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INNOVATIVE TRICKLING BIOFILTER SYSTEM FOR HOSPITAL WASTEWATER TREATMENT

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ABSTRACT

Innovative Trickling biofilter system was applied for wastewater treatment of Danang Rehabilitation – Sanatorium Hospital in this study. The results have shown that the removal efficiencies of COD and BOD_5 at loading of 2.5 - 4 kg/m^3.day were about 90 %. The inlet concentrations of $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ were so high as 33.1 and 26.2 mg/L, respectively. However, the remaining of treated wastewater concentration is 1.4 and 5.2 mg/L, corresponding to the removal efficiencies of 97 and 80 %, respectively. Otherwise, the values of total suspended solid (TSS), phosphates (P), and coliforms were below the limitations of QCVN 28:2010/BTNMT, column A. Resulting from the obtained data in this study, we emphasize that the innovative trickling biofilter system with air supply is appropriate with health-care wastewater treatment and consistent with economic and operating conditions in Vietnam.

Keywords: biofiltration system, health-care wastewater, wastewater treatment technologies.

1. INTRODUCTION

In Vietnam currently, there are over 13,500 health facilities, where discharge nearly 310,160 m^3 watsewater and 7.3 tons medical solid waste per day in the central. Similarly, there are 38.8 medical solid waste and 90,752 m^3 wastewater also in local routes. However, the survey of Ministry of Health showed that there were only 65.3 % medical, 12 % of health and 50 % of drug manufacturing facilities responding with discharge standard of National Technical Regulation on Health Care Wastewater (QCVN 28: 2010/BTNMT). Regarding for solid waste treatment, there are only 69 % of hospitals and 32 % of priventive medicine facilities treat by incinerators, landfill or services of medical treatment. The remainings are self raw treatment, even simply treated by burning [1].

Hospital wastewater contains highly biodegradable organic (BOD_5), large amount of suspended solids and rich ammonia nitrogen contents. In particular, hospital wastewater is typical source containing a large amounts of pathogenic bacteria. At almost all the surveyed hospitals, the analyses of wastewater samples have shown that the total coliform ranged 10^6 10^7 MPN/100 mL (most probable number), exceeding several times versus the permissible standard

[2]. In addition, hospital wastewaters contain a number of germs, bacteria and other dangerious pathogenic types. Therefore, if the hospital wastewater without any effective treatment, these germs will be dispersed into the environment and the receiving water body, increasing the risk of disease outbreaks, causing serious impacts to the environment and public health. The specific contents of the wastewater are indicated in Table 1.

Table 1. Specific contents of the wastewater.

Parameter	Unit	Range	Specific value
pH	-	6,5-7,5	7,0
SS	mg/L	100 - 200	150
BOD_5	mg/L	120 – 250	200
COD	mg/L	150 - 350	300
Total Coliform	MPN/100 mL	10^6 - 10^9	10^6 - 10^7

Parallelly to the contaminant parameters of organic, nitrogen and bacteria, the hospital wastewater also contains some heavy metal elements with small amounts, such as manganese, copper, mercury, chromium.... However, the analyses of heavy metals in hospital wastewater usually indicate that their concentrations are smaller than the standard (QCVN 28: 2010/BTNMT) allowance [3].

Any applied technique for hospital wastewater treatment has to respond to the available conditions and operating costs, which is an issue that needs to solve in reality. Presently, many hospitals are equipped with large scale and modern technique, but the operation encounters many difficulties due to the complicated technology, the cost per unit of wastewater treatment is too high. Therefore, almost every system is lack of full capacity operating, inefficient or non-operation.

Currently, there are several technological groups to treat hospital wastewater, which can be summarized as the following: the tradiational aeroten activated sludge (AAS); submerged biological filter (SBF); sequencing batch reactor (SBR); anaerobic anoxic and oxic process (AAO); forced and air aeration; largoon and wetland [2, 4-6]. The general features of previous works (7-17) are compared with each others as for the advantages and disadvantages in Table 2.

Table 2. Comparison of technological groups for hospital watsewater treatment.

