Original Research Article

Bio-tower Application for Wastewater Treatment

ABSTRACT

The study tested the performance of a batch-type recirculating laboratory scale bio-tower for the treatment of municipal wastewater. Performance tests were done with a HACH DR-1900 spectrophotometer include chemical oxygen demand, total phosphorus and nitrogen ammonia.

This study showed that the recirculated laboratory type bio-tower containing 0.276 ft^3 (0.008 m^3) of polypropylene growth media with a surface area of 6.624 ft^2 (0.615 m^2) can reduce the chemical oxygen demand between 70% to 87%. NH_3-N reduction was found to be between 94% to 96%, and total phosphorus reduction was between 69% and 87% for flow rates of 0.6 l/min to 1.5 l/min.

Keywords: Bio-tower*, Wastewater treatment, chemical oxygen demand, total phosphorous,* ammonia nitrogen

1. INTRODUCTION

The most significant challenge facing our world in the future pertains to clean water. The constantly increasing needs for water resources for residential, commercial and industrial use accelerate the depletion of the water resources. Reuse of the effluent water before and after treatment can become an effective solution to the shortage of the water resources. Currently golf courses require on average of 48.2-acre-feet to 386.2 acre-feet (15,706,000 to 125,844,000 gal/year) of water for irrigation purpose annually [1]. Today mostly fresh water or well water resources is used for irrigation purposes. This irrigation water might come in the future from resources such as: Storm runoff from impervious surfaces captured in retention ponds, high flow (flood) water diversion into storage ponds, secondary or tertiary effluent from a Waste Water Treatment Plant (WWTP), grey water, and treated or raw water from a local public water supply distribution systems [2].

A bio-tower or sometimes known as trickling filter is one of the two main types of biological control units [3]. Industrial and municipal WWTP use bio-towers as part of the secondary treatment process [4, 5]. A bio-tower is a round tank structure and contain usually engineered growth media with a high surface area [6]. Rock, slag and wood was a common growth media in the past but provide lower surface area and void volume, limiting the hydraulic flow rate of the bio-tower and therefore require larger more costly systems for WWTP. Today, materials such as Polyvinyl Chloride (PVC), Polypropylene (PP) with a defined specific surface area between 90 to 226 m^2/m^3 are utilized [7, 8].

In bio-towers, a distribution system equally spreads the wastewater (WW) over a biofilm covered growth media. The wastewater then trickles over the medium and is collected at the bottom of the bio-tower. The growth media is located above the bottom of the bio-tower to ensure air transfer throughout the filter media. A pump lifts the inflowing wastewater to the distributor as well as partially recirculates the effluent. [9]

Even though, bio-towers traditionally remove organic matter by heterotrophic bacteria, this process can be successfully combined with a nitrification process. Nitrification is the sequential reaction from ammonium over nitrite to nitrate, carried out by the autotrophic nitrosomonas and nitrobacter bacteria. [10] In the upper portion of the bio-tower, the heterotrophic bacteria outgrow the nitrifying species. As soon as the organic matter in the WW is subsequently decreased below a threshold concentration of approximately 20 mg/l soluble BOD_5 (biochemical oxygen demand), the nitrifying bacteria can compete and initiate nitrification [9, 11].

Past studies provide good empirical data for setting up combined carbon oxidation and nitrification trickling filters. Choosing the right BOD-loading is of primary importance to achieve proper nitrification, whereas a low BOD-loading generally means good nitrification. The United States Environmental Protection Agency (USEPA) has recommended organic loading rates per unit volume for different filter media and Richards and Parker (1986) have published comparable data on a surface area basis [9, 10, 11].

According to the USEPA, temperature highly influences the nitrification and must be set in a range between 4 and 45 degree Celsius temperature. Even though there is no consistent data that quantifies the effect of different temperatures on nitrification, satisfactory nitrification occurs in the range from 15 to 25 °C. The pH-value of the wastewater should range from 6.5 to 8.0 to ensure process stability [9]. The rate of dissolved oxygen usually does not limit combined nitrification and carbon oxidation processes with natural air draught, as they are typically operate with low organic loading rates. Recirculation of the effluent and therefore increasing hydraulic loading can improve nitrification rates above 50% for moderate or high temperatures. Recirculation has also a quite pronounced effect on removal of organic matter for deep bio filters, as in a bio-tower [12, 13, 14]. A recent study shows that a bio-tower can remove volatile organic compounds, which would harm humans and the environment [15].

