

TREATMENT EFFICIENCY OF GREYWATER THROUGH ANOXIC-AEROBIC BENCH SCALE UNIT

SM Labib Redwan¹

¹Department of Civil Engineering, Khulna University of Engineering & Technology (KUET),
Khulna-9203, Bangladesh

ABSTRACT

Wastewater treatment is vital for protecting environmental health, ensuring safe water supplies and managing industrial waste. The anoxic-aerobic process, a biological treatment method which degrades organic materials using suspended microorganisms. This study evaluates effluent discharge quality through COD and BOD removal efficiencies under varying Hydraulic Retention Times (HRT). The bench-scale setup included an equalizer tank, anoxic and aerobic glass tanks and a sedimentation basin as a secondary clarifier. The COD removal efficiency of the treatment unit is 80.57%, 42.49% and 35.12% for HRT of 3.45, 1.85 and 1.45 hours in the anoxic tank and 8.65, 4.65 and 3.6 hours in the aerobic tank. The BOD removal efficiency of the treatment unit is 75.7%, 52.49% and 50.5% with that HRTs respectively. This process is crucial for reducing environmental hazards, enabling water reuse for irrigation, and ensuring safe effluent discharge into natural water bodies.

Key words: Anoxic-Aerobic, HRT, Organic materials, Removal efficiency, Wastewater treatment.

INTRODUCTION

According to the United Nation's Wastewater Development Report (UNWDR), around 3857.3 trillion m³ of freshwater is consumed annually, with agriculture utilizing approximately 44% of this water via irrigation and evaporation. The remaining 56% is discharged as wastewater, which includes 628 trillion m³ of industrial sewage and 314 trillion m³ of municipal wastewater [1]. 80% of the wastewater produced in developing countries is discharged into the environment untreated, even though over half of the world's population uses contaminated water sources to fulfill growing demand (UNESCO 2003). In several countries, households serve as the primary point source of nutrients in highly populated metropolitan areas. The amount of sanitation, the presence or absence of sewage infrastructure, and the quality of wastewater treatment all affect how much environmental strain is placed on the environment. Environmental and health policies at the federal level have a significant influence on sanitation improvement [2]. Before being discharged into water bodies or land, or used for irrigation and agriculture, municipal sewage and wastewater from multiple sectors must be collected, treated, and transported to a wastewater treatment plant to ensure the general public's health and access to clean water. The improper handling of industrial and municipal wastewater threatens the overall health of aquatic ecosystems. The quantity and caliber of wastewater generated by homes and companies differ greatly, and these wastewater effluents have high levels of chemical oxygen demand due to global industrialization and urbanization, which prioritize wastewater management more than in developing nations. Bangladesh, as a developing country, generates a huge amount of gray water from households and other sectors. Khulna being the 3rd largest city contributes to generate a huge amount of greywater and black water due to rapid industrialization. It has been noted that most of the water in the sewers originates from structures such as residences, eateries, hotels, colleges, and hospitals. The primary objective of treating municipal wastewater was to lower the amount of dangerous bacteria, dissolved inorganic compounds, suspended particles, and things that required oxygen. But in recent times, there has been a greater focus on developing methods for getting rid of the solid waste left over following municipal treatment procedures [3]. There are two types of biological wastewater treatment processes like activated sludge process and biofilm reactor process. Since biological treatment technologies are more effective in removing organic matter and nitrogen compounds than physicochemical technology, they are more extensively used [4]. However, reusing urban wastewater

provides a number of advantages for agriculture, such as lowering water use, repurposing nutrients, ensuring farmers have access to water supplies, and preventing surface water contamination.