Technology	Avantages	Disadvantages
Aerobic activated sludge	- Treated water meets standards	- Often maintainance and spare part - High operation cost (sludge return and air flow) - Bacteria and foam (detergent) dispersion - High skill operation
Submerged biofilter	- None sludge return - Easy installation	- Inefficient when unstable electricity. - Uncontrolling for overall system

Biofilter	- Treated water meets standards - None sludge pumping and air blow - Low operation cost - Simple operation	- Yield depends on temperature
Largoon	- Low investment cost - Low operation cost	- Treated water missing standard - Large area - Efficiency depends on the weather - Uncontrol operation

Obviosly, each of the technologies has different characteristics, advantages and disadvantages, but the technological selection will associate with the operating conditions of a hospital. While surveying the wastewater treatment at Danang Rehabilitation – Sanatorium Hospital, we have proposed appropriate technology solution in oder to apply with the trickling biofilter with natural air supply for saving and low cost operation that will be presented in this paper.

2. EXPERIMENT

2.1. Wastewater

Experimental wastewater was collected from drainage of Danang Rehabilitation – Sanatorium Hospital. The specific parameters of the wastewater samples are indicated in Table 3.

Table 3. The specific parameters of wastewater of Danang Rehabilitation – Sanatorium Hospital Hospital.

No	Parameter	Unit	Value	QCVN 28:2010, Column B
1	pH	-	7.4	6.5 – 8.5
2	BOD_5 (20 °C)	mg/L	195	50
3	COD	mg/L	360	100
4	Total suspended solid (TSS)	mg/L	196	100
5	Ammonium (N)	mg/L	32	10
6	Nitrate (N)	mg/L	11	50
7	Phosphorus (P)	mg/L	13	10
8	Coliform	MPN/100 mL	25000	5000

2.2. Experimental pilot

2.2.1. Experimental system

Experiments were carried out in the innovative trickling biofilter system with designed capacity of 30 m^3 per day and the entire system is installed in the area of Danang Rehabilitation – Sanatorium Hospital in My An, Ngu Hanh Son, Danang City. The experimental diagram is illustrated in Figure 1. The parameters such as: environmental temperature; iner reactor temperature, pH in and outlet, COD, BOD_5, $N\text{-}NH_4^+$, NO_3^-, TSS and Coliform were measured four times per day and during ninety days in total.

2.2.2. Experiment procedure

Wastewater is drainaged to the grit chamber and equalization tanks with designal capacity of 1.5 and 7.5 m^3, then pumped in to the first settling tank (reactor diameter: D = 1.28 m; settling area height: HS = 2.5; diameter of reactor area: d = 4.2 m; settling velocity: Vs = 1.25 m/h), where coagulant and wastewater are mixed; after that watstewater continues running into the main trickling biofilter (biofilter tower) system (iner diameter of 1.2 m; mediafilter height of 2.5 m and media volume of 3.39 m^3), where wastewater is dispersed by water dispersion frame. The experiment was carried out in the environmental temperature at summer time (34-39 ^oC).

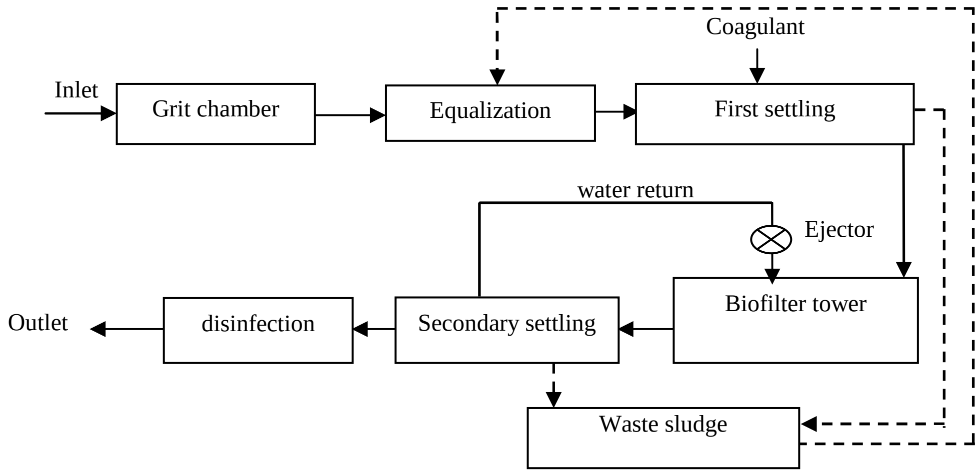

Figure 1. Trickling biofilter system at Danang Rehabilitation – Sanatorium Hospital.

2.2.3. Technical characteristics and operation of ejector

To enhance the capacity of air sucking and increase performance of the biofilter tower, the wastewater distribution structure was computed accurately and disposed supplement ventilation by ejector installing on the return pump line (wastewater is circulated around 30 %). Because of the creating negative pressure of ejector in the space of nozzle section, the air was sucked into its empty chamber. This supplement would rise the wastewater pressure into the biofilter tower and induce low temperature inside. Hence, this could also increase the air sucking by temperature disparity between watewater and envinronment.

