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Recycle Domestic Wastewater by Biotechnology

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Abstract: ***This paper presents the results of research on the effectiveness of treating COD and nitrogenous compounds by biological treatment systems, using mobile media, the system is operated continuously in 4 different stages: Phase 1 with a hydraulic retention time (HRT) of 6 h, phase 2 of 7 h, phase 3 of 8 h and phase 4 of 8 h, with addition of the microorganism substrate to the aerobic biological tank and anaerobic. Aeration rates in different periods are respectively1 Ln/L*min, 2 Ln/L*min, 3 Ln/L*min, 4 Ln/L*min. During the operation of the system, the concentration of MLSS in aerobic tanks reached 2500 - 7210 mg/L, in anaerobic tanks reached 4000 - 8140 mg/L. The research results show that the COD, NH_4^+-N, NO_3^--N, NO_2^--N content at the input of the system have the corresponding values in the range of 100 - 230; 60 - 70, 0.226 - 0.330 and 0.032 - 0.072 mg/L respectively. In all 4 operation phases, at the outflow, the content of COD remains negligible. In phase 4, after going through the treatment system, the removal efficiency of NH_4^+-Nis highest. Its content is only 3.04 ± 0.13 mg/L. The content of NO_3^--Nreaches 0.04 ± 0.021 mg/L and the content of NO_2^--N reaches 0.01 ± 0.001 mg/L. The results show that this system can be used to treat COD and nitrogen compounds that meet the standards of domestic water and can continue to develop this technology to provide for places where clean water is scarce.***

Keywords*:* Domestic wastewater, COD, NH_4^+, NO_3^-, NO_2^-, microorganism, MLSS

1. Introduction

Domestic wastewater is derived from human activities discharged after use. Domestic wastewater usually contains high levels of organic substances such as BOD_5, COD, TSS, NH_4^+, $N_{org}$and bacteria. In Vietnam, it is often discharged directly into the environment, causing serious impacts on the environment. On the other hand, water is a resource that humans can use, it plays an important role in the development of not only people, but any industry or field that needs water in the production process. The lack of clean water for daily activities is a major cause of serious health consequences for human life, especially in the mountains and islands, where water supplies are challenging and expensive.

In fact, there are many methods to treat domestic wastewater such as physical methods using membrane, chemical, biological and combined methods. An appropriate treatment method depends on many factors such as flow, pollutant discharge load, climatic conditions, economic conditions, actual status of treated materials and treatment objects, etc… In particular, the biological treatment methods today are being focused because it is relatively simple, environmentally friendly, low operating costs and relatively high treatment efficiency. However, these methods mainly handle pollutants that meet the standard to discharge into the environment. (Kuschk, Wiessner et al. 2006, Crittenden, Trussell et al. 2012).

To meet the standard of domestic water, the pollutants in domestic wastewater after treatment must have a content of substances much lower than the discharge standard. To meet this requirement, usually using reverse osmosis membrane technology (RO), nano filtration (NF) or using ultrafiltration membrane technology (UM) or plasma technology ... However, these methods requires pretreatment and high technology investment cost, in addition, the rate of wastewater discharge is relatively large. (Shon, Phuntsho et al. 2013, Dũng, Huy et al. 2018, Biniaz, Ardekani et al. 2019).

Biotechnology has been known and used for the treatment of wastewater widely, it is simple, environmental friendly with low treatment costs.In biotechnology, the removal of pollutants such as organic compounds, nitrogen compounds can take place in many different ways such as aerobic biology, anaerobic biology, anaerobic biology gas, biofilter ... Their removal efficiency depends mainly on the type of treatment system, the content of oxygen supplied to the system, the temperature, the content of bacteria as well as the retention time of the system.(Iorhemen, Hamza et al. 2016, Nam, Hiep et al. 2016)

In order for the quality of treated wastewater to reach the standards, it is necessary to optimize the conditions for the treatment. This paper presents the results of the study, evaluating the effectiveness of anaerobic and anaerobic biological systems, under different retention time conditions, different aeration rates and conditions for adding biological media. Study, thereby evaluate the efficiency of the removal of COD, NH_4^+ and TSS in the system and select the optimal conditions for the treatment of domestic wastewater in Co Nhue Tu Liem District, Hanoi Vietnam.

