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THE EFFECT OF HYDRAULIC RETENTION TIME ON THE PERFORMANCE OF AN ANOXIC-AEROBIC PROCESS FOR WASTEWATER TREATMENT

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ABSTRACT

A significant amount of organic material was discovered in the wastewater that was released into watercourses, well surpassing the maximum permitted effluent discharge standards. The most economical approach is biological wastewater treatment, which employs microorganisms to degrade pollutants in the wastewater. Understanding the proper hydraulic retention time of a facility's wastewater tanks is crucial for its efficient operation. So, the performance of the anoxic-aerobic treatment system was evaluated across three different hydraulic retention times (HRTs). A laboratory-scale anoxic-aerobic tank with a sedimentation basin was designed based on the characteristics of municipal wastewater. The treatment unit achieved COD removal efficiencies of 84.98%, 92.56%, and 90.60% with HRTs of 10.5, 8.5, and 6.5 hours in the aerobic tank and 4.2, 3.4, and 2.6 hours in the anoxic tank, respectively. Sufficient assimilation of microorganisms in the aerobic and anoxic tanks maintains removal effectiveness despite a decline in HRT.
Keywords: *wastewater, anoxic-aerobic process, hydraulic retention time, chemical oxygen demand*

INTRODUCTION

The health of aquatic ecosystems is threatened by the inadequate management of municipal and industrial wastewater (Bashir et al., 2020). There is a wide range in both quantity and composition of wastewater produced by households and industries. These wastewater effluents have been discovered to have extremely high levels of chemical oxygen demand. Evaporation, coagulation-flocculation, ion exchange, and membrane technology are all examples of physicochemical processes that are employed in wastewater treatment (Lefebvre and Moletta 2006). Due to the energy-intensive nature of many physicochemical technologies, their startup and operating costs are comparatively high (Jang et al. 2013). Biological treatment methods have been widely adopted due to their low cost and great efficiency in contrast to physicochemical technology in the removal of organic matter and nitrogen compounds (Lefebvre and Moletta 2006). The efficiency of organic compound removal is typically largely dependent on the type of biological treatment employed (Zorita et al., 2009). Additionally, it has been demonstrated that the design process of biological treatment influences the overall efficacy of micropollutant removal (Padrón-Páez et al., 2020). The anoxic-aerobic is a biological wastewater treatment process that uses pollutants as a food source for many different types of suspended microorganisms. The pollutants are converted to more organisms (biomass) and some byproducts by introducing aeration and agitation in the mixture for a specified period of time where the biomass is allowed to settle out through sedimentation and is disposed of or reintroduced to the treatment process to provide organisms that will continue to remove pollutants. Many parameters, such as nutrient content (Rene et al. 2008), anoxic/aerobic phase fraction (Hu et al. 2011), solid retention time (Moussa et al. 2005), and hydraulic retention time (HRT), can affect the performance and microbial community of a bioreactor (Kargi and Uygur 2003). HRT is recognized as a critical operating parameter that affects bioreactor performance and microbial community composition, along with the aforementioned contributing factors (Wang et al. 2009). According to research conducted by Durai et al. (2011), reducing the HRT from 3 to 2 days dramatically reduced the COD removal effectiveness of an SBR treating tannery wastewater by salt-tolerant bacterial strains. The effects of HRT on the structure and function of the sludge microbial community in synthetic industrial wastewater in an activated sludge system with yeast as the main sludge microbe were described by Han et al. (2010). This research was primarily motivated by a desire to investigate the effect of HRT on the efficiency of anoxic-aerobic systems used to treat municipal wastewater.

METHODOLOGY

After defining the wastewater quality at three sample points and analyzing secondary data, the specifications for the design of the treatment units were established. On the basis of the results of the raw wastewater analysis, the treatment method was selected and design calculations were performed. In this case, COD removal from wastewater was accomplished using an anoxic-aerobic unit, followed by sedimentation, because this approach is both efficient and easy to maintain. There was a substantial variation in the content of the wastewater samples collected in the research area. Table 1 gives the results of the various physicochemical characteristics measured in the wastewater samples used for design. Table 2 summarizes the treatment unit design parameters that were achieved through calculation.

