EVALUATING WASTEWATER TREATMENT EFFICIENCY OF MEDICAL CENTERS IN BINH DUONG PROVINCE

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Abstract

This paper presents a comprehensive analysis of the wastewater management system implemented at a medical center located within the Bau Bang Industrial Park in Binh Duong province, Vietnam. With a staff of 166 and 60 beds, the facility operates in accordance with TCVN 4470:2012 General Hospital design standards, serving a diverse range of water demands including domestic, medical, and auxiliary requirements. The wastewater management system is meticulously designed to handle both rainwater and wastewater separately. Rainwater is efficiently collected through surface and roof drainage networks, while domestic and medical wastewater undergo discrete collection processes. The medical center's wastewater treatment facility, operating at a capacity of 100 m³/day, employs a multistage treatment process to ensure compliance with stringent regulatory standards (QCVN 28:2010/BTNMT, column B, K = 1). This process includes preliminary treatment, anaerobic and aerobic biological treatment, membrane filtration, and disinfection. The facility consistently meets quality parameters outlined in QCVN 28:2010/BTNMT, exhibiting effective removal rates for organic pollutants, suspended solids, ammonia, phosphates, and pathogens. Furthermore, the medical center demonstrates commendable environmental stewardship through its stormwater drainage infrastructure, which integrates seamlessly with the local drainage network, safeguarding against environmental contamination. Overall, the wastewater management practices at the medical center exemplify best practices in environmental management within the healthcare sector. This study provides valuable insights into the design, implementation, and performance evaluation of wastewater treatment systems in industrial settings, contributing to the global discourse on sustainable wastewater management practices.

Keywords: Bình Dương, biological treatment, environmental standards, medical center wastewater, treatment system, Vietnam

1. Introduction

Hospital wastewater is a specialized type of wastewater originating from healthcare and medical activities within healthcare facilities such as hospitals, clinics, and medical centers. Unlike typical domestic wastewater, hospital wastewater often contains a multitude of hazardous and potentially infectious substances, particularly from medical treatment, handling, and disposal of medical wastes (Pauwels et al., 2006; Yan et al., 2020; Verlicchi et al., 2018). The composition of hospital wastewater typically includes a variety of organic and chemical compounds, pathogenic microorganisms, and various residues from activities such as surgeries, medical testing, sterilization and processing of medical equipment, and personal hygiene. Common constituents found in hospital wastewater include pharmaceuticals, oils, fats, proteins, sugars, salts, and pathogenic microorganisms such as bacteria, viruses, and fungi (Li et al., 1993; Kumarathilaka et al., 2015; Szekeres et al., 2017). The hazards associated with hospital wastewater include increased risk of environmental pollution and potential harm to human health and organisms in the environment. Hospital wastewater contains hazardous substances that can pose dangers to human health through direct contact or through the contamination of water and food sources. Additionally, pathogenic microorganisms in wastewater can spread infectious diseases through environmental exposure routes (Frédéric et al., 2014; Khan et al., 2021; Zang et al., 2020; Mendoza et al., 2015). The management of wastewater is of paramount importance in contemporary society, particularly in industrialized regions where the discharge of pollutants can pose significant risks to public health and environmental integrity. Within this context, the effective treatment of wastewater becomes imperative, especially in specialized facilities such as medical centers, where diverse and complex contaminants may be present. This paper provides an in-depth examination of the wastewater management system implemented at a prominent medical center located within the Bau Bang Industrial Park in Binh Duong province, Vietnam. With a staff comprising 166 officers and employees, and equipped with 60 beds, the medical center plays a crucial role in providing healthcare services to the local community. However, the operation of such facilities necessitates a considerable demand for water, encompassing domestic usage, medical procedures, laboratory testing, and ancillary activities. Consequently, the effective management of wastewater becomes essential to ensure compliance with regulatory standards, protect public health, and mitigate environmental impacts.In line with the principles outlined in TCVN 4470:2012 General Hospital design requirements by the Ministry of Science and Technology, the medical center's wastewater management infrastructure is meticulously designed to address the diverse water demands and stringent regulatory requirements. The facility's water supply primarily relies on the services of the Binh Duong Water Environment Joint Stock Company, with an average usage flow of 28 m^3/day and night.The wastewater management system encompasses a multifaceted approach, involving the separate collection and treatment of rainwater, domestic wastewater, and medical effluents. Rainwater runoff is efficiently collected through a network of surface and roof drainage systems, ensuring rapid drainage and minimizing the risk of flooding. Conversely, domestic and medical wastewater streams are subject to discrete collection processes, with measures in place to prevent cross-contamination and ensure the integrity of the treatment process.Central to the wastewater treatment infrastructure is a facility with a capacity of 100m^3/day, designed to meet the stringent quality standards outlined in QCVN 28:2010/BTNMT regulations. This facility employs a sophisticated treatment process, encompassing preliminary treatment, anaerobic and aerobic biological treatment, membrane filtration, and disinfection. Through this comprehensive approach, the facility aims to achieve high levels of pollutant removal, including organic matter, suspended solids, pathogens, ammonia, phosphates, and oils and fats. Moreover, the medical center demonstrates a commitment to environmental stewardship through its stormwater drainage infrastructure, which integrates seamlessly with the local drainage network. This closed drainage system not only prevents environmental contamination but also contributes to the sustainability of the surrounding ecosystem. By examining the design, operation, and performance of the medical center's wastewater management system, this paper seeks to provide valuable insights into the challenges and opportunities associated with wastewater treatment in industrial healthcare settings. Furthermore, the study underscores the importance of adopting sustainable practices and leveraging advanced technologies to address the evolving complexities of wastewater management in the 21st century. Through this interdisciplinary approach, the paper aims to contribute to the global discourse on sustainable development and environmental protection.