2. Experimental

2.1 Chemicals

Chemicals used in the study include: NH_4^+,NO_3^-, NO_2^-, $HgCl_2$, KI, NaOH, $KNaC_4H_4O_6.4H_2O$, H_2SO_4, NH_4Cl, KNO_3, $NaNO_2$, CH_3COOH, NaOH, Phenol, α − naphtylamin, EDTA, chemicals of Pa manufactured by Merck, Germany. To determine COD, used HACH rapid reagent (USA)

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2.2 Inflow wastewater characteristics

Domestic wastewater is taken from the domestic sewer at the lane of 136 Ho Tung Mau, which is discharged from daily activities of households, a part of water generated from households doing business in food service. Wastewater is collected at the time of relatively large discharge, from 9-12 h or 16-18 h during the day of sampling, then transferred to the laboratory for loading into the treatment system.

The main parameters of domestic wastewater in CauDien area – Hanoiwas measured, with concentrations of 125–158 mg/L TSS, 100-230 mg/L COD, 55.15- 68.55 mg/L NH_4^+-N, 0.04–0.08 mg/L NO_2^- -Nand 0.01-0.14 mg/L NO_3^--Nto feed for the treatment system.

2.3 Treatment system

The treatment system consists of 7 tanks: 1- Inflow water tank: made of PE material with a volume of 20 liters. 2- Aerobic tank: cylindrical structure made of PVC material, d = 110 mm, height h = 70 cm, containing aerobic activated sludge, (substrate), volume of empty water is 3.7 L The amount of oxygen provided by the air pump connected to the air distribution balloon. 3- Reverse filtration tank 1: similar to an aerobic tank, with a height of h = 63 cm, supplemented with filtration materials including 1-2 gravel, yellow sand, and activated carbon, the volume of empty water is 2.35L. 4- Anaerobic tanks: height h = 62 cm, containing anaerobic activated sludge (substrate combination), the volume of empty water is 2.75L. 5- Filter tank 2: is designed as a filter tank with an empty water volume of 2.35L (Figure 2-1).

Wastewater is pumped quantitatively continuously into the inflow water tank. The flow of wastewater into the treatment tanks is adjusted by the valve of the inflow water tank, in order to adjust the HRT of the system in 4 phases: Phase 1 with a HRT of 6 h, speed aeration with values 1 Ln/L*min. Phase 2 with a HRT of 7 h, aeration speed with values of 2 Ln/L*min. Phase 3 HRT of 8 h, aeration speed with values of 4 Ln/L*min. Phase 4 HRT of 8 h, aeration speed with values of 4 Ln/L*min, with the addition of microbial media to aerobic and anaerobic biological tanks.

Figure 2.1: Domestic wastewater treatment system used in research (1- Inflow water tank; 2- Aerobic tank; 3, 5- Reverse filtration tank 1 and 2; 4- Anaerobic tank; 6 Inflowwater storage tank 7- Sludge Flush valve)

Samples are taken daily at the inflow, outflow, aerobic, anaerobic and in filter tanks, by cylinders and stored in a sample vial made of polymer. Samples can be measured immediately, or stored at -20°C.

2.4 Measuring methods

The inflow water flow is measured with a cylinder, COD content is determined by COD reagent manufactured by HACH USA, Compounds of nitrogen: NH_4^+-N, NO_3^--N,NO_2^--N is analyzed by spectral methods of molecular absorption, UV-VIS Optizen 2120UV, England.