2.2.4. Biological media used in the biofilter tower

Biological filter media used in this study was a media block that is made of PVC materials (density of 100 kg/m^3, 90-97% porosity and surface of 220 - 250 m^2/m^3). The size of the block was 0.5 * 0.5 * 0.5 m including corrugated plastic panels in two opposite directions, and the wave height of 60 mm (Figure 2). The advantages of this type are uniform thickness; high air circulation; high surface attached of microorganism; uniform wastewater distribution; low installation and maintenance cost; large exposed surface; chemical resistance; high durability and reducing system clogging.

Figure 2. The media biofilter.

To shorten the time for installation system, the entire block was soaked into the equalization tank, which induced the microorganisms attaching to the surface of the filter media and this step was processed in 30 days. After that the filter media was placed inside the biofilter tower. After completing the system installation, all the experiments were tested with loads varying from 2.5 to 4 kg BOD_5/m^3/day. At each loading, the experiment was conducted in a period to achieve stable results of measurement. The daily monitoring parameters such as pH; temperature; flow; organic and nutrient removal (COD, BOD_5, NO_3^-, NH_4^+) efficiencies were examined.

2.3. Analysis methodology

Wastewater samples were collected and stored in the insulated box and transported to the laboratory, then stored in a refrigerator at 4 °C (the Danang Environmental Technology Center) to measure and analyze parameters as follows:

- COD was determined by using potassium dichromate method according to ISO 6491: 1999 on ECO25 COD reactor, Velp, Italy.

- BOD_5 was determined by dilution and additional transplants allithioure according to TCVN and incubation in FOC225I, Velp, Italy.

- pH and temperature were measured with pH TOADKK meter, Japan.

- Total suspended solids were determined by filtering method according to TCVN 6625: 2000.

- Ammonium nitrogen was determined by indophenol standard using a Cannon 6179-1: 1996 and optical measuring system by a device of Shimazu UV-VIS 2450, Japan.

- Nitrogen-nitrate was determined by spectrometry using standard acid sunfosalixylic 6180-1996 and optical measuring system by a device of Shimazu UV-VIS 2450, Japan.

- Phosphorus content was determined according to ISO 6202: 2008 - spectrometric method using ammonium molybdate.

- Coliform bacteria was estimated by identifying and counting according to ISO 6187-2: 1996.

2.4. Methods of statistical data treatment

All the obtained results were conducted by taking mean value that reflects precision and errors of the data. All the data presented in the tables and figures were treated by using statistics of Microsoft Excel software.

3. RESULTS AND DISCUSSION

3.1. COD removal efficiency

The variation of COD load and COD removal treatment efficiency is shown in Figure 3.

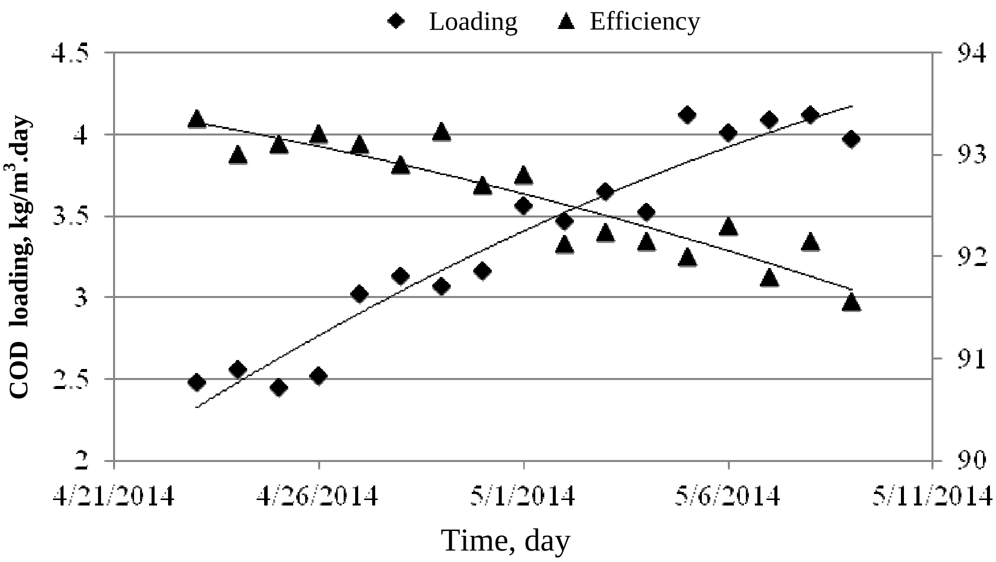

Figure 3. Variation of COD loading and removal efficiency over a period of 16 days.