2. Experimental

2.1. Research subjects

The Medical Center in Bau Bang district has 100 beds with 5 Departments - Rooms, and 10 specialties. In 2023, the medical center received 84.501 medical examinations.

2.2. Methods

To evaluate the efficiency and performance of the wastewater treatment system implemented at the medical center in Bau Bang Industrial Park, an experimental study was conducted. The experiment aimed to assess the ability of medical center to treat both domestic and medical wastewater effectively while meeting regulatory standards:

(i) Sampling Strategy: Wastewater samples were collected from various points within the medical center's drainage and treatment system, including inflow points, treatment tanks, and treated water outlets. Sampling was conducted at regular intervals over a predetermined period to capture variations in wastewater composition and quality.

(ii) Characterization of Wastewater: Parameters such as pH, COD (Chemical Oxygen Demand), BOD5 (Biochemical Oxygen Demand), SS (Suspended Solids), ammonia, phosphate, oils and fats, nitrate, and coliform bacteria were analyzed in accordance with standard methods outlined in QCVN 28:2010/BTNMT.

(iii) Experimental Setup: Controlled experiments were conducted to simulate different operating conditions of the wastewater treatment system, including varying influent flow rates and pollutant loadings. Pilot-scale treatment units representing each stage of the treatment process (equalization tank, anaerobic tank, anoxic tank, aerobic treatment module, membrane filter tank, and disinfection tank) were operated under controlled conditions. Instrumentation and monitoring equipment were installed to measure parameters such as dissolved oxygen, temperature, and turbidity throughout the treatment process.

(iv) Data Collection and Analysis: Data on wastewater quality and treatment performance were collected continuously during the experiment. Statistical analysis techniques were applied to assess the correlation between influent characteristics and treatment efficiency. The removal efficiencies of organic pollutants, nutrients, and pathogens were calculated based on the difference between influent and effluent concentrations.

(v) Reporting: The results of the experimental study were documented in a comprehensive report, including detailed descriptions of the experimental setup, methodology, data analysis, and interpretation of results. Recommendations for optimization or improvement of the wastewater treatment system were provided based on the findings of the experiment.

3. Results and discussion

3.1. Introduction to the wastewater treatment system at the medical center

According to 2022 statistics, the Medical Center has 166 officers and employees, 60 beds. According to TCVN 4470:2012 General Hospital, design requirements of the Ministry of Science and Technology, the water demand is about $1m^3$/bed/day, including Domestic water for inpatients (including daily activities of 1 patient, 1 visitor, nurse, doctor, hospital staff and water supply for laundry), water for medical examination outpatient treatment, water for experiments, testing, toilet water for departments, laundry detergent, canteen, water for watering plants,....the water used for the Center is the water source of Binh Duong Water Environment Joint Stock Company with an average usage flow of 28m3/day and night (based on data compiled in 2022).

