى ضعف تصرف المياه الخام الداخله للنموذج.