3. Results and Discussion

3.1 Bacterial growth

The effeciency of contaminants treatment depends greatlyon the content of bacteria in biological tanks. The results of MLSS content analysis in the first 2 phases of system operation are shown in figure 3-1 below:

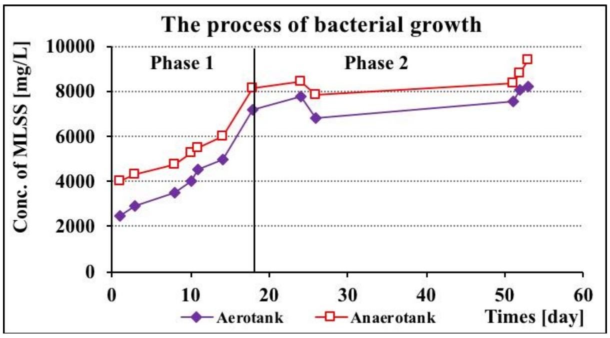

Figure 3.1: Bacterial growth through time

Results have shown that, in the first phase of operation, the MLSS content increases steadily with time of operation. During this period, its value increased from 2500 to 7210 mg/L and in aerobic tanks from 4000 to 8140 mg/L. In phase 2 of the system operation, the MLSS content in the system is relatively stable, its value is about 6800-8200 in aerobic tanks and 7500- 9370 mg/L in anaerobic tanks. The results show that, during operation, bacteria in both systems is very well developed, especially in the early stages of operation, in phase 2, the bacteria content is stable, this content is consistent. suitable for processing.

3.2 COD removal efficiency

The efficiency of COD treatment in the system in different phases is shown in Figure 3-2 below:

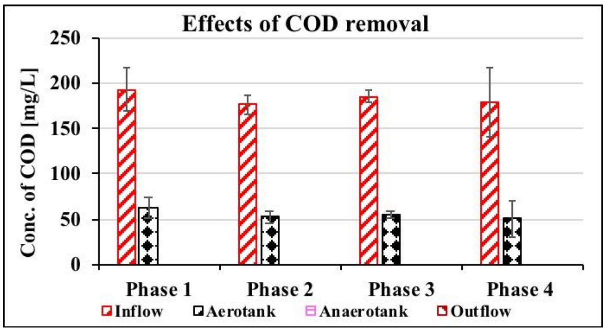

Figure 3.2: The content of COD in different operating phases (phase 1 from 11 to 17/2; phase 2 from 19 to 26/2;

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phase 3 from 26 to 30/2;phase 4 from March 2 to April 24, 2019)

The results show that the COD content of the input wastewater is not stable, its value ranges from 100 - 230 mg/L. In phase 1 of the operation with a HRTof 6 h, its input value is in the range of 174 - 220 mg/L. However, after going through the aerobic tank, the content was only 63.00 ± 11.13 mg/L. The results showed that, although the input value fluctuated quite large, however, after treatment in the aerobic tank, COD content was quite stable, the efficiency of aerobic biological treatment was quite high. The process of removing COD in an aerobic tank takes place as follows:

$$(CH_2O)_n + O_2 \xrightarrow{bacteria} CO_2 + H_2O + Q \quad (1)$$

The results indicated that, in anaerobic tanks, the COD content was not detected, indicating that the system was able to thoroughly treat COD under this condition. The process of eliminating organic compounds in subsequent stages through filtration and through anaerobic bacteria. The process of removing COD in anaerobic biological system goes as follows(Wang, Fan et al. 2014):

$$(CH_2O)_n \xrightarrow{Methangenase} CH_4 + H_2O \quad (2)$$

$$(CH_2O)_n + NO_2^- \xrightarrow{Denitrifier} CO_2 + H_2O + N_2 \quad (3)$$

$$(CH_2O)_n + NO_3^- \xrightarrow{Denitrifier} CO_2 + H_2O + N_2 \quad (4)$$

$$(CH_2O)_n + SO_4^- \xrightarrow{Desunfuricant} CO_2 + H_2O + N_2 \quad (5)$$

The results showed that, with the HRT of 6 h, the MLSS content was quite high in phase 1, making the COD treatment efficiency quite high, it could eliminate 100%.