The uses pollutants as a source of food for a range of suspended microorganisms. More organisms (biomass) and certain byproducts are produced from the contaminants by agitating and aerating the mixture for a predetermined period of time. Many parameters, such as nutrient content [5], anoxic/aerobic phase fraction [6], solid retention time [7], and hydraulic retention time (HRT), can affect the performance and microbial community of a bioreactor HRT is acknowledged as a crucial operating parameter that influences the composition of the microbial population and the performance of bioreactors [8], in addition to the previously listed contributing elements. The average concentration of contaminants in wastewater effluent differed significantly amongst cells with various HRTs. Except for conductivity, the concentration of contaminants in the effluent dropped significantly when HRT increased from one to three days, but it only slightly decreased when HRT increased to four days[9]. The average removal efficiency of the system for BOD, COD was found to be 79% and 70%, respectively, indicating its exceptional effectiveness in removing pollutants[10]. The impact of HRT on the objectives of this study included designing and constructing a modified septic tank and assessing the efficacy of the created purification tank. This program was implemented and evaluated as part of a research project investigating innovative decentralized wastewater treatment techniques[11]. The assessment also looks at the state of the art of MBBR technology for nutrient removal (i.e., COD and BOD, nitrogen and phosphorus) through the process functionality and configuration of established (like IFAS) and under development (like PN/A) applications[12]

The main goal of wastewater treatment is typically to enable the disposal of human and industrial effluents without endangering human health or causing unacceptable harm to the environment and the removal efficiency of the model in terms of removal effectiveness of BOD₅ and COD under various hydraulic retention time and sludge retention time. There are two more objectives to be accomplished through the paper are to design and develop of a bench-scale wastewater treatment plant for the municipal drainage to reuse the treated water for agricultural purposes and to compare operational performance over the long term for future development and practical application of this study. To find out the characteristics of municipal wastewater from student's residential hall of Khulna University of Engineering and Technology, Khulna, this whole experiment is performed along with evaluating the removal efficiency of these parameters by anoxic-aerobic wastewater treatment process with various HRT

METHODOLOGY

A bench scale anoxic-aerobic wastewater treatment system was used to evaluate the removal efficiency of key pollutants Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD) in greywater. The experimental setup consisted of an equalizer tank, an anoxic tank, an aerobic tank and a secondary clarifier. The equalizer tank was used to stabilize and regulate the influent flow and ensuring a consistent input to the treatment system. It ensured constant treatment conditions by acting as a buffer against variations in the quantity and quality of the influent. The biological denitrification process in which anaerobic microorganisms broke down organic contaminants in the absence of oxygen was made easier by the anoxic tank (0.0052 m³ volume). Following the anoxic treatment, the aerobic tank (0.013 m³ volume) offered an oxygen-rich environment in which aerobic microorganisms could further break down the residual organic waste. An electrical air pump and perforated diffusers were used to continually supply oxygen to this tank for maintaining dissolved oxygen levels. In order to effectively remove COD and BOD, this aeration made sure there was enough oxygen for the oxidation of organic contaminants. The system was operated under three distinct hydraulic retention time (HRT) conditions to assess the influence of residence time on treatment efficiency. The first set of conditions had an anoxic HRT of 3.45 hours and an aerobic HRT of 8.65 hours, the second set had an anoxic HRT of 1.85 hours and an aerobic HRT of 4.65 hours and the third set had an anoxic HRT of 1.45 hours and an aerobic HRT of 3.6 hours. The impact of shorter or longer retention durations on the microbiological treatment procedures and total pollutant elimination evaluated according to the different HRTs. Excess biomass was settled in the secondary clarifier which also made sure the treated wastewater was clean before it was released.