The following study explores if the combined nitrification and organic matter removal from Municipal Waste Water (MWW) using a Laboratory Benchtop Bioreactor System (LBBS).

2. MATERIAL AND TESTING

2.1. Laboratory Benchtop Bioreactor System:

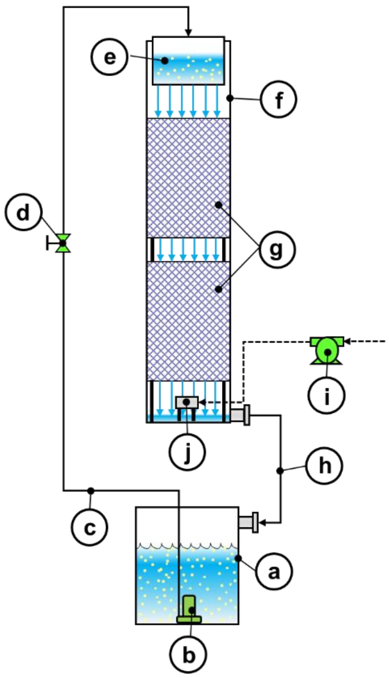
A Laboratory Benchtop Bioreactor System (LBBS) was designed and installed according to Figure 1. The LBBS consisted of a 15 l WW reservoir, made from a 5 gal (18.92 l) pail (a). The wastewater is pumped from the reservoir with small 25-Watt pond pump (b). The pond pump has a maximal flow rate of 4.40 gal/min (16.66 l/min) at a head of 5.5 ft. (1.67 m) at a rate of 0.5 l/min trough a Polyvinyl Chloride (PVC) hose with a 10 mm inside diameter (c) to the distributer (e) build from a small 0.5 liter PVC container. The distributor had 50 holes with 2 mm in diameter equally spaced on the bottom. The flow is regulated with a hose clamp valve (d). The distributer trickled the influent onto Polypropylene (PP) bacteria growth media (g), which was cut randomly from 0.276 ft^3 (0.008 m^3) recycled Bentwood CF-1900 cross flow media with 48 ft^2/ft^3 157 m^2/m^3 [8] to a maximum size of 1.0 x 1.0 x 1.0 in (25 x 25 x 25 mm). The cut media is installed in two equal 250 mm long segments with a diameter of 90 mm into the glass tank with 900 mm in height and 90 mm in diameter (f) separated by 40 mm with a distance holder . Each installed segment from 0.138 ft^3 (0.004 m^3) cut crossflow media has a surface area of 6.624 ft^2 (0.615 m^2).

After the suspension made its way through the growth media (g), the suspension is collected in the lower part of the glass tank and transferred back to the reservoir (b) with a 10 mm diameter PVC hose (h).

The LBBS operation ability is tested with tap water before the start up was initiated.

For starting up the LBBS, Cow Manure (CM) with 12% solids content was obtained from the SUNY-Morrisville Farm. The CM was diluted 100 times with tap water. 10 liter of the diluted CM-suspension is then put into the reservoir (a) and den pumped with pump (b) at a rate of 0.5 l/min trough pipe (c) to the distributer (e). The flow regulation occurred with valve (d).

The distributer (e) trickled the CM-suspension onto the growth media (g) were bacteria contained in the cow manure started to grow removing the contaminants contained in the CM-suspension. After the CM-suspension made its way through the growth media (g) it runs back with pipe (h) into the reservoir (b). Airflow at 0.14 gal/min (0.5 l/min) is supplied with a



fish tank air pump (i) into the bottom of the LBBS using a fish tank air stone (j).

Figure 1: Laboratory Biotower; a) Reservoir, b) Pump, c) Feed Pipe, d) Valve, e) Distributor f) Reactor Vessel, g) Growth Media, h) Return Pipe, i) Air Pump, j) Air Stone

The LBBS continued to operate in this way for 3 weeks. The evaporated portion of the CM-suspension in the reservoir is replaced daily with diluted new CM suspension, until the growth media contains a cover of brown bacteria. After the 3-week inoculation phase, the reservoir is emptied and cleaned. The initial testing starts with 10 liters of WW as described in the following sections 2.2 and 2.3.