Currently, the water usage needs of the Medical Center in Bau Bang Industrial park mainly come from the daily needs of officials, employees, doctors, and patients; washing medical equipment, laundry, canteen, watering plants, and fire prevention,.... The local water supply system is supplied from the Bau Bang water plant branch, supplied to the underground water tank with a capacity of $378m^3$ by PPE pipeline Ө42. From the underground water tank, water is pumped to the $18m^3$ roof water tank using a PPE Ө42 pipe. From the roof water tank, water is distributed for use in the domestic water system along vertical pipes Ө60, Ө49. The three domestic pumps are pumps – Qb = $18m^3$/h, Hb = 50m, N = 6kw. Sanitary water supply pipes use PPE pipes. The waste treatment items of the medical center include:

(i) Rainwater drainage system: Based on the general planning of the Bau Bang urban area, Lai Uyen commune, Bau Bang district, Binh Duong province, there has been a rainwater drainage system built with a reinforced concrete sewer system of 1,000 square meters, so rainwater collected from the roof and collected surface water on the yard into manholes then led to the general drainage system.

(ii) Wastewater drainage system: The wastewater drainage system is designed separately from the rainwater drainage system. Fecal wastewater has been treated locally in the toilet areas (by a three-chamber septic tank) then along with lavabo wastewater, floor collection hopper, and medical wastewater is collected by a separate pipe system. All of this wastewater is collected by domestic wastewater sewers including sewers with reinforced concrete structures. All wastewater will be collected into the local wastewater treatment system meeting QCVN 28:2010/BTNMT, column B before being connected to the centralized wastewater treatment station of Bau Bang Industrial Park.

The center has built a wastewater treatment system with a capacity of $100m^3$/day.night on an area of $200m^2$. The treated wastewater meets the National Technical Regulations on Medical Wastewater QCVN 28:2010/BTNMT column B, k = 1, connected to the wastewater collection infrastructure of Bau Bang Industrial Park.

3.2. Measures for rainwater drainage, wastewater collection, and treatment

3.2.1. Water collection and drainage

The rainwater and wastewater collection system in the central campus is built separately into two separate systems. The yard area is concreted and has the necessary slope for rainwater to drain quickly. On the roofs of office buildings and garages, a rainwater collection system is arranged with uPVC pipes with a diameter of D90mm to collect all the rainwater generated into manholes around the hospital. Rainwater overflowing on the surface of internal roads, yards, etc. is collected by an underground stormwater drainage system along internal roads. All rainwater at the hospital will be collected separately by precast concrete circular drains with dimensions D168, D20, and D300mm, then flow into the drainage system of the Ben Van stream before draining into the Thi Tinh River. The drainage diagram is shown in Figure 1

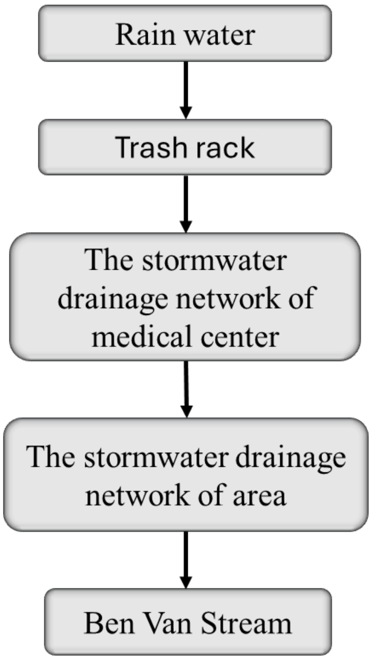

Figure 1. The drainage diagram of medical center

3.2.2. Wastewater collection and drainage

The wastewater collection system is designed and built separately from the rainwater drainage system, divided into two main subsystems: the Domestic Wastewater Collection System and the Medical Wastewater Collection System. Medical wastewater, which includes wastewater from operating rooms, laboratories, and similar facilities, is collected completely separately from domestic wastewater and is disinfected before being directed into the general collection pit of the wastewater treatment system. Domestic wastewater, after passing through septic tanks, along with wastewater from the cafeteria, is collected into the common collection pit. From this pit, the wastewater is transferred to an equalization tank and then treated through an aerobic biological tank and an anoxic tank. This process removes organic pollutants and reduces key indicators such as COD, BOD5, Ammonia, total Nitrogen, and SS. Finally, the wastewater is disinfected before being connected to the centralized wastewater treatment station of Bau Bang Industrial Park.

The treated wastewater of the wastewater treatment station with a capacity of 100m^3/day meets discharge standards QCVN 28:2010/BTNMT, column B (K = 1) will be transported by a 200mm diameter pipe, 144m long along road D9 according to Connected to a wastewater collection manhole, under the management of Bau Bang Industrial Park.