As shown by the results in Figure 3, when increasing the COD load from 2.5 to 3.0 kg COD/m^3.day the COD removal efficiency reaches average value of 93 %. This efficiency a lit bit decreases to about 91 - 92 %, while COD loading rises from 3.5 to 4 kg COD/m^3.day, which is corresponding to the COD concentration of in and outlets at 350 and 30 mg/L. Basing on these achieved values, it could be inferred linearly as the COD removal reaching around of 90 % at 5 kg/m^3.day.

3.2. BOD_5 removal efficiency

The resulting values in Figure 4 show that the BOD_5 removal efficiency achieves 94 % at loading of 2.5 to 3.0 kg/m^3.day. However, this efficiency reduces of around 6 % versus previous reloading, while increasing the BOD_5 load of 4 kg/m^3.day, that is corresponding to in and outlets COD concentration of 184 and 17.4 mg/L, respectively. Referring to the regulation at column A of QCVN 28:2010/BTNMT [3], the BOD_5 concentration of treated water is below that BOD_5 loading of 4 kg/m^3.day. The obtained data in this work figure out that the trickling biofilter system at Danang Rehabilitation – Sanatorium Hospital is appropriate to the loading of 4 kg COD/m^3.day.

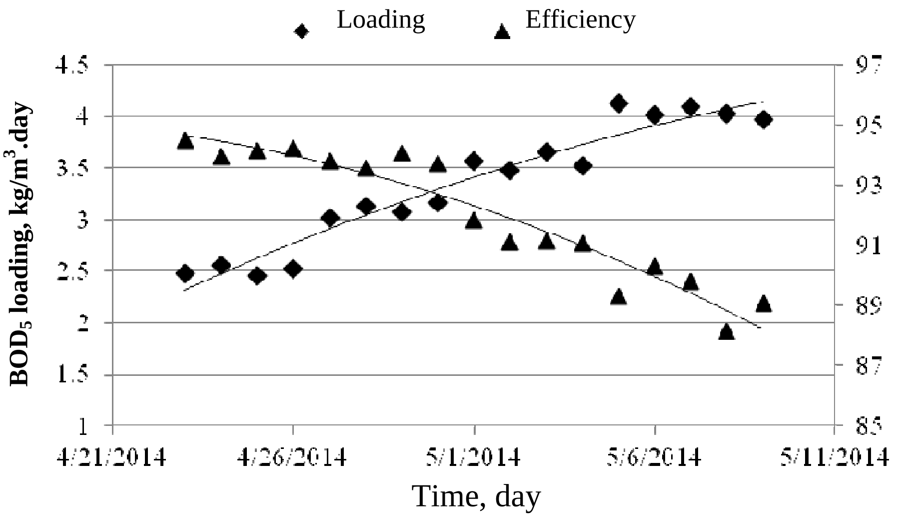

Figure 4. Variation of BOD_5 loading and removal efficiency over a period of 16 days.

3.3. N-NH_4^+ removal efficiency

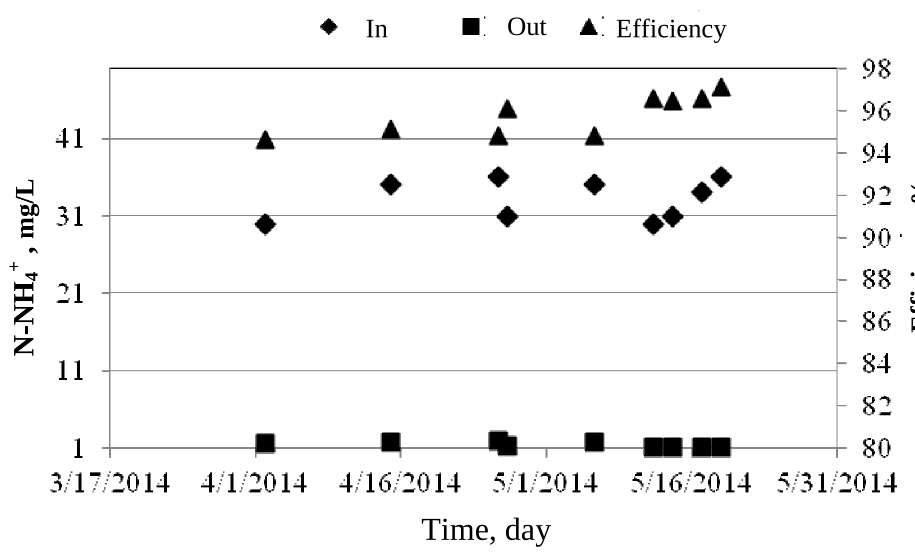

Figure 5. N-NH_4^+ removal efficiency.

