SUITABILITY OF THE HOSPITAL WASTEWATER TREATMENT SYSTEM IN BINH DUONG PROVINCE TO THE ENVIRONMENTAL CARRYING CAPACITY

Dao Minh Trung[(1)]

(1) Thu Dau Mot University

Corresponding author: trungdm@tdmu.edu.vn

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Abstract

As the number of healthcare facilities increases, stringent management of wastewater treatment systems becomes imperative. This study investigates a wastewater treatment system designed for a general clinic in Bình Dương Province, Vietnam, which complies with Vietnamese environmental standards. The clinic, located in Bến Cát City, serves approximately 200 patients per day and generates an average wastewater volume of 1.7m³/day. The treatment system, with a capacity of 10m³/day, employs a combination of biological and chemical methods, including anoxic and aerobic processes, to efficiently reduce pollutants. Results indicate that the treated wastewater meets the QCVN 28:2010/BTNMT, column A standards, ensuring minimal environmental impact when discharged into the Thi Tinh River. The study demonstrates the system's effectiveness in managing hospital wastewater, contributing to environmental protection and public health.

Keywords: Bình Dương, biological treatment, chemical treatment, environmental standards, hospital wastewater, public health, treatment system, Vietnam

1. Introduction

Hospital wastewater is a specific type of effluent generated from medical activities, including diagnosis, treatment, care, and medical research. It is one of the most hazardous types of wastewater due to its content of various chemicals, bacteria, viruses, and other toxic substances. The composition of hospital wastewater is complex and diverse, including organic and inorganic substances, pathogenic microorganisms, unused pharmaceuticals, disinfectants, and heavy metals (Gupta et al., 2020; Verlicchi et al., 2010). Improper treatment of hospital wastewater can lead to severe consequences for both human health and the environment. Wastewater containing pathogenic microorganisms can cause dangerous outbreaks, directly impacting public health (Rabbani et al., 2017). The chemical substances and heavy metals in the wastewater can pollute water sources, soil, and air, resulting in the degradation of the living environment and ecosystems. Additionally, the residual antibiotics and pharmaceuticals can contribute to the development of antibiotic-resistant bacteria, posing a significant challenge to global healthcare (Kümmerer et al., 2009; WHO et al., 2012; Emmanuel et al., 2005). Currently, several treatment methods are employed to mitigate these impacts. Common methods include biological, chemical, and mechanical treatments. Biological treatment typically uses microorganisms to decompose organic substances in wastewater. Chemical treatment involves the use of strong oxidizing agents such as chlorine and ozone to disinfect and neutralize harmful substances (Seow et al., 2016; Sangamnere et al., 2023). Mechanical treatment usually combines processes like filtration, sedimentation, and precipitation to remove solid particles and impurities . These methods must be implemented continuously and comprehensively to ensure that the treated wastewater meets safety standards before being discharged into the environment (Pauwels et al., 2006; Threedeach et al., 2012).

As of the most recent data, Bình Dương province in Vietnam hosts a robust healthcare infrastructure. The development strategy of province includes continuous improvements and expansions in healthcare services to meet the increasing demands of its residents. As of recent reports, Bình Dương has 32 hospitals and medical centers providing various healthcare services to the local population. This strategic development in healthcare is crucial, given Bình Dương's growing industrial base and increasing population, which necessitates a well-established and responsive healthcare system to support both residents and the workforce in the region. As the number of healthcare facilities increases, the management of wastewater treatment systems must be more stringent. In this study, the author introduces a wastewater treatment system that meets Vietnamese standards and is suitable for environmental conditions.

2. Experimental

2.1. Research subjects

General Clinic in Ben Cat City, Binh Duong Province with an area of 1.960m^2, 15 beds, 200 visits/person/day.

2.2. Methods

Methods of collecting and analyzing data. Calculating the load according to Circular 76/2017/TT-BTNMT.