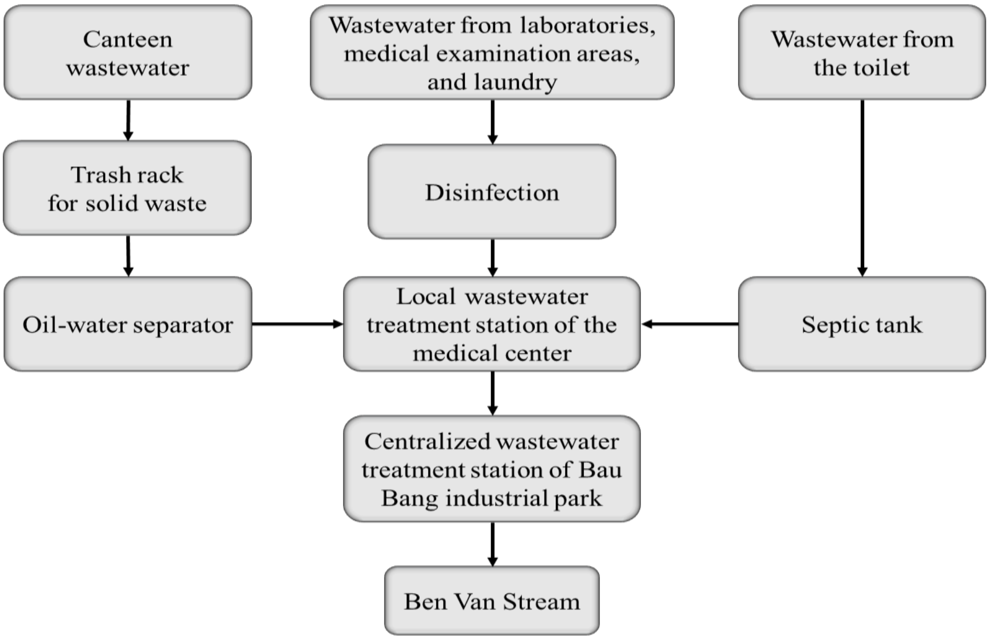

Figure 2. The wastewater collection system of the medical center.

3.2.3. Wastewater treatment technology

The wastewater treatment project with a capacity of 100 m^3/day has been built and operated since 2020. The treated wastewater meets the National Technical Regulation on medical wastewater QCVN 28:2010/BTNMT, column B, K = 1. The treatment technology diagram of the medical center is shown in Figure 3. Wastewater is preliminarily treated by source (cafeteria wastewater was through an oil-water separator, and domestic wastewater was through a septic tank) and concentrated into the collection tank before being transferred to the equalization tank. At the equalization tank, there is an aeration system arranged at the bottom of the tank to aerate the wastewater and uniformly mix the wastewater before entering the next treatment steps. Water from the equalization tank is led through the anaerobic tank. In an anaerobic environment, anaerobic microorganisms will decompose organic compounds, and the value of COD, and BOD is significantly reduced. Next, the wastewater is directed to the anoxic tank. In the absence of oxygen or without aeration. Microorganisms decompose organic substances into simpler substances that are easier to process. This is the main process to reduce Nitrogen and Phosphorus in wastewater. Wastewater after being treated in the anoxic tank is pumped to the aerobic treatment module. In the aerobic tank, the aerobic biological treatment process takes place thanks to the amount of oxygen dissolved in the water with an appropriate amount of oxygen provided by a shallow air blower and air distribution system. Fine foam for activated sludge to decompose organic matter (BOD_5) in wastewater. In this tank, microorganisms existing in suspension will absorb oxygen, and organic compounds and use nutrients Nitrogen and Phosphorus to synthesize new cells and release energy. In addition to the process of synthesizing new cells, there is also an endogenous decomposition reaction that reduces the amount of activated sludge. However, the process of synthesizing new cells still dominates because optimal conditions are maintained in the tank, so a large amount of activated sludge is produced. To increase treatment efficiency, in the aerobic tank, it is necessary to install additional microbial substrates so that the attached aerobic organisms can grow and develop. Thus, the aerobic treatment process not only removes organic impurities (BOD_5) but also partially removes Nitrogen and Phosphorus in wastewater thanks to the process of synthesizing new cells. Microorganisms adhere, grow and develop on the surface of the microbial substrate. Oxygen gas is forcibly supplied to the conditioning tank and aerobic tank through a system of air distribution pipes and air distribution discs. To ensure the necessary amount of oxygen for the growth of microorganisms.

