STUDY ON AMMONIUM REMOVAL IN DOMESTIC WASTEWATER FROM DORMITORY OF NATIONAL UNIVERSITY OF CIVIL ENGINEERING

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Abstract: *Currently, there are 84 universities and institutes in Hanoi with the corresponding number of universities and institutes. There are also a number of dormitories with different scales ranging from a few hundred to several thousand students. Thus, the amount of wastewater from the dormitories is also relatively large. The wastewater discharge into water body without treatment, the pollutants in general and nitrogen in particular will seriously affect the environment. Base on these issues, the paper studied the problem of ammonium treatment in domestic wastewater from dormitory, experimental research in laboratory scale with real wastewater from dormitory of National University of Civil Engineering (NUCE). Treatment technology is partial nitritation combined with anaerobic anaerobic oxidation (anammox). Within the scope of this research, the papermention only to the anammox process, i.e, the wastewater was controlled suitable ratio of the ammonium to nitrite concentration for the anammox process. This paper does not mention about the partial nitritation process. The results showed that, with the operational time of 193 days, the influent T-N concentration fluctuated from 90-180 mgN/L, and T-Nremoval efficiency increased from 29.4% to 61.4% in stepwise. The concentrations of nitrogen compounds at the end of each experimental period is satisfied for the National Technical Regulation on domestic wastewater, QCVN 14:2008/MONRE, column B. This is a positive result for developmentof a pilot scale model for ammonium removal from domestic wastewater.*

Keywords: *anammox; biomass carrier, domestic wastewater;* NH_4^+*-N;* NO_2^-*N.*

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1. Introduction

According to Ministry of Education and Training and the data compiled by the author, there are 84 universities and institutes in Hanoi [1] and the corresponding number of universities and institutes.There are also a number of dormitories with different scales ranging from a few hundred to several thousand students. Moreover, in the future, more dormitories for students in Hanoi will also be planned with centralized scale so the wastewater discharged from the dormitories is quite large. Therefore, the problem of treatment of pollutants in general and ammonium in particular in domestic wastewater from of universities'dormitories is very necessary.

The dormitoryscale of National University of Civil Engineering (NUCE) is about 1000 students. Wastewater in dormitoryis collected separately,wastewater from the toilet (black water) discharge into the septic tank and grey water will be discharged directly to the drainage network. According to the survey data [2], septic tank effluent with high ammonium concentration, fluctuate from about 80 to 180mg/L. This is the cause of water eutrophication, If the wastewater from septic tank discharge into water body without ammonium removal.

Relative to ammonium removal technologies, beside the traditional technologies such as nitrification and denitrification, partial nitrification combined with anaerobic ammonium oxidation (anammox) also promises more advantages.

This combined process would require only 50% of the oxygen needed for the traditional nitrification-denitrification method and, being fully autotrophic, no addition of organic carbon is needed. The anammox process can be thus effective for nitrogen removal from wastewaters with low carbon content; in addition, sludge production is very limited amount thus making it an economically favourable treatment option. The stoichiometry of the anammox reaction has been determined as below [3]:

$$NH_4^+ + 1.32\ NO_2^- + 0.066\ HCO_3^- + 0.13H^+ \rightarrow 1.02\ N_2 + 0.26\ NO_3^- + 0.066\ CH_2O_{0.5}N_{0.15} + 2.03\ H_2O \quad (1)$$

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The application of anammox process for nitrogen removal from wastewater containing high ammonium concentration has been implemented such as reject water from more than 100 wastewater treatment plants [4] or mainstream wastewater in moving bed biofilm reactor (MBBR) [5].

The ammonium removal from slaughterhouse wastewater was applied anammox process in Netherland. The organic matter of the slaughterhouse wastewater was treated by previous biological anaerobic process. With the influent ammonium concentration of 112 mg N/L, the effluent ammonium concentration was quite low of 6.4 mg N/L [6].

In addition, wastewater of seafood processing was treated by activated sludge process and partial nitritation combined with anammox process. COD removal efficiency was 85%. Maximum T-N removal rate was 0.6 kg N/m^3/day [7].