Table 1 Characteristics of wastewater for design consideration

Wastewater Characteristics	Concentration (mg/L)
BOD	145±48
sBOD	75±11
COD	350±89
sCOD	145±19
rbCOD	85±13
TSS	192±25
VSS	144±18
TKN	45±14
NH_4-N	30±8
Alkalinity as $CaCO_3$	240 ±103
bBOD/BOD ratio	1.6 (assumed)

Table 2 Summary of the design data

Design Parameter	Concentration
Flow	0.028 m^3/d
The specific growth rate μ_{AOB} for the ammonia-oxidizing bacteria	0.216 g VSS/g VSS .d
Design SRT	7.0 d
The biomass production	1.90811 g VSS/d
Aeration tank volume	0.013 m^3
MLVSS in the aeration tank	2161.88 g/m^3
Retention time in the aerobic tank	11 hours
Oxygen requirement	0.3692 g O_2/hr
The observed yield based on TSS	1.32 g TSS/g BOD
The observed yield based on VSS	0.953 g VSS/g BOD
Volumetric BOD loading	0.321 kg/m^3.d
The active biomass concentration in the anoxic tank	879.89 g/m^3
Anoxic tank volume	0.0052 m^3
Retention time in the anoxic tank	4.5 hour
RAS ratio	60%
The volume of the secondary clarifier	0.002 m^3
Solids loading in the secondary clarifier	4.9 kg MLSS/m^2.h

Effective treatment unit design is dependent on the precise value of untreated influent characteristics. Treatment units can only be designed and controlled efficiently if their operation and design are based on constant monitoring of wastewater characteristics and their quantity from various sources. Having an inflow wastewater value of BOD/COD of around 0.5 indicates that organic matter can be efficiently removed by the anoxic-aerobic treatment method. To accomplish COD removal, a mechanical device was installed to ensure a constant supply of oxygen inside the aeration chamber (glass tank) measuring 40 cm (L) x 25 cm (W) x 13 cm (H) for the duration of the experiment. Before the aeration chamber, a pre-anoxic denitrification basin (glass tank) of 16 cm (L) x 25 cm (W) x 13 cm (H) was employed. The chamber has a freeboard of 7 cm to prevent flooding. The HRT for the aerobic tanks varied from 10.5 hours, 8.5 hours, and 6.5 hours respectively, and in the anoxic tank that was 4.2 hours, 3.4 hours, and 2.6 hours respectively. The secondary clarifier was made in a cylinder shape with a hopper boat in a cone shape at the bottom built out of CGI sheeting, with an inner diameter of 16 cm, a height of 15 cm, and a freeboard of 5 cm. An agitator was installed inside to maintain sludge suspension in the anoxic zone. In order to keep the DO levels in the aerobic tanks between 3.0 and 4.0 mg/L, the air was supplied through pipes with extremely small pores. Through the release of waste-activated sludge (WAS) from the secondary clarifier, the SRT of the treatment unit was maintained at 7 days. For all systems, a peristaltic pump ensured that the mixed liquor recirculation rate and returned sludge ratio remained constant at 60%. During operation, 100% internal recirculation was kept between the aerobic and anoxic tanks.