Wastewater after being treated through the aerobic tank is directed to the MBR membrane filter tank. Membrane filter tank replaces second sedimentation tank and filter, as well as reduces the load of disinfection tank (can replace disinfection tank): Wastewater passes through the MBR membrane filter tank, and the pollution parameters are always treated to ensure class A allowed standards. Next, the water is passed through the disinfection tank through the water collection system to completely eliminate the remaining pathogenic bacteria (Coliform).

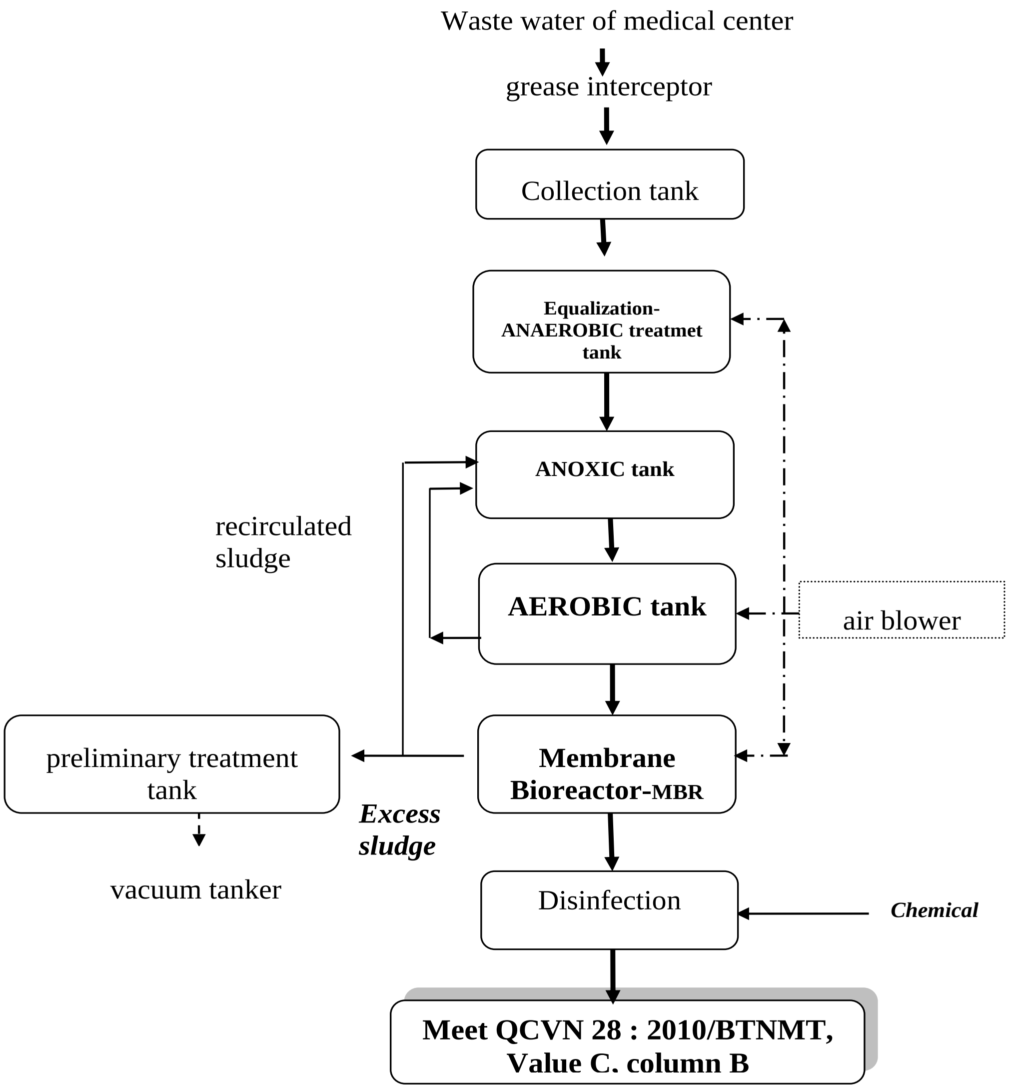

Figure 3. The wastewater treatment system of medical center

The paper aims to reflect the typical conditions of the system, therefore, the samples were collected at various points in the final modules of the treatment system over different time intervals. The quarterly water monitoring results in Table 1 are the average results. Anaerobic and aerobic biological processes, along with MBR (Membrane Bioreactor) filtration, are generally effective for treating a wide range of contaminants in medical wastewater. However, these methods might have limitations, such as their effectiveness against certain pharmaceuticals, heavy metals, and other persistent organic pollutants.