In phase 2, when the HRT is increased to 7 h, the aeration speed of 2 Ln/L.min, the input COD content ranges from 165 to 186 mg/L. However, after going through the treatment system, the COD content decreases gradually according to the stages of the system.Waste water after going through aerobic tank, COD content is only 52.51 ± 6.27 mg/L. At the outflow, it is similar to phase 1, the COD content is not detected. Research results indicate that, with a greater HRT, the removal efficiency is higher. Similar to phases 1 and 2, in phase 3 with HRT of 8 h, the content of COD is more stable, its value is in the range of 177 -190 mg/L. When going through the aerobic tank, its content is only 54.54 ± 3.91. In anaerobic tanks, COD is also completely removed. In phase 4, with aHRT of 8 h and in the two biological tanks added the substrate,the inflow content of COD fluctuates the largest, its value is in the range of 100 -230 mg/L. However, after the treatment process in the aerobic tank, its content was only 50.43 ± 19.65 mg/L. In anaerobic tanks, as in the 4 phases above, the COD content was completely removed

The research results show that, during the operation of the system, bacteriaactivates very well, the research system gives very high and relatively stable removal of COD. The content of COD after treatment can meet the standards of domestic water.

3.3 Removal ofNH_4^+

Evaluation of the removal efficiency of NH_4^+-N in the system are shown in Figure 3-3. The results showed that, during the study period, the content of NH_4^+-N inflow ranged from 55.50 to 68.50 mg/L, but at the outflow, its content was only 2.06 up to 8.49 mg/L, depending on the different stages.

In phase 1, the HRT of the system is 6 h, the aeration rate of 1 Ln/L.min, the input content of NH_4^+-N is in the range of 62.41 to 65.78 mg/L, however after wastewater passing through the system, the content of NH_4^+-N at the output is only 7.31 ± 1.00 mg/L (removal efficiency reaches 88.66%). During operation, NH_4^+ content decreased with stages. In aerobic tanks, the content of NH_4^+-N was only 28.71 ± 3.29 mg/L, which corresponded to the removal efficiency of 55.49%. In anaerobic tanks, its content was only 10.60 ± 0.73 mg/L, corresponding to a removal efficiency of 63.07%. At this phase, the system operation is still new, the concentration of MLSS in anaerobic tanks is in the range of 2500 - 7210 mg/L, while in anaerobic tanks, the MLSS content is higher, its content reaches 4000 - 8140 mg/L. During this period, the HRT of the system is short, the growth of bacteria is not high, besides, the aeration rate is only 1 Ln/L.min, so the removal ability of nitrogen compounds is still low, yet tomet the requirements. The NH_4^+ removal process in the system can be performed by the following processes:

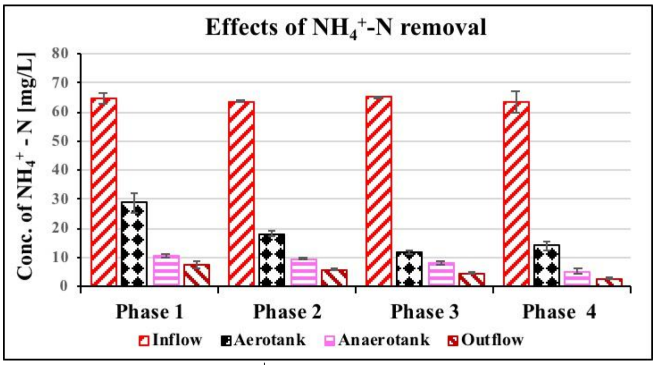

Figure 3.3: NH_4^+ removal efficiency by different operation stages (phase 1 from 11 to 17/2; phase 2 from 19 to 26/2; phase 3 from 26 to 30/2;phase 4 from March 2 to April 24, 2019)

In the aerobic system, mineralization of nitrogen compounds takes place(Rashidi, GhaffarianHoseini et al. 2015):

$$C_3H_7NO_2 + O_2 \rightarrow NH_4^+ + CO_2 + H_2O \quad (6)$$

Next to the nitrification process:

$$NH_4^+ + O_2 \xrightarrow{Nitrosomonas} NO_2^- + H_2O \quad (7)$$

$$NO_2^- + O_2 \xrightarrow{Nitrobacter} NO_3^- + H_2O \quad (8)$$

There are also the Sharon processes(Lee 2003):

$$NH_4^+ + NO_3^- \xrightarrow{VSV} N_2O + H_2O \quad (9)$$

$$NH_4^+ + NO_2^- + HCO_3^- + H^+ \rightarrow N_2 + NO_3^- + CH_2O + H_2O \quad (10)$$

In addition to the above processes, assimilation of nitrogen to create biomass takes place:

$$NH_4^+ + HCO_3^- + CO_2 + H_2O \rightarrow C_5H_7O_2N + O_2 \quad (11)$$

In an aerobic biological tank, the removal process takes place mainly along the nitrification and Sharon/Anammox pathways (Lee 2003). In anaerobic biological tanks, the removal process is mainly based on the Sharon/Anammox

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path.