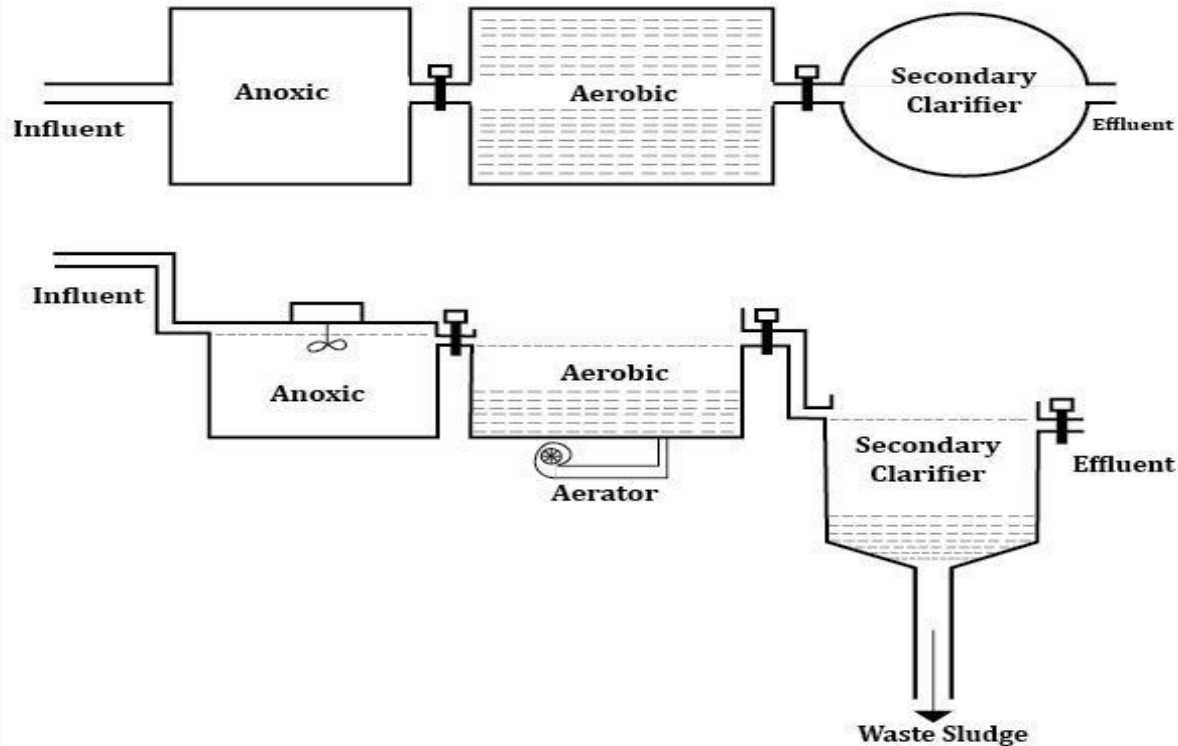


Figure 1 Schematic diagram of the treatment unit

Samples of the wastewater were collected in containers with a strong plastic screw. There were at least two or three washes of the container before any samples were taken. In order to collect wastewater samples at the middle of the trunk drains, each sample pot was sunk below the water's surface, allowed to fill and then the top of the container was submerged under water. The wastewater samples were taken to the laboratory next day where they were treated and analyzed. Samples were often preserved until analysis for a maximum of 24 hours at 4 °C.

The samples were analyzed for COD and BOD using standard laboratory methods. COD was measured using a DR 2700 spectrophotometer which is a widely recognized tool for determining the oxygen demand of wastewater. For BOD₅ analysis, the Azide modification on Winkler method was employed where the samples were incubated for five days to assess the oxygen consumption during the microbial degradation of organic matter. The influent and effluent samples were analyzed and compared to determine the removal efficiencies of both COD and BOD with the results expressed as percentages of reduction. To guarantee the system's stability over time, the operational factors including flow rates and microbial growth were also tracked to the main pollutants COD and BOD. Based on the treatment process capacity to fulfill regulatory discharge requirements and its potential for repurposing and its performance was evaluated.

RESULTS AND DISCUSSION

The environmental, biological, and chemical factors all influence the effluents' composition. Specific water quality parameters for both the raw wastewater and the effluent were evaluated in the Environmental Engineering Laboratory (KUET) using standard methods. The performance of a bench-scale anoxic-aerobic wastewater treatment unit was evaluated for greywater treatment at varying hydraulic retention times (HRT). Hydraulic retention time (HRT) had a significant impact on the removal efficiencies of the anoxic-aerobic wastewater treatment system which is efficiently eliminated organic contaminants COD and BOD.