Hospital wastewater often contains dominant organic matter, microorganism and high nitrogen concentration [6]. Hence, nitrogen is also focused on moving out in this study. Trickling filter with ejector system, this aims to return treated water at secondary settling tank to biofilter tower again. This process could enhance nitrification; denitrification and organic removal occurring, thus, this is the key of innovative point in this study (Figure 5). As demonstrated by this figure, the $N\text{-}NH_4^+$ concentration in treated water of 1.4 mg/L was removed virtually and totally at oulet, which corresponds to a removal efficiency of 98 %.

3.4. $N\text{-}NO_3^-$ removal efficiency

Relationship between $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$ is always associate by *Nitrosomonas* and *Nitrosobacter* bacteria [6], which participates in ammonia into nitrate content metabolic process. Thus, this is affirmed that the entire microorganism attached on the surface of filter media done well their roles of nitrogen transfer.

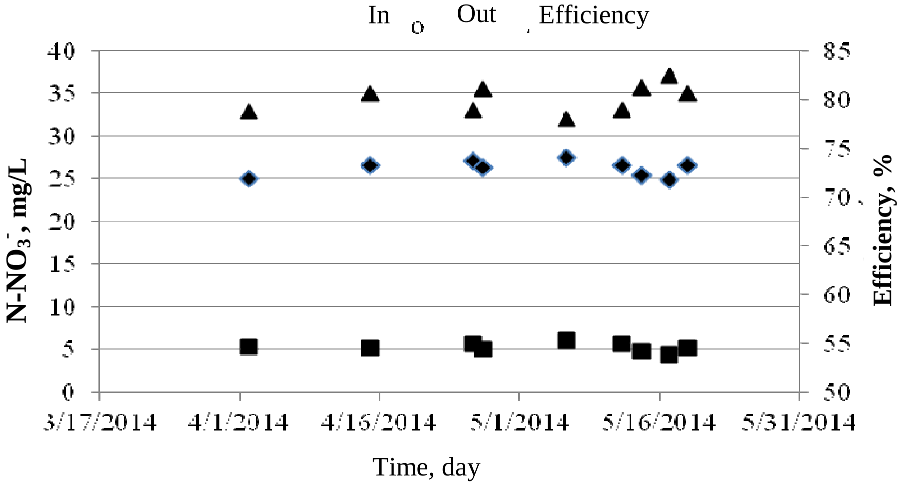

Figure 6. $N\text{-}NO_3^-$ removal efficiency.

Table 4. Evaluation of parameters for in and outlets system of Danang Rehabilitation – Sanatorium Hospital.

TT	Parameter	Unit	Inlet	Outlet	QCVN 28:2010 Column A
1	pH	-	7.8	7.6	6.5 – 8.5
2	BOD_5 (20 °C)	mg/L	184	17.4	30
3	COD	mg/L	360.8	19.9	50
4	TSS	mg/L	185	34	50
5	Ammonium	mg/L	33.1	1.38	5
6	Nitrate	mg/L	26.2	5.20	30
7	Phosphorus	mg/L	12.60	5.45	6
8	Coliform	MPN/100 mL	26000	920	5000

The part of *Nitrosomonas* inside the system did convert N-NO_3^- into N_2 with quite high efficiency (80 %) within the average value of in and outlet at 26.2 and 5.2 mg/L. The observed outlet concentration could indicate that the innovative trickling filter responds well the regulation of QCVN 28:2010/BTNMT (A column) for hospital wastewater treatment. The high efficiency of N-NO_3^- and other removal parameters are also illustrated in the Table 4.

The overall data mentioned in Table 4 show lower value than that allowed by QCVN 28:2010/BTNMT, column A.

3.5. Evaluation of ejector application

In order to evaluate ejector efficiency, the ejector experiments with and without operation were conducted in this study. Each experiment was tested for 15 days measuring the outlet parameter (see Table 5).