Similarly, the reject water with high ammonium concentration was treated by partial nitritation and anammox in separated concept.The result obtained quite good with high T-N removal rate of 5.7-10.5 kg N/m^3/day [8].

In Vietnam, the application of anammox process for treatment of domestic wastewater is rarely. While, the ammonium removal from wastewater of livestockwas obtained satisfactory result. Ammonium concentration in livestock wastewater was fluctuated from 290-424 mg N/L. In lab-scale of 10 L/day, the ammonium removal was achieved of 80-95%. In addition, in pilot-scale of 500 L/day, the ammonium removal was similar of 80-97% [9].

Subsequently, tanning wastewater with ammonium concentration fluctuated from 294-326 mg N/L was applied by anammox process in different scales [10].

In lab-scale of 10 L/day, the reactor was operated about 210 days, the removal efficiencies reduced from95%, 74% and 68.6% when ammonium loading rate were increasedfrom (0,3; 0,45; 0,6) kg NH_4^+-N/m^3/day [10].

Meanwhile, the influent ammonium concentration of 1 m3/day in pilot scale was from 219 to 278 mg N/L. The maximum and average increased removal efficiency were 75.5% and 62.7%, respectively[10].

In pilot scale of 1.5 m^3/day, the influent ammonium concentration was stable with 152-177 mg N/L. Theeffluent ammonium concentrations were 48-94 mg N/L. The maximum increased removal efficiency was 69.8% and the average value of 60%[10].

The largest pilot scale of 2 m^3/day, the influent and effluent ammonium concentrations were fluctuated from 148 to 192 mg N/L and from 71 to 120 mg N/l, respectively. The ammoniumremoval efficiencies were obtained highest of 58.1% and the average removal efficiency was low of 47%[10].

With the above results, the study of partial nitritation and anammox process with combined or separated concepts for ammonium removal from wastewater containing high ammonium concentration in lab-scale were successfully. These are confident information to develop treatment technology of wastewater containing high ammonium concentration such as domestic wastewater, slaughterhouse wastewater, reject water, etc applied by anammox process with low cost versus high removal efficiency.

Consequently, this research was implementedin the experimental lab-scale to evaluate ammonium removal capacity in domestic wastewater from NUCE's dormitory.

However, anammox bacteria were authotropth group. Hence, this kind of bacteria can grow up without organic carbon. Therefore, the effect ofthe COD/N ratio to anammox process was assessed in Chamchoi's study. The ammonium removal efficiencies were reduced from 84% to 60% corresponding to COD/N ratioswere increased from 0.6 to 1.3 [11]. It is meaning thatit is not recommended to increase COD/N ratio higher than 1.3.

In this research, the organic matter from effluent septic tank was removed by previous anaerobic membrane bioreactor (AnMBR) with a controlled COD parameter below 80 mg/L [2]. Wherefore,the COD/N was always controlled less than 1 and it was not affected for anammox process. Furthermore, the appropriate NH_4^+-N/NO_2^--N ratio of 1:1 for anammox process was maintained by previous partial nitritation process.

2. Materials and methods

Laboratory-scale Fixed Bed Reactor

The fixed-bed reactor was used with a total volume of 1.62L. The reactor had an inner diameter of 7.1cm and total height of 41cm. The polyethylene (PE) material is used as biomass carrier. The reaction

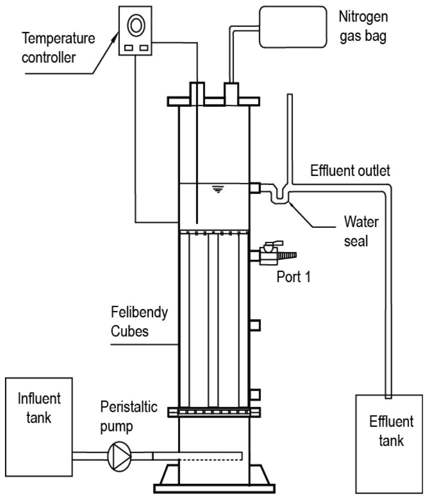

Figure 1. *Schematic diagram of fixed bed reactor using PEbiomass carrier material*