2.2. Testing Regime and Sample Collection:

10 l of wastewater was collected directly form the influent stream of primary clarifier and filled into the reservoir of the LBBS prior to each test run. During each test run a 30 ml WW sample were collected directly from the reservoir of the LBBS at the beginning of the test (0-hour), after 4 hours, 8 hours and 24 hours. Flow rates applied to the bio-tower system were 0.6 l/min, 0.8 l/min, 1 l/min and 1.5 l/min. Based on the above flow rates the daily (24h) hydraulic loading is 0.7 m^3/m^2d, 0.94 m^3/m^2d, 1.18 m^3/m^2d, and 1.76 m^3/m^2d respectively.
After each test, the treated wastewater in the reservoir is discharged and replaced with new 10 l of pre-clarified wastewater. Samples were stored in a refrigerator at 4°C between collection and analyzation.

2.3 Testing and Recording:

To verify the exact concentration of Chemical Oxygen Demand (COD), Total Phosphorous (TP) and Ammonia Nitrogen (NH_3-N) a HACH DR900 Spectrophotometer and a HACH DRB200 Reactor is used for analyzation. The analyzation of the collected 30 ml samples followed HACH Method 8000 [16] for COD using HACH COD TNTplus Vial Test (3-50.0mg/L), HACH Method 10127 [17] for TP using HACH -TNT Reagent Set (1-100.0mg/L), and HACH Method 10031[18] for NH_3-N using HACH-TNT Reagent Set (0.4-50.0mg/L).

3.0 Results:

Figure 2 to 5 shows that under different flow rates in the LBBS, Chemical Oxygen Demand (COD), Total Phosphorus (TP) and Nitrogen ammonia (NH_3-N) concentration decreased dramatically at first 8-10 hours independent from the WW values of each test at the 0-hour. Values of the WW shown at the 0-hour are different values due to the daily fluctuation of the incoming WW at the WWTP at the day of collection [5, 19]. At a flow rate 0.6 l/min, COD concentration dropped from 55.0 to 7.0 mg/l, TP dropped from 1.6 to 0.3 mg/l and NH_3-N dropped from 9.2 to 0.4 mg/l. At a flow rate 0.8 L/min, COD concentration dropped from 130.0 to 32.0 mg/l, TP dropped from 5.4 to 0.5 mg/l, and NH_3-N dropped from 12.5 to 8.0 mg/l and NH_3-N dropped from 7.6 to 0.3 mg/l. At a flow rate 1.5 L/min the COD concentration dropped from 57.0 to 11.0 mg/l, TP dropped from 3.7 to 0.6 mg/l and NH_3-N dropped from 11.5 to 0.6 mg/l. After 8 hours, the concentration of COD, TP and NH_3-N kept at a very low level. In this case, the bioreactor significantly reduced COD, TP and NH_3-N content in wastewater at different flow rates.

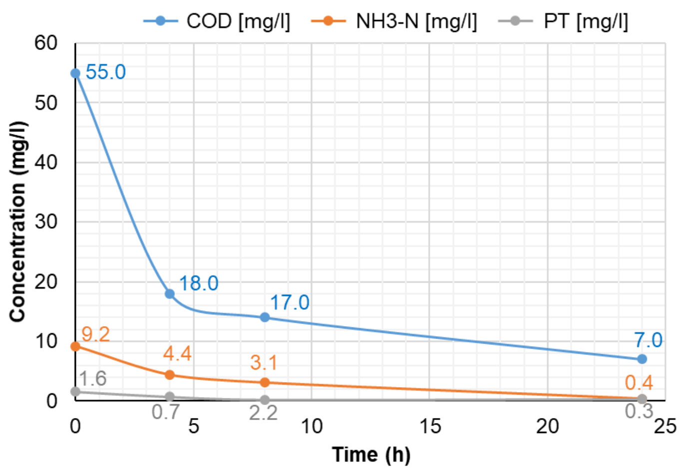


Figure 2: COD, TP and NH_3-N at 0.6 l/min flow rate.

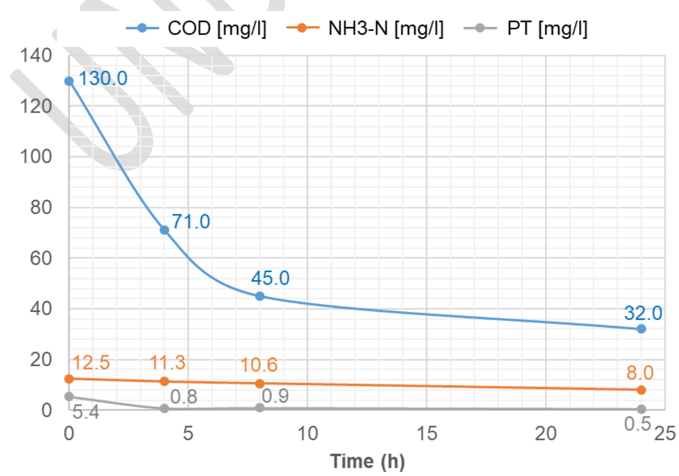


Figure 3: COD, TP and NH_3-N at 0.8 l/min flow rate.