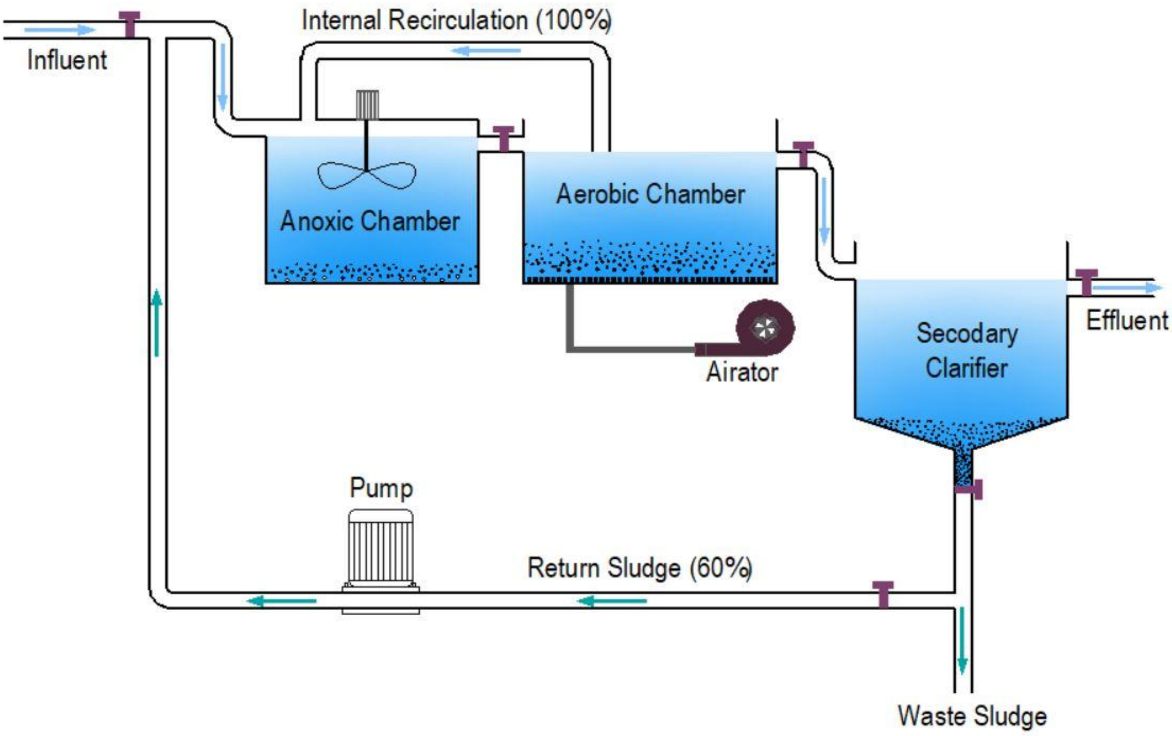

Figure 1 Schematic diagram of the treatment unit

The wastewater samples were collected in containers of 1 and 30 liter capacities, respectively, with a strong plastic screw. There were at least two or three washes of the container before any samples were taken. At the midway of the trunk drains, wastewater samples were obtained by sinking each sample pot 5 to 10 centimeters below the surface of the water, allowing it to fill, and then shutting the top of the container under water. The following day, wastewater samples were carried to the laboratory. Then, the wastewater sample was analyzed and treated. Until analysis, samples were sometimes kept for no more than 24 hours at 4 ℃. Both influent and effluent were collected and transported to the laboratory for evaluation of various wastewater parameters. Chemical oxygen demand (COD), dissolved oxygen (DO), and pH were measured in the laboratory to determine the effect of HRT on wastewater treatment.

RESULTS AND DISCUSSIONS

The chemical, biological, and environmental conditions all play a role in determining the quality of effluents. In the Environmental Engineering Laboratory (KUET), standard methods were used to test specific water quality parameters for the raw wastewater and the effluent. The chemical oxygen demand of wastewater is a measurement of the quantity of oxygen required for the decomposition of organic waste, including biodegradable and non-biodegradable substances. All the outflows of the city dispose of wastewater with a high content of non-biodegradable organic materials, as depicted in Figure 1. In this study, the influence of hydraulic retention time on COD removal performance in an anoxic-aerobic wastewater treatment process was investigated. The overall removal efficiency was calculated after operating the treatment unit at three distinct hydraulic retention times. An HRT of 10.5 hours in the aerobic chamber and 4.2 hours in the anoxic chamber was used for the first 13 days of operation of the treatment unit. After the approach, the COD concentration in the anoxic chamber was reduced to 258.02±102.30 mg/L and in the aerobic chamber it was decreased to 166.04±130.01 mg/L from the initial raw wastewater value of 620.34±240.44 mg/L. Compared to the wastewater from the previous chamber, the COD reduction percentages in the anoxic and aerobic zones were 58.53% and 35.64%, respectively. After sedimentation in the secondary clarifier, an overall COD removal efficiency of

84.98% was reported in the treatment unit. The initial low percentage of removal can be attributed to the inability to assimilate microorganisms in a shorter time. Effluent and raw wastewater COD concentrations are shown to have fluctuated and decreased over time in Figure 2.