Table 5. Evaluation of ejector efficiency.

Parameter	Biofilter tower	Secondary Settling	Reservoir tank	Disinfected tank	Efficiency
Without ejector					
COD (mg/L)	34	28	26	25	
NO_3^- (mg/L)	14	7.13	7.0	7.0	
PO_4^{3-} (mg/L)	6.0	6.0	6.0	6.0	
Ejector					
COD (mg/L)	27.5	26	20	20	20 %
NO_3^- (mg/L)	10.4	5.7	5.2	5.2	26 %
PO_4^{3-} (mg/L)	6.0	5.4	5.4	5.4	10 %

Comparison of the results is presented in Table 5 that shows a significant difference between the experiments done with and without ejector for organic (COD) and nutrients (NO_3^- and PO_4^{3-}) removal efficiencies. It is clear to note an increasing value with ejector operation of 20, 26 and 10 %, respectively. This can be confirm the role of ejector system that shows the key for enhancing more efficiency.

3.6. Evaluation of treated wastewater cost

Table 6. Total cost of 1 m^3 treated wastewater.

TT	Item	Cost (VND)
1	Energy	1,246.8
2	Chemical	135.8
3	Labour	757.6
Treated wastewater (VND/m^3.day)		2,140.2

Total actual costs of treated wastewater were calculated and assessed by the approval council of Vietnam Academy of Science and Technology (see Table 6) [18], which indicate that the innovative trickling biofilter for hospital wastewater treatment is an appropriate and of lower cost application. And this is an advantage to practical implementation.

4. CONCLUSIONS

The application of innovative trickling biofiter system has improved efficiency and operation stability in outdoor conditions of Danang Rehabilitation – Sanatorium Hospital wastewater and regarding from the above obtained data in this work, the authors give some conclusions as following:

- The COD and BOD_5 removal efficiency achieved higher loading of 4 kg/m^3.day, corresponding to over 90 % and 88 – 94 %, respectively.

- The combination of ejector showed the entire amount $N\text{-}NH_4^+$ were metabolished and remained in outlet treated water of 1.38 mg/L.

- $N\text{-}NO_3^-$ denitrification efficiency of system reached 80 %, corresponding to an in and outlets of 26.2 and 5.2 mg/L, respectively. The overall parameters of treated water are below the standards allowed in column A of QCVN 28: 2010/BTNMT.

- The cost for a wastewater treatment unit is computed to be at 2,354 VND.

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TÓM TẮT

PHƯƠNG PHÁP LỌC SINH HỌC CẢI TIẾN TRONG XỬ LÍ NƯỚC THẢI BỆNH VIỆN

Đỗ Văn Mạnh[1,*], Trần Văn Hòa[1], Huỳnh Đức Long[1], Trương Thị Hòa[1], Hoàng Lương[2]

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Hệ thống lọc sinh học cải tiến được ứng dụng trong nghiên cứu xử lí nước thải tại Bệnh viện Điều dưỡng và Phục hồi chức năng thành phố Đà Nẵng. Kết quả nghiên cứu đã chỉ ra cho thấy với tải lượng COD và BOD_5 ở mức 2,5 - 4 kg/m^3.ngày, hiệu suất xử lí của hệ thống đều đạt trên 90 %. Nồng độ $N\text{-}NH_4^+$ và $N\text{-}NO_3^-$ trong nước thải đầu vào của hệ thống ở mức khá cao lên đến 33,1 và 26,2 mg/l, tuy nhiên sau quá trình xử lí thì hàm lượng còn lại trong nước thải đầu ra chỉ còn 1,38 và 5,2 mg/l, tương ứng với hiệu suất loại bỏ $N\text{-}NH_4^+$ và $N\text{-}NO_3^-$ lần lượt là 97 và 80 %. Bên cạnh đó các chỉ tiêu như tổng chất rắn lơ lửng, phốt phát và coliforms đều nằm dưới giới hạn cho phép xả thải tại cột A của tiêu chuẩn QCVN 28:2010/BTNMT. Từ số liệu thu được trong nghiên cứu, chúng tôi đánh giá hệ thống lọc sinh học cải tiến cấp khí tự nhiên rất phù hợp để xử lí nước thải ngành y tế và phù hợp với điều kiện kinh tế và vận hành tại Việt Nam.

Từ khóa: lọc sinh học nhỏ giọt, nước thải y tế, công nghệ xử lí nước thải.