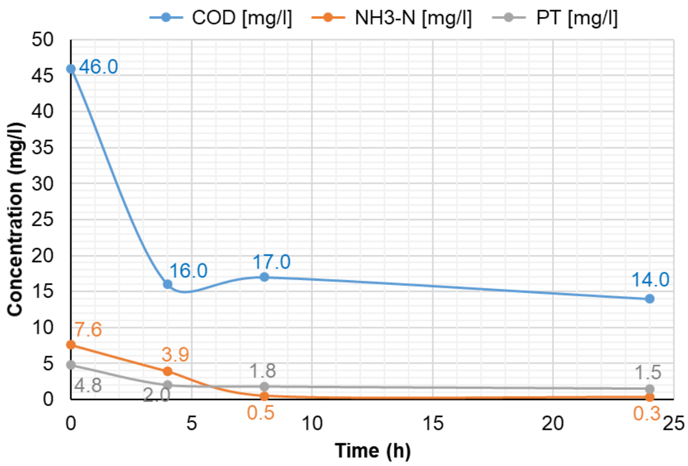


Figure 4: COD, TP and NH_3-N at 1.0 l/min flow rate.

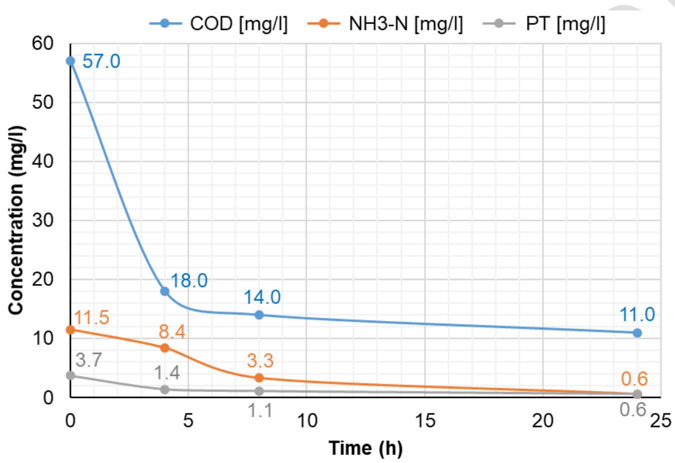


Figure 5: COD, TP and NH_3-N at 1.5 l/min flow rate.

Also, as the flow rate increased, the COD percentage reduction decreased as shown in Table 1. This can be explained by a shorter residence time of the wastewater in the reservoir and bioreactor giving the microorganisms not enough time to degrade the COD. Also, insufficient oxygen supply in the tower might have an effect on the microorganisms, inhibiting an effectively degradation of COD. NH_3-N reduction was found to be between 94% and 96%, whereas TP reduction was between 69% and 87%.Overall, depending on the daily WW supply the LBBS was able to achieve effluent permit levels of TP of 0.8 mg/l, NH_3-N of 0.5 mg/l, and COD <4 mg/l.

Table 1. COD, TP and NH_3-N reduction at different flow rate

Flow rate(l/min)	COD reduction percentage	N reduction percentage	P reduction percentage
0.6	87%	96%	81%
0.8	78%	94%	87%

1.0	70%	96%	69%
1.5	81%	95%	84%

4. CONCLUSION

In this study shows that a bench type laboratory bio-tower containing 0.276 ft³ (0.008 m³) PP bacteria growth media, can reduce 70%-80% COD, over 90% TP and over 80% of NH_3-N in 8 hours.
The bio-tower was operated with sampled WW from WWTP. Operational flow rates were 0.6 l/min, 0.8 l/min, 1.0 l/min and 1.5 l/min and a daily (24h) hydraulic loading of 0.7 m³/m²d, 0.94 m³/m²d, 1.18 m³/m²d, and 1.76 m³/m²d respectively.
Future study should be focus on higher flow rates and upscale of the bio-tower operation that would generate enough water usable for irrigation purposes based on local and state regulations.

5. REFERENCES

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