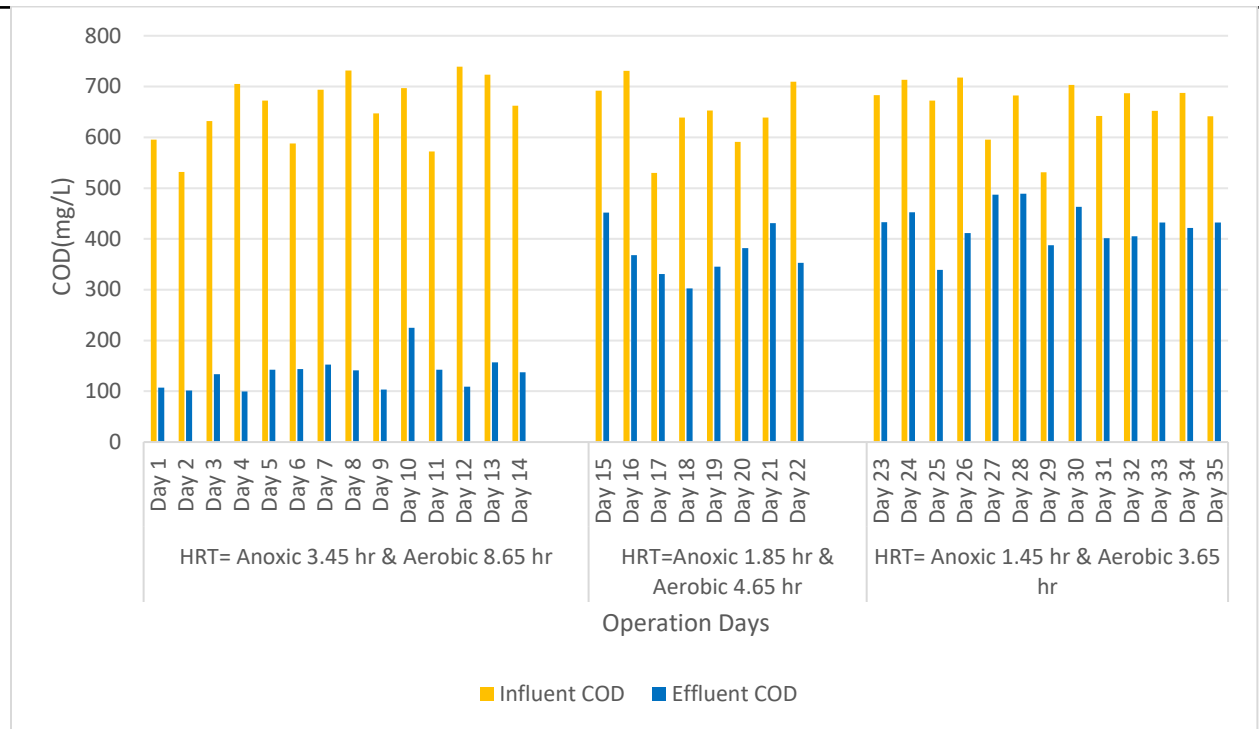


Figure 2 Variation of COD for different HRTs

The chemical oxygen demand of wastewater is a measurement of the quantity of oxygen required for the decomposition of organic waste, including biodegradable and nonbiodegradable substances. In Figure 2, the COD concentration in mg/L is depicted on different days considering three distinct HRTs at both influent and effluent stages, namely the equalizer tank and effluent tank. The graph illustrates a clear reduction in COD concentration in the effluent compared to the influent indicating the efficacy of the wastewater treatment process in removing pollutants.