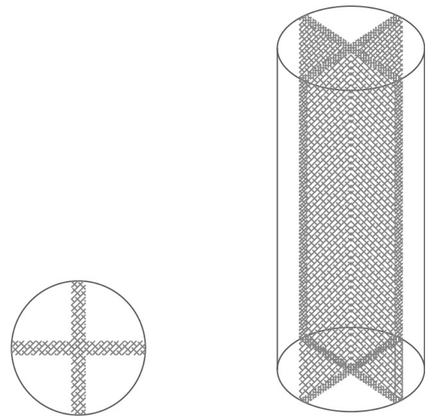

Figure 2. *Frame structure of PE biomass carrier material*

zone volume of 0.65 L is a part of reactor which contain biomass carrier material. This reaction zone volume was used for determinations of hydraulic retention time (HRT). HRT was changed from 24h to 6h. The clarification zone (above the reaction zone) was 0.34L. Figs.1 and 2 show the schematic diagram of the fixed-bed reactor andframe structure of PE biomass carrier material, respectively.

Influent wastewater was fed in up-flow mode using peristaltic pumps (Eyela Co., Ltd., Tokyo). Nitrogen gas was collected by using gassampling bags. Airtight integrity wasmaintained in the capped reactor using effluent water traps. Reactor temperatureswere maintained at 33^oC to 35^oC by using external ribbon heating elements. Black vinyl sheet enclosures were used to maintain dark conditions.

Seed sludge

The anammox sludge (Planctomycetes)distributed by Meidensa company, Nagoya, Japan was used as seed sludge as. Before start-up, 50 ml of the seed sludge was attached on the surface of the PE sponge material.

Synthetic wastewater for 2 weeks starting up of the fixed bed reactor

Synthetic wastewater was prepared by adding ammonium and nitrite in the forms of $(NH_4)_2SO_4$ and $NaNO_2$, respectively, to a mineral medium according to the composition given in Table 1.

Table 1. *Composition of synthetic wastewater*

Compositions	Units	Concentration
$(NH_4)_2SO_4$	(mgN/L)	Variable 30-50
$NaNO_2$	(mgN/L)	Variable 30-50
$KHCO_3$	(mg/L)	125.1
KH_2PO_4	(mg/L)	54.4
$FeSO_4.7H_2O$	(mg/L)	9.0
EDTA	(mg/L)	5.0

Characteristic of wastewater from NUCE's dormitory [1]

Table 2. *Characteristic of wastewater from NUCE's dormitory [2]*

Parameters	After septic tank	AfterAnMBR	After Partial Nitritation
TSS (mg/L)	215.63±103.1	49.58±37.57	-
COD (mg/L)	493.02±180.64	62.15±18.64	-
NH_4^+-N (mg/L)	123.48±50.38	124.8±53.33	45-90*
NO_2^--N (mg/L)	-	-	25-80*

**: by this research*

Operational conditions

Influent was fed in up-flow mode using a peristaltic pump (Eyela Co., Ltd., Tokyo). The reactor temperature was maintained at 33^oC to 35^oC, controlled by the thermal stability equipment of the aquarium. Light is known to have a negative effect (30-50% rate reduction) on ammonium removal rate; consequently, dark conditions were maintained using black vinyl sheet enclosures. Purging with nitrogen gas was used on a daily basis to keep dissolved oxygen levels in the influent synthetic wastewater below 0.5 mg/L.

The experiement was implemented from January, 2015 to July, 2015. Operational regime of this experiment is shown in the Table 3 with different HRT and variable influent concentration of ammonium and nitrite.

Table 3. *Operational parameters of fixed bed reactor*

Period	Time (days)	Flow rate (L/d)	HRT (h)	Influent NH_4^+-N (mg N/L)	Influent NO_2^--N (mg N/L)	Note
1a	14 (0-14)	0.65	24	30-50	30-50	Synthetic wastewater (WW)
1b	17 (15-31)	0.65	24	48.3±3.1	35.6±12.3	Diluted WW after AnMBR
2	21 (32-52)	0.65	24	68.3±13.5	47.4±6.3	WW after AnMBR
3	32 (53-84)	0.87	18	76.4±12.3	61.2±10.3	WW after AnMBR
4	30 (85-114)	1.3	12	72.2±16.6	62.1±16.5	WW after AnMBR
5	37 (115-151)	1.73	9	59.7±10.4	50.4±8.8	WW after AnMBR
6	42 (152-193)	2.6	6	69.0±11.7	59.6±9.7	WW after AnMBR