In phase 2, the system operates stable MLSS content is quite high and stable in aerobic tank its content reaches 7780 - 8210 mg/L, while in anaerobic tanks its content is higher, the value ranges from 8420 - 9370 mg/L.With the content of bacteria is higher than phase 1, besides, the HRT is greater, the air speed is greater, the amount of O_2 added to the system is more, so the removal efficiency of NH_4^+-N is better.The content of NH_4^+-N in the aerobic tank was only 18.01 ± 0.93 mg/L, meanwhile, its inflow content is similar to that in phase 1: 63.61 ± 0.43 mg/L, corresponding to a removal efficiency of 71.68%. In anaerobic tanks, the content of NH_4^+-N reached 9.42 ± 0.47 mg/L, corresponding to removal efficiency of 47.70%. At the outflow after the filter, its content is only 5.71 ± 0.31 mg/L, lower than phase 1. The results show that, when the HRT of the system is increased and the amount of O_2dissolved increases, the treatment efficiency of NH_4^+ increases, the removal efficiency of the system in this period reaches 91.02%. However, in this condition, the content of NH_4^+has not met the requirements of domestic water yet

In phase 3, continue to increase the HRT of the system to 8 h and the aeration speed is 3 Ln/L.min. At this phase, the MLSS content is quite high and stable in the tanks. With the content of bacteria is higher than that of phase 1, besides, the HRT is greater, so the removal efficiency of NH_4^+-N is better. The content of NH_4^+-N in the aerobic tank is only 11.87 ± 0.63 mg/L, meanwhile, its inflow content is similar to that in phases 1 and 2, input value 65.12 ± 0.38 mg/L, corresponding to anremoval rate of 81.76%.In anaerobic tanks, the content of NH_4^+-N reached 7.78 ± 0.57 mg/L, corresponding to the removal efficiency of 34.47%. And at the outflow after the filter its content is only 4.51 ± 0.34 mg/L lower than phases 1 and 2, the removal efficiency of the system reaches 93.08%.

In phase 4, the addition of biological media in aerobic and anaerobic tanks, HRT of 8 hours with phase 3 and the addition of air oxygen at aeration rate of 4 Ln/L.min. At this phase in the presence of microorganisms, bacteria adhere to the surface of the substrate, which increases the exposure of pollutants to bacteria, besides, the O_2dissolved increases, which helps the process of denaturation of nitrogen compounds and nitrification process, so the treatment efficiency increases.This is proved by: the content of NH_4^+-N in the aerobic tank 13.90 ± 1.62 mg/L, corresponding to the removal efficiency of 78.02%. Meanwhile, at the outflow of anaerobic tanks, the content of NH_4^+-N was 2.73 ± 0.41 mg/L. Thus, it can be seen that the removal efficiency of the system reaches 95.67% and the content of such outflow can meet the standards of domestic water. From the results of the study, it showed that the operating conditions of the system: the HRT of 8 hours, aeration speed of 4 Ln/L.min, with additional media, MLSS content in biological tanks 7000-9000 mg/L gives the highest NH_4^+ treatment efficiency and its value meets the standards of domestic water supply.

3.4 Removal efficiency of NO_2^- và NO_3^-

Research results of NO_2^--N and NO_3^--N removal in the system are shown in Figure 3-3 and Figure 3-4. Experiment results show that, in the studied periods, the content of input NO_2^--N was in the range of 0 to 0.083 mg/L, the content of input NO_3^--N was in the range of 0 to 0.16 mg/L, however, at its output, its content does not change significantly, its value is 0 to 0.028 mg/L. In addition, according to different stages, their content increases gradually, especially for NO_3^- in stage 4 has the highest increase. Comparing between aerobic and anaerobic treatment tanks, in general, the content of NO_2^- and NO_3^-in aerobic tanks is higher than that of anaerobic tanks.