TABLE 1. Results of periodic wastewater quality monitoring for two years.

No	Parameters	Unit	Analysing results (a quarter of the year)							QCVN 28:2010/ BTNMT column B K= 1
			1/2021	2/2021	3/2021	1/2022	2/2022	3/2022	4/2022	
1	pH	-	6.8	7.1	6.8	6.9	6.9	6.9	-	**6.5 – 8.5**
2	COD	mgO_2/L	13	18	13	13	13	22	-	**60**
3	BOD_5	mgO_2/L	6	7	6	6	6	10	-	**120**
4	SS	mg/L	5	11	31	8	7	56	-	**120**
5	Amoni	mg/L	<0.14	0.28	0.56	0.14	0.14	0.49	-	**4.8**
6	Phosphate	mg/L	0,1	0.09	0.07	0.04	0.05	0.15	-	**12**
7	Oils and fats	mg/L	0.3	<0.3	<0.3	<0.3	<0.3	<0.3	-	**60**
8	Nitrate	mg/L	0.3	1.8	1.4	0.2	0.4	0.5	-	**12**
9	Coliform	MPN/ 100mL	280	230	1.500	640	430	750	-	**24**
12	Salmonella	Bacteria/ 100mL	KPH	KPH	KPH	KPH	KPH	KPH	KPH	**5.000**
13	Shigella	Bacteria/ 100mL	KPH	KPH	KPH	KPH	KPH	KPH	KPH	**KPH**
14	Vibrio Cholearae	Bacteria/ 100mL	KPH	KPH	KPH	KPH	KPH	KPH	KPH	**KPH**

3.3. The suitability of the facility for the environment-carrying capacity

3.3.1. The suitability for the area's stormwater drainage system of medical center

Around the medical center, drainage infrastructure has been built completely and separately from wastewater. A closed drainage ditch system around the buildings, concentrating rainwater from the roof down into the ditches, flowing into manholes connected to the underground sewer network, continuing to flow into the general drainage line of Bau Bang Industrial Park, and to the centralized wastewater treatment system, then drains into Ben Van stream - flows into Ba Lang river, then into Thi Tinh river and flows into Saigon river

3.3.2. The suitability for wastewater collection and treatment system of the medical center

Wastewater generated from the operations of the medical center will be collected separately and directed to the wastewater treatment system of $100m^3$/day for preliminary treatment to meet QCVN 28:2010/BTNMT column B, k = 1 then will be treated. Then, treated water is led by a 600mm diameter pipe, 6m long to connect to the water collection manhole on D9 road, under the management of Bau Bang Industrial Park to Bau Bang Industrial Park's wastewater treatment station for further treatment to meet QCVN 40:2011/ BTNMT, column A → Ben Van stream → Ba Lang stream → Thi Tinh river. Thus, the rainwater and wastewater drainage needs of Bau Bang District Medical Center are within the ability of the local drainage collection system to meet.

Wastewater after treatment by the wastewater treatment cooperative of Bau Bang District Medical Center → connected to the wastewater treatment station of Bau Bang Industrial Park for further treatment to meet QCVN 40:2011/BTNMT column A → Ben Van stream → Ba Lang stream → Thi Tinh River. Ben Van Stream is a drainage stream of the area used for irrigation and drainage purposes and is not used for domestic water supply purposes. The final receiving source is the Saigon River used for domestic water supply purposes. The calculated flow from the Ben Van stream to the Thi Tinh river is about $3m^3/s$. The estimated maximum discharge flow at Bau Bang District Medical Center is $100m^3$/day and night (about $0.0012m^3/s$), accounting for a very small flow compared to the drainage capacity of the Ben Van stream into Thi Tinh River.

4. CONCLUSION

The wastewater treatment system outlined for the medical center exemplifies a comprehensive approach to managing both domestic and medical wastewater. Through separate collection systems and multi-stage treatment processes, the facility ensures the safe disposal of wastewater while meeting stringent regulatory standards. By effectively treating wastewater before discharge, the medical center not only protects the local environment but also safeguards public health. Moreover, the system's compatibility with existing drainage infrastructure underscores its commitment to environmental sustainability and responsible resource management. As nations worldwide grapple with the challenges of wastewater management, the insights gleaned from this system can serve as a valuable blueprint for designing efficient and environmentally sound wastewater treatment solutions globally.

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