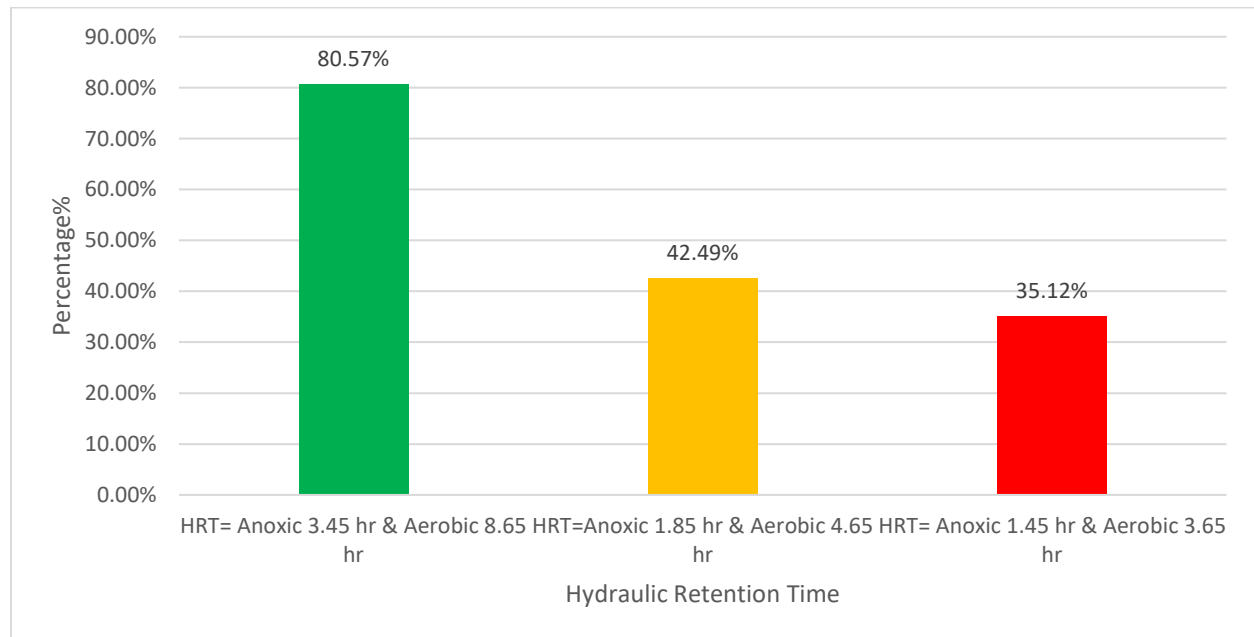


Figure 3 Removal Efficiency of COD for various HRTs

The figure 3 shows the removal efficiency of COD in various Hydraulic Retention Time. The longest HRT of 3.45 hours in the anoxic tank and 8.65 hours in the aerobic tank had the best COD elimination

efficiency of 80.57% highlight the significance of enough contact time for the microbial degradation. COD removal dropped to 42.49% when HRT was shortened to 1.85 hours in the anoxic tank and 4.65 hours in the aerobic tank. The efficiency further decreased to 35.12% with the smallest HRT of 1.45 hours anoxic tank and 3.6 hours aerobic tank. The removal efficiency in both the anoxic and aerobic tanks decreased because the microorganisms were unable to completely decompose the organic waste in shorter hydraulic retention time.