Chemical analyses

The experiment was conducted in the laboratory of Water Supply and Sanitation Division, Faculty of Environmental Engineering, National University of Civil Engineering. Parameters of influent and effluent stream were analyzed 3 times per week. Ammonium concentrations were measured by colorimetic method with Nessler reagent at wavelength of 420nm. In accordance with Standard Methods [12], nitrite concentrations were estimated by the colorimetric method (4500-NO_2^-B) and nitrate by the UV spectrophotometric screening method (4500-NO_3^-B). Nitrite was determined to have an interfering response in the nitrate UV screening method of 25% of the nitrate response on a nitrogen weight basis, thus the results were corrected by calculation. Levels of pH were measured by using a MettlerToledo-320 pH meter and DO was measured by using a DO meter (D-55, Horiba).

3. Results and discussion

3.1 Influent and effluent concentrations and removal efficiencies of nitrogen compounds

Table 4. *The concentrations of nitrogen compounds in 6 operational periods of the fixed bed reactor*

Period	Inf. NH_4-N (mg/L)	Eff. NH_4-N (mg/L)	NH_4-N removal efficiency (%)	Inf. NO_2-N (mg/L)	Eff. NO_2-N (mg/L)	NO_2-N removal Efficiency (%)	Inf. NO_3-N (mg/L)	Eff. NO_3-N (mg/L)	Inf. T-N (mg/L)	Eff. T-N (mg/L)	T-N removal efficiency (%)
1a (14d)	38.0±10.2	28.7±5.2	22.6±10.7	34.0±12.3	20.3±5.5	36.7±18.1	0.6±0.3	3.0±2.1	72.6±22.4	52.0±11.3	26.3±11.4
1b (17d)	48.3±3.1	31.6±8.1	35.6±17.7	35.6±6.2	19.4±7.4	44.3±26.0	4.4±1.7	7.7±2.8	88.4±7.0	58.7±12.0	33.9±16.7
2 (21d)	68.3±13.5	47.5±14.0	30.8±12.5	47.4±6.3	27.1±9.9	40.7±26.2	8.6±3.0	13.2±3.4	124.3±14.2	87.7±21.6	29.4±14.8
3 (32d)	76.4±12.3	32.9±13.2	55.1±21.2	61.2±10.3	17.5±11.4	70.1±20.7	12.4±5.2	20.8±6.5	150.0±20.4	71.2±21.6	51.3±17.5
4 (30d)	72.2±16.6	22.7±9.0	69.6±7.1	62.1±14.5	14.5±6.8	76.6±9.3	8.7±3.7	18.3±4.0	143.0±30.9	55.5±16.0	61.4±6.5
5 (37d)	59.7±10.4	19.0±7.8	66.7±14.6	50.4±8.8	15.6±6.9	67.2±18.3	9.2±3.6	17.6±5.4	119.2±20.7	52.2±10.5	54.4±14.2
6 (42d)	69.0±11.7	21.9±11.7	69.6±12.0	59.6±9.7	16.6±10.9	73.4±13.0	15.9±3.4	24.9±4.2	144.4±19.6	63.4±19.7	56.8±8.6

Influent NH_4^+-N and NO_2^--N levels were changed from 30 to 50mg N/L for start-up period of 14 days (period 1a) by using synthetic wastewater with composition in Table 1. In period 1b (the next 17 days), the domestic wastewater from NUCE's domitory after AnMBR was diluted to maintained low NH_4^+-N and NO_2^-N concentrations of 48.3±3.1 mg/L and 35.6±12.3 mg/L for adapting of Planctomycetes bacteria. HRT was kept of 24 h. With this conditions, the effluent NH_4^+-N and NO_2^--N concentration were changed from 20 to 15 mg N/L and 20 to 10 mg N/L, respectively. These effluent values will not affect to the bacteria and this time is properly to increase the influent NH_4^+-N and NO_2^--N concentrations for the period 2.