The results of the study indicated that, during operation according to different retention times, different aeration rates, and the addition of microorganisms, it did not significantly affect the efficiency of the treatment. These two types of compounds can be proved by their content in treatment tanks, their value is lower than standard of domestic water (see Figures 3-3 a and b).

This can be explained, in all 4 phases of operating the system, in the aerobic tank, the initial process of nitrification (see reaction 7-8), the product is made up of this process. continue to participate in reaction with residual NH_4^+ to convert to N_2O, $N_2$and NO_3^- compounds (see reaction 9 -10) (Lee 2003, Wang, Fan et al. 2014),thereby not only eliminating NO_2^-, NO_3^-but also remove NH_4^+ so the content of NO_3^- and NO_2^- in aerobic tanks is insignificant. The reduction of the total nitrogen concentration in the NH_4^+-N, NO_3^--N and NO_2^--N compounds in the aerobic tank in 4 different phases is respectively: 35.56; 45.14; 52.94 and 47.08 mg/L.From the results of the study showed that the removal ability of the total nitrogen in the aerobic biological tank in phase 3 is the highest, its value reaches 52.94 mg/L corresponding to the HRT of the system is 8 hours, 3Ln/L.min aeration speed, without microbiological substrate.

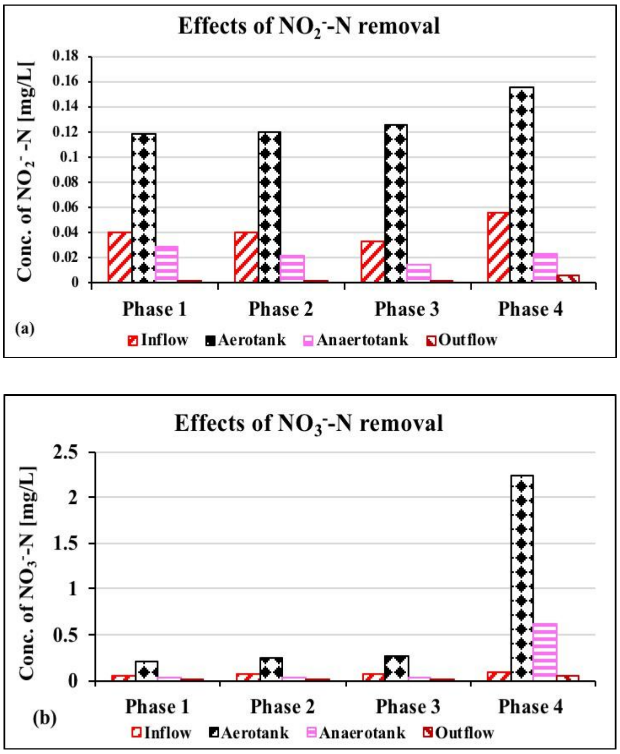

Figure 3.3: NO_2^-removal efficiency (a) and NO_3^-removal efficiency (b) by different operation stages(phase 1 from 11

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to 17/2; phase 2 from 19 to 26/2; phase 3 from 26 to 30/2;phase 4 from March 2 to April 24, 2019)