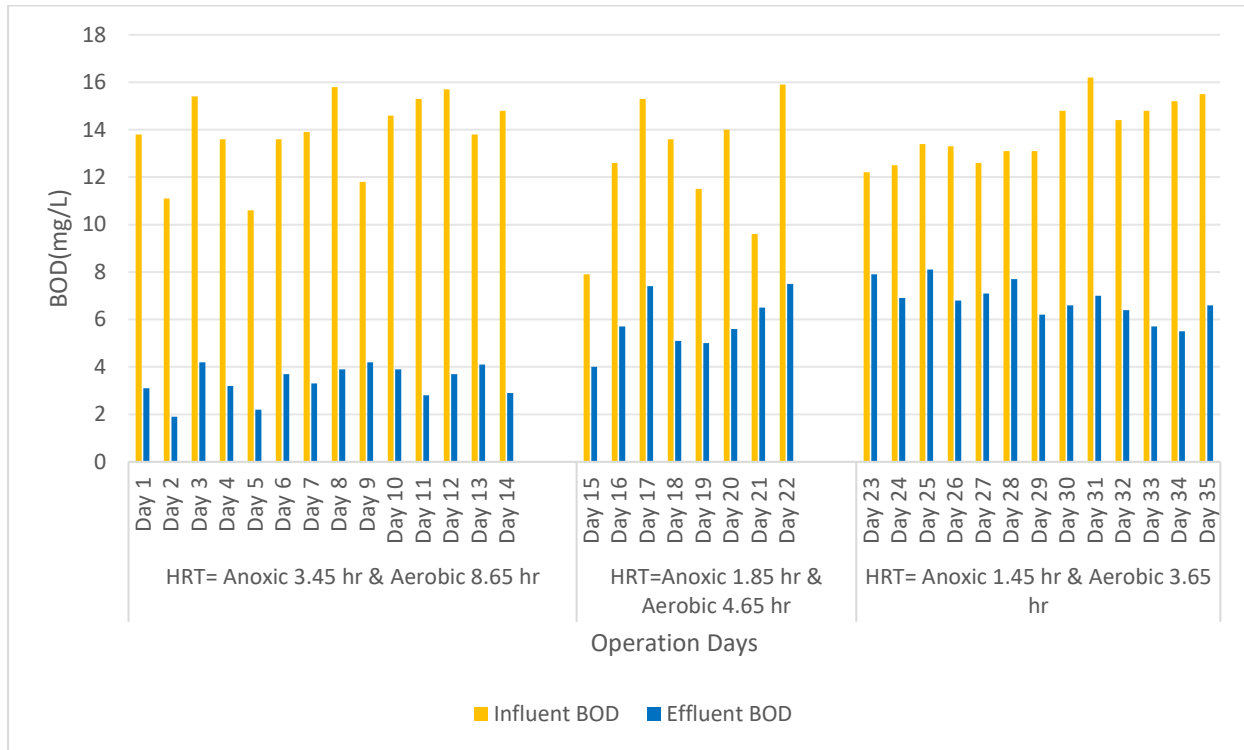


Figure 4 Variation of BOD for different HRTs

In figure 4, the graph shows the influent and effluent BOD levels clearly demonstrates the effectiveness of the wastewater treatment process in reducing BOD. The influent water initially shows high BOD indicating a significant presence of biodegradable organic matter. As the water moves through the primary settling tank, there is a noticeable reduction in BOD₅ which leads to an increase in Dissolved Oxygen levels. The aeration basin further reduces BOD₅ with the graph showing a steady decline and minimal fluctuation in efficiency indicating the consistent performance of the system. The secondary clarifier plays a crucial role in achieving a substantial reduction in BOD₅, as microorganisms continue to break down the organic matter. The effluent BOD levels, as depicted in the graph, are significantly lower than those of the influent, highlighting the success of the treatment process in improving water quality and ensuring the effluent meets environmental discharge standards.