2.2.1. Calculating the maximum pollutant load of pollutants in the upstream and downstream

$$L_{td} \text{ (kg/day)} = Q_s \times C_{qc} \times 86.4$$

L_{td} (kg/day): Maximum load of surface water quality parameters;

Q_s (m^3/s): The flow rate of the river section needs to be assessed before receiving water;

C_{qc} (mg/L): The limit value of the pollutant concentration under consideration is specified in surface water quality standards to ensure the intended use of the water source being evaluated, QCVN 08:2023/BTNMT, level D;

86.4: Unit conversion factor from (m^3/s)×(mg/L) to (kg/day).

2.2.2. Calculating the load of existing water quality parameters in the receiving source

$$L_{nn} \text{ (kg/day)} = Q_s \times C_{nn} \times 86.4$$

L_{nn} (kg/day): A load of water quality parameters present in the water source;

Q_s (m^3/s): The flow rate of the river section needs to be assessed before receiving water;

C_{nn} (mg/L): Analyzing results of surface water quality parameters;

86.4: Unit conversion factor from (m^3/s)×(mg/L) to (kg/day).

2.2.3. Calculating the load of pollutant parameters in the wastewater source

$$L_t \text{ (kg/day)} = Q_t \times C_t \times 86.4$$

L_t (kg/day): Pollutant load in the waste source;

Q_t (m^3/s): Largest wastewater flow;

C_t (mg/L): Analyzing results of pollution parameters in wastewater discharged into the river;

86.4: Unit conversion factor from (m^3/s)×(mg/L) to (kg/day).

2.2.4. Calculating the ability to receive wastewater and the carrying capacity of the river

$$L_{tn} = (L_{td} - L_{nn} - L_t) \times F_s$$

L_{tn} (kg/day): The ability water source to absorb pollutant loads;

L_{td} (kg/day): Maximum load of surface water quality parameters;

L_{nn} (kg/day): A load of water quality parameters present in the water source;

L_t (kg/day): Pollutant load in the waste source.

F_s is a safety factor in the range of 0.3 - 0.7.

3. Results and discussion

The General Clinic relies on water supplied by Binh Duong Water - Environment Joint Stock Company for diverse purposes including the daily activities of employees, the medical treatment of 200 guests per day, daily living and patient treatment, and cleaning or washing medical instruments and equipment. According to current water demand, the average amount of water consumed per month is 51.3m^3, which equates to around 1.7m^3/day (calculated 30 days/month). In addition, the hospital uses water for fire prevention and suppression. This amount of water is not utilized on a regular or intermittent basis, hence it is not included in daily needs. The General Clinic has some ancillary structures including two separate systems: a water supply system and a rainwater collection and drainage system leading to the Cu Day Canal, Thi Tinh River (Figure 1); the collection system from the toilet is pre-treated in three-compartment septic tanks before going to the centralized treatment system; water collection system from the process of cleaning instruments, medical equipment, treatment activities, floor cleaning, and laundry is led directly to the centralized treatment system; and the drainage system after being treated is drained into Cu Day Canal. The wastewater collection facility is shown in Figure 2.