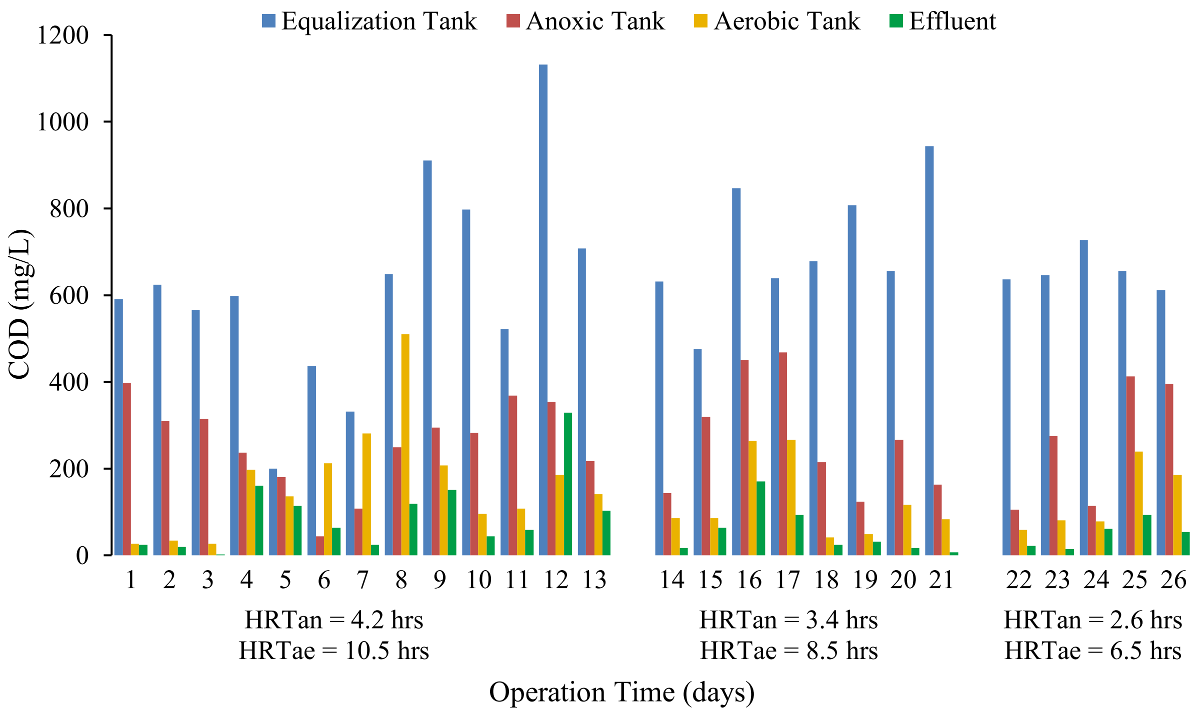

Figure 2 Variation of COD concentration at various chambers at different HRT

The treatment unit was in operation from day 14 to day 21, with HRTs of 3.4 hours in the anoxic chamber and 8.5 hours in the aerobic chamber. The COD concentration of the raw wastewater was reduced from 799.88±147.83 mg/L to 268.76±134.32 mg/L in the anoxic chamber and to 123.55±90.09 mg/L in the aerobic chamber. The COD removal efficiency in the anoxic chamber relative to the raw wastewater was 62.13% and in the aerobic chamber, relative to the prior anoxic chamber was 54.02%. The treatment unit was able to achieve an overall removal efficiency of 92.56% after sedimentation in the secondary clarifier. The removal efficiency in both the anoxic and aerobic chambers improved as biomass generation grows.