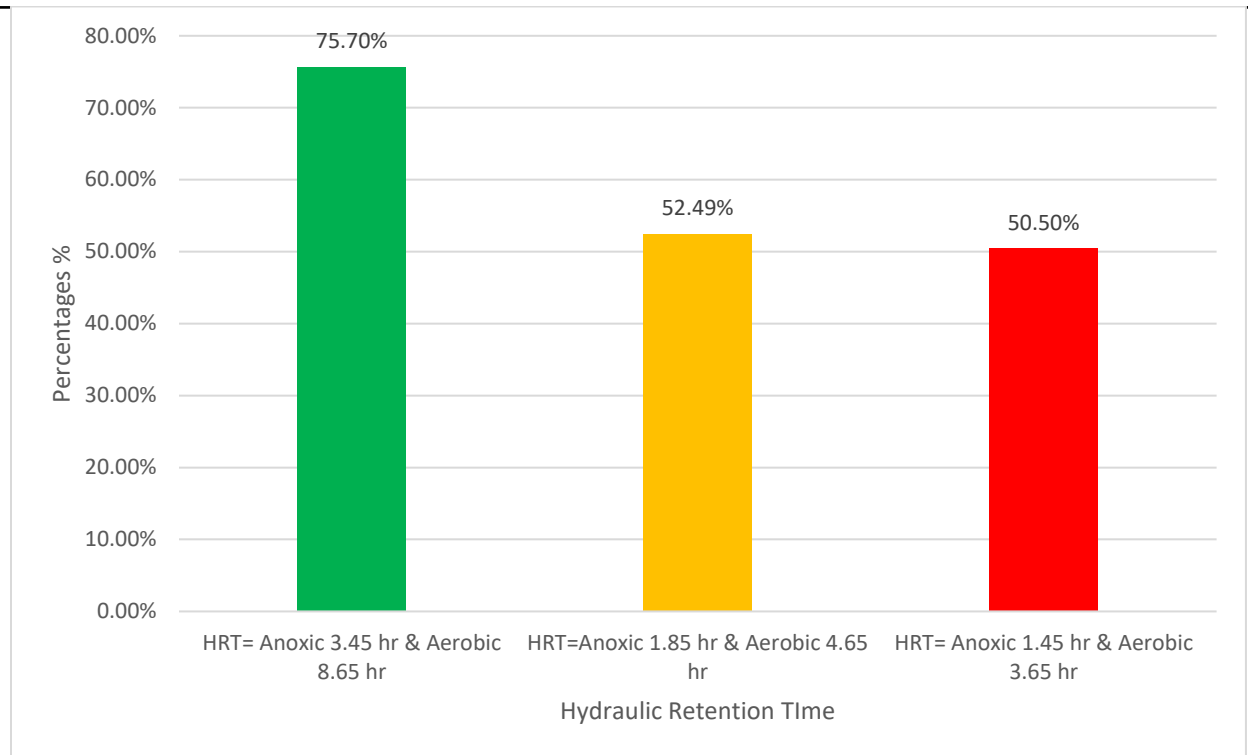


Figure 5 Removal Efficiency of BOD for various HRTs

In figure 5, the highest BOD removal efficiency of 75.70% was achieved with the longest HRT which involved 3.45 hours in the anoxic tank and 8.65 hours in the aerobic tank. This result emphasizes the importance of providing sufficient contact time for microorganisms to effectively degrade organic matter. However, when the HRT was reduced to 1.85 hours in the anoxic tank and 4.65 hours in the aerobic tank, BOD removal efficiency decreased to 52.49%. The efficiency further dropped to 50.50% with the shortest HRT of 1.45 hours in the anoxic tank and 3.6 hours in the aerobic tank. These findings indicate that shorter HRTs do not allow enough time for microbial processes to fully break down organic contaminant leading to lower removal efficiencies.

CONCLUSION

The performance of a bench-scale anoxic-aerobic wastewater treatment system for treating greywater was investigated. The treatment system was evaluated under different hydraulic retention times (HRTs) and flow rates focusing on the removal efficiencies of Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD). The treatment unit showed the highest removal efficiency at the longest HRT, with a notable decrease in efficiency as the HRT was shortened. The result emphasized that sufficient contact time between wastewater and microorganisms is essential for optimal pollutant removal. Shorter HRTs led to reduced treatment efficiency due to limited microbial interaction time demonstrate the critical role of HRT in the treatment process. The alternating anoxic and aerobic stages effectively facilitated the biodegradation of organic contaminants directly impacting the reduction of BOD and COD levels. The study suggests that the anoxic-aerobic treatment process is capable of meeting environmental discharge standards, making it a promising option for greywater treatment and water reuse applications.