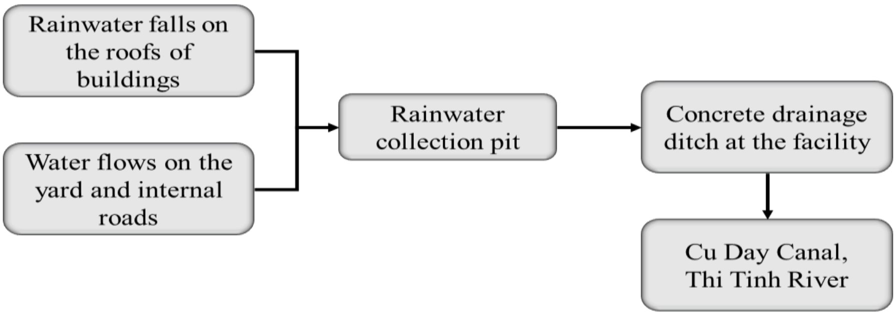

Figure 1. Diagram of water collection and drainage routes at the General Clinic

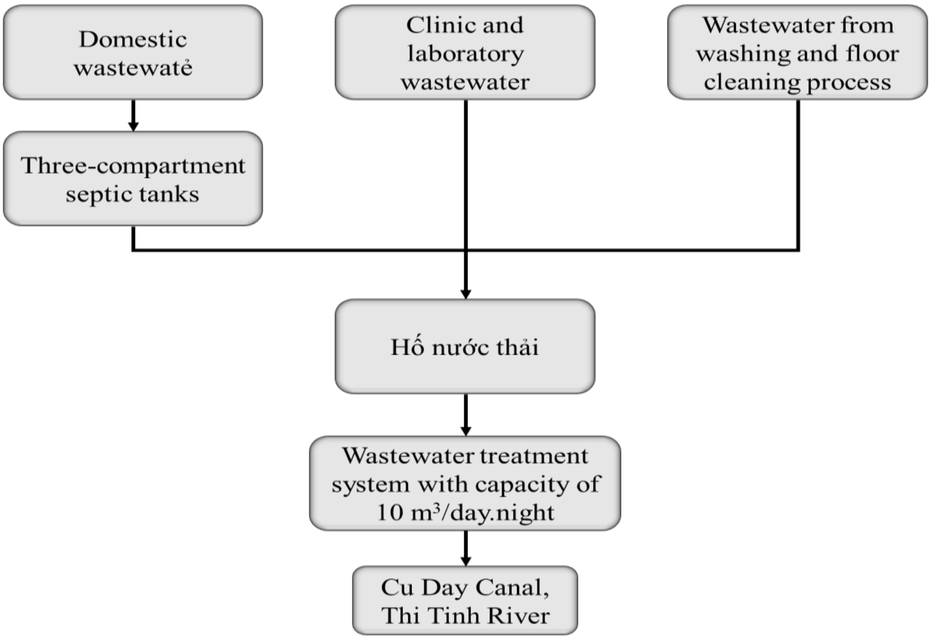

Figure 2. Diagram of actual wastewater collection at the facility

Domestic wastewater generated from septic tanks and medical activities will be directed to the collection tank. The collection tank has the effect of concentrating water sources into the wastewater treatment system. The wastewater then passes through intermediate tanks and leads to the main treatment system with a capacity of $10m^3$/day.night. The biological method is the main treatment method in the system. In the main treatment system, an anoxic equalization tank plays a role in regulating the flow and concentration of wastewater, creating a stable working regime for the works behind it, and avoiding the phenomenon of the treatment system being overloaded. The two main bacterial strains involved in this process are *Nitrosonas* and *Nitrobacter* (Gee et al., 1987; Bao et al., 2023). In an oxygen-deficient environment, these bacterial strains will reduce Nitrate (NO_3^-) and Nitrite (NO_2^-) to create N_2 to escape from the water according to the metabolic chain (Tiso et al., 2015) (chain 1):

$$NH_4^+ \rightarrow NO_3^- \rightarrow NO_2^- \rightarrow N_2O \rightarrow N_2\uparrow \text{ (\textit{chain 1})}$$

Organic compounds containing phosphorus will be converted by the *Acinetobacter* bacteria into new compounds that do not contain phosphorus and compounds that contain phosphorus but are easily decomposed by aerobic bacteria (Cho et al., 1985). For the smoothing process of nitrification and phosphorization, the anoxic equalization tank is equipped with a submersible pump with the function of stirring the water flow, creating an oxygen-deficient environment for the development of anoxic microorganisms. In the aerobic tank, microorganisms will receive oxygen and convert organic compounds into food, increasing biomass and reducing the pollution load in wastewater to the lowest level. To ensure that oxygen and nutrients are always enough for microorganisms to survive and grow (Samer et al., 2015). Oxygen will be continuously supplied to the tank for 24/24 hours, and nutrients will be supplied periodically (If the concentration of nutrients in the wastewater is not enough). Organic compounds in wastewater will be consumed by aerobic microorganisms in the tanks according to the following equation (Reineke et al., 2001):