During period 2 (the next 21 days), HRT was still kept of 24 h, NH_4^+-N and NO_2^--N concentrations were

68.3±13.5 mg/L and 47.4±6.3 mg/L, effluent NH_4^+-N concentration was reduced step by step from 62.2 to 32.9 mg N/L. NH_4^+-N and NO_2^--N removal efficiencies were still low of 30.8±12.5% and 40.7±26.2 %, respectively.At the end of this period, the HRT was reduced from 24hrs to 18hrs because the effluent NO_2^--N concentration was reduced from 39.0 to 14.5mg N/L, which concentration did not inhibited for this bacteria.

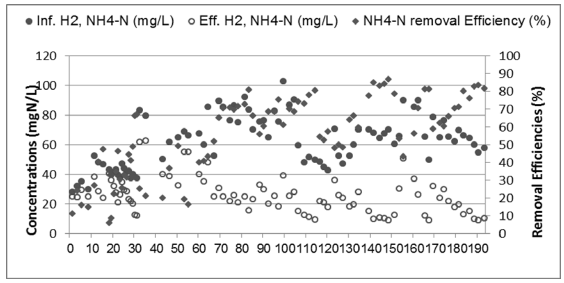

Figure 3. *Changes in NH_4^+ - N concentrations during operational periods*

Similar to period 2, periods of 3 to 6 was operated with HRT was decreased stepwise from 24 hrs, 18 hrs, 12 hrs, 9 hrs and 6 hrs when effluent concentrations of NO_2^-N reduced to about 10 mg N/L at the end of each period to avoid inhibition for bacteria. The detail data was shown in Figs. 3 and 4. and Table 4.

However, the day 55 of period 3, the effluent NO_2^-N concentration quite high of 45.5 mg N/L due to decrease HRT from 18 hrs to 12 hrs and influent NH_4^+-N was 66.4 mg N/L and 60.5 mg N/L. If this effluent NO_2^-N concentration was kept in longer time, the bacteria may be inhibited and affected to process, therefore, at that time, the influent pump was stopped in temporary for 3 days for recover of bacteria's activity. This situation was occurred similarly in the day 155 of period 6 when HRT was reduced from 9 hrs to 6 hrs and the influent pump was also stopped in temporary.

In generally, the effluent concentrations of NH_4^+-N also reduced to appropriate 10 mg N/L at the end of each period, which satisfy to National technical regulation on domestic wastewater, QCVN 14:2008/MONRE, colum B.

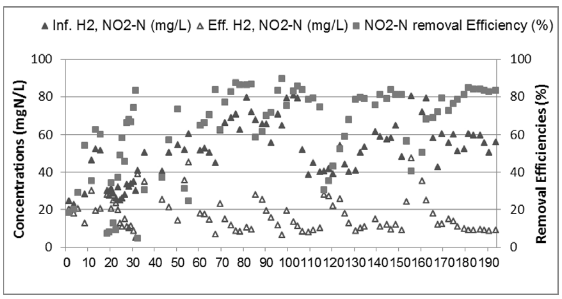

Figure 4. *Changes in NO_2^-N concentrations during operational periods*

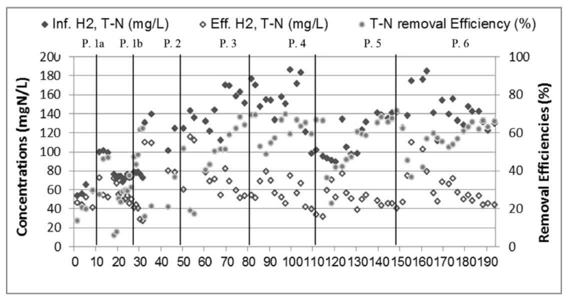

Figure 5. *Changes in T-N concentrations during operational periods*

3.2 Influent and effluent T-N concentrations and T-N removal efficiencies

Influent and effluent T-N concentrations and T-N removal efficiencies were shown in Fig. 5. Influent T-N concentrations were changed from 124.3±14.2 to 150.0±20.4 mg N/L, while effluent T-N concentrations from 87.7±21.6 to 52.2±10.5 in the periods 2 to 6 with the real wastewater. T-N removal efficiencies were increased stepwise from 29.4±14.8, 61.4±6.5. The detail data of T-N concentrations is shown in Table 4.