REFERENCES

- [1] A. K. Islam, "Domestic and industrial wastewater generation and its energy recovery potential in Bangladesh," *Clean. Energy Syst.*, vol. 6, no. November, p. 100092, 2023, doi: 10.1016/j.cles.2023.100092.
- [2] P. J. T. M. van Puijenbroek, A. H. W. Beusen, and A. F. Bouwman, "Global nitrogen and phosphorus in urban waste water based on the Shared Socio-economic pathways," *J.*

-
- Environ. Manage.*, vol. 231, no. October 2018, pp. 446–456, 2019, doi: 10.1016/j.jenvman.2018.10.048.
- [3] A. Sonune and R. Ghate, “Developments in wastewater treatment methods,” *Desalination*, vol. 167, no. 1–3, pp. 55–63, 2004, doi: 10.1016/j.desal.2004.06.113.
- [4] O. Lefebvre and R. Moletta, “Treatment of organic pollution in industrial saline wastewater: A literature review,” *Water Res.*, vol. 40, no. 20, pp. 3671–3682, 2006, doi: 10.1016/j.watres.2006.08.027.
- [5] E. R. Rene, S. J. Kim, and H. S. Park, “Effect of COD/N ratio and salinity on the performance of sequencing batch reactors,” *Bioresour. Technol.*, vol. 99, no. 4, pp. 839–846, 2008, doi: 10.1016/j.biortech.2007.01.037.
- [6] Z. Hu, J. Zhang, H. xie, S. Li, J. Wang, and T. Zhang, “Effect of anoxic/aerobic phase fraction on N₂O emission in a sequencing batch reactor under low temperature,” *Bioresour. Technol.*, vol. 102, no. 9, pp. 5486–5491, 2011, doi: 10.1016/j.biortech.2010.10.037.
- [7] M. S. Moussa, C. M. Hooijmans, H. J. Lubberding, H. J. Gijzen, and M. C. M. Van Loosdrecht, “Modelling nitrification, heterotrophic growth and predation in activated sludge,” *Water Res.*, vol. 39, no. 20, pp. 5080–5098, 2005, doi: 10.1016/j.watres.2005.09.038.
- [8] F. Kargi and A. Uygur, “Nutrient removal performance of a five-step sequencing batch reactor as a function of wastewater composition,” *Process Biochem.*, vol. 38, no. 7, pp. 1039–1045, 2003, doi: 10.1016/S0032-9592(02)00236-4.
- [9] D. Ghosh and B. Gopal, “Effect of hydraulic retention time on the treatment of secondary effluent in a subsurface flow constructed wetland,” *Ecol. Eng.*, vol. 36, no. 8, pp. 1044–1051, 2010, doi: 10.1016/j.ecoleng.2010.04.017.
- [10] S. B. Nayan, Q. H. Bari, P. K. Debnath, and J. A. Saju, “Performance study of pilot-scale anaerobic-aerobic filter system for faecal sludge treatment,” *Proc. 5th Int. Conf. Civ. Eng. Sustain. Dev. (ICCESD 2020)*, no. 3, pp. 1–12, 2020.
- [11] S. B. Nayan, Q. H. Bari, P. K. Debnath, and J. Ahmed, “Influence of Different Hydraulic Retention Time on Modified Septic Tank System for Faecal Sludge Treatment,” *Sci. Lett.*, no. April, pp. 18–24, 2021, doi: 10.46890/SL.2020.v02i04.001.
- [12] A. di Biase, M. S. Kowalski, T. R. Devlin, and J. A. Oleszkiewicz, “Moving bed biofilm reactor technology in municipal wastewater treatment: A review,” *J. Environ. Manage.*, vol. 247, no. May, pp. 849–866, 2019, doi: 10.1016/j.jenvman.2019.06.053.