Aerobic microorganisms + Organic compounds + O_2 + biomass (*chain 2*)

Water leaving the biological tank has COD and BOD5 content reduced by 80-95%. After being biologically treated in the aerobic biological tank, wastewater along with sludge will flow into the biological sedimentation tank (Mason et al., 1997; Ehrig et al., 1992). At the settling tank, the gravity settling process occurs, the activated sludge settles to the bottom of the tank, and the clear water through the water collection trough will lead to the disinfection tank. In the disinfection tank, chlorine is added to the tank to remove bacteria in the water. Ensure the output wastewater meets QCVN 28:2010/BTNMT, column A. The technological process of the wastewater treatment system is shown in Figure 3.

According to calculations, the largest amount of wastewater generated can be $5.6m^3$/day.night, that equivalent to $0.00006m^3/s$. The average flow rate of Thi Tinh River is about $9.64m^3/s$ (synthetic report on the Project to develop regulations for zoning discharge of canals, rivers and streams in Binh Duong province). Therefore, water from General Clinic discharge into Thi Tinh River causes the flow of river increase insignificantly. In addition, the discharge regime of General Clinic into Thi Tinh River is in the form of surface discharge, thus the impacts on the river bed are almost non-existent. To evaluate the receiving capacity of Thi Tinh River for wastewater generated from the General Clinic. They conducts monitoring of wastewater quality after the treatment system and surface water at Thi Tinh River 30m downstream from the discharge location periodically once a year. The monitoring results meets the standard of QCVN 28:2010/BTNMT, column A, K = 1.2 and wastewater quality after treatment system meets the standard of QCVN 08:2023/BTNMT, level D, both are shown in Table 1.

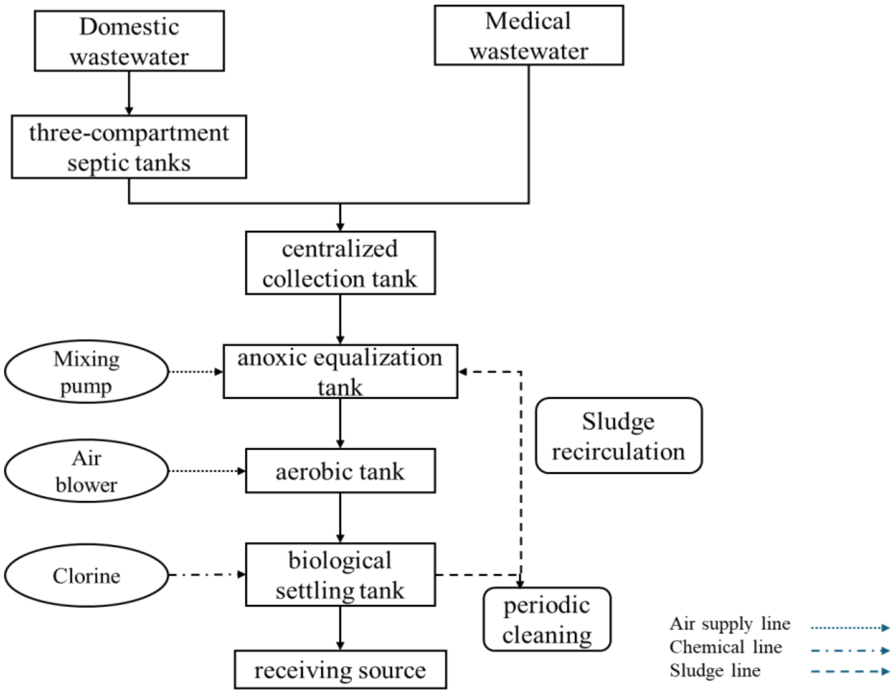

Figure 3. Technological process of wastewater treatment system.