Then, for the next five days, the anoxic and aerobic chambers were run with HRTs of 2.6 hours and 6.5 hours, respectively. As for chemical oxygen demand, it decreased from 655.70±43.05 mg/L in the raw wastewater to 260.34±147.45 mg/L in the anoxic chamber and 128.07±79.42 mg/L in the aerobic chamber. Figure 3 illustrates the removal efficiency of COD in several chambers with varying HRT.

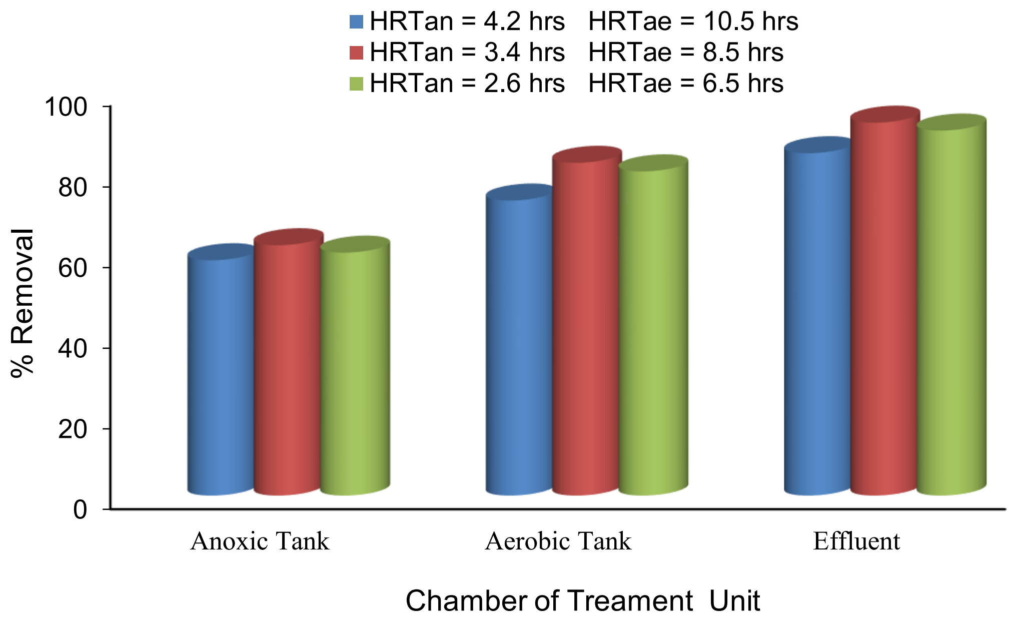

Figure 3 Removal percentage of COD at various chambers at different HRT

The initially reduced removal efficiency at higher HRT was attained due to a lack of microbial assimilation in the anoxic and aerobic tank. In spite of the modest decrease in HRT, an increase in effluent removal efficiency was noticed. After several days of operation, both the anoxic and aerobic tanks had accumulated substantial amounts of mixed liquid suspended solids (MLSS), for which an increase in biomass production was responsible for the enhanced removal efficiency. When the HRT was reduced further, the removal efficiency in both the anoxic and aerobic tanks decreased because the microorganisms were unable to completely decompose the organic waste in such a short HRT.

CONCLUSION

The effects of hydraulic retention time on the performance of an anoxic-aerobic batch reactor treating municipal wastewater were explored. As determined by the amounts of COD, the wastewater from municipal drainage systems contained high quantities of biodegradable organic pollutants. With HRTs of 10.5, 8.5, and 6.5 hours in the aerobic tank and 4.2, 3.4, and 2.6 hours in the anoxic tank, respectively, the combined anoxic-aerobic chamber achieved COD removal efficiencies of 73.23%, 82.6%, and 80.47%, respectively. Reduced HRT often results in lower COD removal efficiencies; however, moderate HRT reductions may maintain removal efficiencies due to the presence of extensive microbial assimilation in the anoxic and aerobic chambers.

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