In anaerobic tanks, the content of NO_3^--N and NO_2^--N is lower than of aerobic biological tanks in all 4 phases of operation (see Figures 3-3a and b). In anaerobic environments, the removal of NO_3^--N and NO_2^--N is mainly through denitrification (see Equation 3,4) and Sharon process(Lee 2003, Wang, Fan et al. 2014).Because their input content in anaerobic tanks is quite low, their removal efficiency in this tank is also quite low, the decrease of the total nitrogen concentration in compounds NH_4^+-N, NO_3^--N and NO_2^--N in the aerobic tank in 4 different phases respectively: 18.39; 9.13; 4.44 and 10.52 mg/L.After passing through anaerobic tanks, their content is negligible, particularly in phase 1, its content is only 0.03 ± 0.001 mg/L for NO_3^--N and 0.03. ± 0.006 mg/L for NO_2^--N. In phase 2, its content is only 0.027 ± 0.0017 mg/L for NO_3^--N and 0.021 ± 0.005 mg/L for NO_2^--N. In phase 3, its content is only 0.030 ± 0.005 mg/L for NO_3^--N and 0.015 ± 0.005 mg/L for NO_2^--N. And in phase 4 with the addition of media, the content of NO_3^-it increases to 0.626 ± 0.176 mg/L for NO_3^--N and 0.023 ± 0.007 mg/L for NO_2^--N

The results showed that the content of $NO_3^-$and NO_2^-after going through anaerobic tanks in all 4 phases are much lower than the requirement of domestic water, thereby reducing the HRT of the system, reduce construction and operation costs, improve processing efficiency as well as economical efficiency.

4. Conclusion

Research has been conducted to remove COD, NH_4^+, NO_3^- and NO_2^- in domestic wastewater, using aerobic biological system in combination with anaerobic with the addition of biological substrate. The results of the study showed that, when MLSS content in anaerobic tanks about 7780 - 8210 mg/L and anaerobic tanks about 8420 - 9370 mg/L, with a HRT of 8 hours, the aeration rate in an aerobic tank 4 Ln/L.min, the content of COD, NH_4^+, $NO_3^-$and NO_2^- at the outflow of the system meets the standards of domestic water supply. It is possible to continue researching a number of indicators in domestic wastewater, opening a new direction for treating domestic wastewater into daily-life water to supply clean water on site for areas where water is scarce such as mountainous areas and islands, and contribute to reducing environmental pollution caused by direct discharge of domestic wastewater.

5. Acknowledgements

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References

[1] Biniaz, P., et al. (2019). "Water and Wastewater Treatment Systems by Novel Integrated Membrane Distillation (MD)." chemengineering**3**(8): 1-36.
[2] Crittenden, J. C., et al. (2012). MWH’s Water Treatment: Principles and Design. John Wiley & Sons, Hoboken, NJ, USA.
[3] Dũng, N. n. V. n., et al. (2018). "Nghiên cứu xử lý nước cấp sinh hoạt bằng công ngh ệ phóng đi ện vầng quang kết hợp keo tụ tạo bông." Khoa học ĐHQGHN : Các Khoa học Trái đất và Môi trường,**34**(4): 47-53.
[4] Iorhemen, O. T., et al. (2016). "Membrane Bioreactor (MBR) Technology for Wastewater Treatment and Reclamation: Membrane Fouling." Membranes**6**(2): 1-29.
[5] Kuschk, P., et al. (2006). "Effectiveness of different designed small-scale constructed wetlands to decrease acidity of acid mine drainage under field conditions." Eng. Life Sci.**6**(4): 394-398.
[6] Lee, D. K. (2003). "Mechanism and kinetics of the catalytic oxidation of aqueous amonia to molecular nitrogen." Environ. Sci. Technol.**37**: 5745 – 5749.
[7] Nam, N. H., et al. (2016). "CREATING NITROGEN MODIFIED TiO2 NANO MATERIAL BY UREA COVERED ON LATERITE APPLYING TO TREAT ORGANIC COMPOUND AND BACTERIA IN THE OUTFLOW OF BIOLOGICAL TREATSYSTEM." Journal of Science of HNUE**61**(9): 93-103.
[8] Rashidi, H., et al. (2015). "Application of wastewater treatment in sustainable design of green built environments: A review." Renewable and sustainable energy reviews**49**: 845–856.
[9] Shon, H. K., et al. (2013). "Nanofiltration for water and wastewater treatment a mini review." Drink. Water Eng. Sci.**6**: 47-53.
[10] Wang, G., et al. (2014). "Anoxic/aerobic granular active carbon assisted MBR integrated with nanofiltration and reverse osmosis for advanced treatment of municipal landfill leachate." Desalination**349**: 136–144.

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