TABLE 1. Results of monitoring and water treatment.

No	Parameters	Unit	Result water after treatment	QCVN 28:2010/BTNMT, column A, K = 1,2	Monitoring results	QCVN 08:2023/BTNMT, level D
1	pH	--	6.23	6.5-8.5	6.58	< 6.0 or > 8.5
2	TSS	mg/L	47	60	KPH	> 5
3	BOD_5	mg/L	30	36	8	> 10
4	COD	mg/L	83	120	16	> 20
5	Amoni	mg/L	4.9	6	0.23	0.3
6	Nitrat	mg/L	4.8	36	3.2	--
7	Phosphate	mg/L	3.4	7.2	KPH	--
8	Coliform	MPN/100mL	2.700	3.000	4.700	7.500
9	DO	mg/L	--	--	5.23	≥ 2

To calculate the wastewater receiving capacity of the facility at Thi Tinh River. Calculation of the maximum pollutant load of pollutants in the upstream and downstream, calculation of a load of existing water quality parameters in the receiving source, calculation of load of pollutant parameters in the wastewater source, calculating the ability to receive wastewater and carrying capacity of the river according to Circular 76/2017/TT-BTNMT dated December 29, 2017 was carried out and presented in Table 2 with green, blue and oragne column, respectively.

Table 2. Calculate the wastewater receiving capacity of Thi Tinh river

No	Parameters	Q (m^3/s)			C (mg/L)			L (kg/day)		
		Q_s	Q_s	Q_t	C_{qc}	C_{nn}	C_t	L_{td}	L_{nn}	L_t
1	TSS	9.64	9.64	0.00006	15	KPH	46	12.493	-	0.24
2	BOD_5	9.64	9.64	0.00006	10	8	29	8.329	6.663	0.15
3	COD	9.64	9.64	0.00006	20	15	82	16.658	12.495	0.43
4	Amoni	9.64	9.64	0.00006	0.3	0.22	4.8	250	183	0.025
5	Nitrat	9.64	9.64	0.00006	--	3.2	4.7	--	2.669	0.024
6	Phosphate	9.64	9.64	0.00006	--	KPH	3.3	--	--	0.017
7	Coliform	9.64	9.64	0.00006	7.500	4.700	2.700	6.246.720	3.915.611	13.4

The ability of a water source to receive the pollution load for a specific pollutant from a single discharge point is calculated according to the formula:

$$L_{tn} = (L_{td} - L_{nn} - L_{t}) \times F_{s}$$

The table of calculation results above (Table 2) shows that the index L_{tn}, ability to receive pollutant load of the water source at Thi Tinh River has a value > 0, so the receiving water source is Thi Tinh River and still can receive wastewater from the General Clinic.

4. Conclusion

In conclusion, this study highlights the pivotal role of effective wastewater management in healthcare facilities, particularly in regions experiencing rapid urbanization and industrial growth such as Binh Duong Province, Vietnam. Focusing on a general clinic in Ben Cat City, the research presents a meticulously designed wastewater treatment system that complies with Vietnamese environmental standards. Through a synergistic blend of biological and chemical processes, this system adeptly mitigates the diverse array of pollutants found in hospital wastewater, thereby ensuring minimal environmental impact upon discharge into the Thi Tinh River. The consistent adherence to regulatory requirements underscores the system's efficacy, validating its capability to safeguard both public health and environmental integrity. Furthermore, the study underscores the importance of ongoing monitoring and strict adherence to safety standards in wastewater management practices. By implementing comprehensive treatment methods and conducting regular assessments, healthcare facilities can effectively mitigate the risks associated with hospital wastewater, thereby contributing to the broader goals of environmental sustainability and community well-being. Ultimately, this research serves as a valuable blueprint for other healthcare institutions seeking to implement robust wastewater treatment systems, fostering healthier communities and ecosystems in the process.

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