With these results, it is shown that the application of anammox process for ammonium removal in domestic wastewater from NUCE's dormitory is feasible. The effluent nitrogen compound is satisfied to the National technical regulation on domestic wastewater, QCVN 14:2008/MONRE, column B.

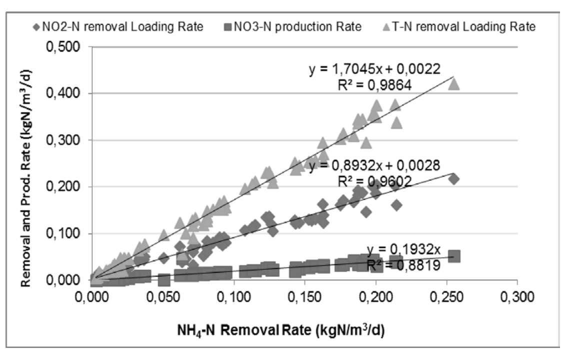

Figure 6. *Ratios of T-N removal, NO_2^--N removal and NO_3^--N production rates to NH_4^+-N removal rates during operational periods*

3.3 Ratios of T-N removal, NO_2^--N removal and NO_3^--N production rates to NH_4^+-N removal rates

Ratios of T-N removal, NO_2^--N removal and NO_3^--N production rates to NH_4^+-N removal rates during the operational time weresummarized in Table 5 and Fig. 6.

***Table 5.** Changes in Stoichiometric ratios of NO_2^-- N removal, NO_3^-- N production and T-N removal rates to NH_4^+-N removal rates during continuous treatment*

Periods	NO_2-N / NH4+-N	NO_3-N / NH_4^+-N	T-N / NH_4^+-N
	Theoretical ratios		
	1.32	0.26	2.06
1a (synthetic WW)	1.6 ± 0.94	0.27 ± 0.15	2.33 ± 0.79
1b (diluted WW)	0.96 ± 0.36	0.19 ± 0.07	1.77 ± 0.31
2 (real WW)	0.99 ± 0.54	0.23 ± 0.1	1.76 ± 0.46
3 (real WW)	1.08 ± 0.22	0.2 ± 0.07	1.88 ± 0.19
4 (real WW)	0.95 ± 0.1	0.19 ± 0.02	1.75 ± 0.27
5 (real WW)	0.85 ± 0.17	0.22 ± 0.15	1.63 ± 0.27
6 (real WW)	0.91 ± 0.09	0.19 ± 0.02	1.72 ± 0.1

During periods of 1a, 1 b and 2, NO_2^--N/NH_4^+-N, NO_3^--N/NH_4^+-N and T-N/NH_4^+-N ratios were fluctuated as shown as Table 5, due to this period is the starting up and bacteria may need the time for adapting to new environment. From periods 3 to 6, these ratios were quite stable and closed to the theoretical ratios as shown in Fig. 6 and Table 5. Therefore, the system was opertated more stable over time.

After 193 days of operation, anammox biomass was adapted and attached on the surface of PE sponge material in domestic wastewater and the red color biomass was observedas shown in Fig. 7.

***Figure 7.** Attached biomass observation after 193 days*

4. Conclusions

In the fixed-bed reactor using PE sponge material as biomass carrier with real domestic wastewater from NUCE's dormitory after AnMBR, NH4+-N and NO2-N removal efficiencies in average value improved over the operational time from 30.8% to 69.6% and 40.7% to 76.6%, respectively. During operational time of 193 days, T-N removal efficiencies in average value increased stepwise from 29.4% to 61.4% with influent T-N concentrations fluctuated from 90 to 180 mg N/L. The effluent nitrogen compounds meet the National Technical Regulation on domestic wastewater, QCVN 14:2008/MONRE, column B.The result showed the nitrogen compound removal in domestic wastewater is able to be appliedby this anammox process. However, the fluctuated influent T-N concentration may inhibited and sock to bacteria if the operational regime is not appropriate.

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