Asian Journal of Advanced Research and Reports

16(9): 8-17, 2022; Article no.AJARR.89870
ISSN: 2582-3248

Application and Testing of a Laboratory Biotower Septic Tank System for Effluent Treatment - A Laboratory Study

Klaus Dölle [a*] and Simon Lex [b]

[a] *Department of Chemical Engineering (CE), College of Environmental Science and Forestry (ESF), State University of New York (SUNY), 1 Forestry Drive, Syracuse, New York, 13210, USA.*
[b] *Faculty of Chemistry, Technical University of Munich, Lichtenbergstr. 4, Munich, Bavaria, D-85747, Germany.*

Authors' contributions

This work was carried out in collaboration between both authors. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/AJARR/2022/v16i930494

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/89870

Original Research Article

Received 20 May 2022
Accepted 25 July 2022
Published 28 July 2022

ABSTRACT

A laboratory biotower septic tank system was designed, installed, started up with unfiltered wastewater during a 9-day start-up phase, and operated at a hydraulic retention time of 5-, 15-, and 20 days with filtered waste water and 5-, 10-, and 15 days for liquid cow manure.

The system was operated at a laboratory room temperature of 23.0±0.5°C (73.4 ± 0.9°F). The system had an influent pH of 7.5 ±0.1 and a slightly higher pH of 8.0±0.1 for the effluent for filtered wastewater, and an influent pH of 7.3 ±0.1 and a slightly increased effluent pH of 7.5 ± 0.1 for the operation with liquid cow manure.

This research showed that the system is able to achieve an effluent chemical oxygen demand level between 17 ±1 mg/l, and 19 ±1 mg/l for a hydraulic retention time between 5-, and 20 days for filtered waste water, and between 23 ±1 mg/l and 32 ±3 mg/l for a hydraulic retention time between 5-, and 15 days for liquid cow manure at highly varying influent chemical oxygen demand levels between 25 ±1 mg/l and 74 ±15 mg/l and 293 ±46 mg/l to 335 ±14 mg/ for filtered wastewater and liquid cow manure respectively.

The Total solids content in the effluent of the system showed an increase for the filtered wastewater and liquid cow manure influent with increasing hydraulic retention rate from of 55 mg/l to 71 mg/l and from 25 mg/l to 53 mg/l respectively.

**Corresponding author: Email: kdoelle@esf.edu, kdelle@esf.edu;*

Total suspended solids for both, the filtered wastewater and the liquid cow manure was below the 4mg/l mark, except for the liquid cow manure 5-day hydraulic retention rate which had a value of 20 mg/l.

Keywords: Biotower; cow manure; contaminants; septic system; sewage; wastewater; wastewater treatment.

1. INTRODUCTION

This research project focuses on finding a sustainable solution to provide clean water and minimize pollution of water bodies and sustain their beauty and environmental habitat. This represents today a challenge with ever growing U.S. urban and suburban developments. Water pollution affects local wildlife and us humans equally worldwide and we all should work on solutions that minimize and perhaps eliminating waste and water pollution [1,2].

Today, newly developed urban and suburban housing areas are too far away, making it too expensive to connect them to already existing wastewater treatments, or existing wastewater treatment plants cannot handle the additional wastewater without expensive upgrades. This in return would result in substantial higher sewer fees for the existing and new developments causing political pressure on municipal governments.

The current solution is to implement decentralized wastewater treatment systems, also known as septic systems. However, municipal governments in urban and suburban governments are faced with the burden of underperforming decentralized water treatment systems and need to find solutions on how to protect waterbodies in the affected areas [3].

The United States Environmental Protection Agency (EPA) states today, that of every five households one operates a decentralized wastewater treatment system, also known as septic system [4]. Underperforming decentralized wastewater treatment systems might contribute to the pollution of nearby water bodies, by discharging under- or untreated human wastewater.

This can cause nitrification and increase in phosphorus components, which can increase algae growth mostly during warm summer month in the water body and can affect the environment, public health and the economy [5,6]. In addition, urban sources such as increased use of fertilizers in agricultural operations, improper sewage systems, and heavy rain events contribute to the amount of nutrients entering water bodies [7, 8, 9]. This can lead to an increase of nutrient levels in streams and lakes, changing them from oligotrophic to eutrophic [10].

In the field of wastewater treatment decentralized wastewater system are well known. They consist of a tank with an influent and effluent pipe. Liquid containing the organic degradable contaminants enter the system through a influent pipe and settle in the tank based on the high Hydraulic Retention Time (HRT) of the system. The process of biocenosis starts as soon as the liquid enters the system. The organic degradable constituents that are solubilized in the influent and organic degradable particles that settle on the bottom of the tank are broken down by an anaerobic bacteria regime in the tank. Because septic systems contain no mixing the degradation of organic compounds is a very slow process [11, 12].

Newer septic system have a wall in the middle, which divides the tank into two connected compartments. This avoids the direct passage of contaminants in the influent the system to the outlet and improves settling process in the first compartment [11].

The processed liquid discharges as effluent and percolates through a drain field downwards till it reaches the ground water table. Contaminants that are small enough can potentially reach aquifers as they make its way through the drain field soil layers [13,14].

Wastewater in a domestic setting can contain many different potential pollutants which cause a risk to aquifers. These pollutants can be chemicals, household detergents from laundry and dishwashing, Phosphorous (P), Nitrogen (N), Ammonia (NH_4-N), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), Suspended Solids (SS), and pharmaceutical compounds due to the medication need of residents [15-19].

The objective for this research work is to design, build, install and start up a laboratory system which is a combination of biotower system described by Dölle et al. [16,20] and a laboratory septic system described by Dölle & Lex [12]. The newly developed system will allow to test the degradation of organic components of various Wastewater (WW) effluent types.

The reported research could help to improve the operation and processes of current septic systems and improve the described complex problematics current septic systems cause in regard to release excess nutrients into the environment.

2. MATERIALS AND METHODS

The material and methods section describes the laboratory type systems, procedures and effluent materials that were used for this research study.

2.1 Materials

2.1.1 Influent materials

Wastewater was sampled from a primary clarifier at the Cleanwater Educational Research Facility (CERF) located at the Village of Minoa Wastewater Treatment plant in Minoa, NY.

From The State University of NEW York Dairy Farm operation in Morrisville, NY cow manure was sampled.

PVC hoses, CPVC pipe and fitting material from Charlotte Pipe and Foundry Company, plywood particle board, silicone caulk, and purple PVC primer and clear cement from Oatey® for fusing the PVC and CPVC pipe parts together was obtained from a nearby hardware store.

2.1.2 Laboratory biotower septic tank system

To treat the effluent a Laboratory Biotower Septic Tank (LBTST) system as shown in Fig. 1., was designed and build.

For the LBTST system unites two main components, a Laboratory Benchtop Septic (LBS) system according to Doelle et al. [16,20] and a Laboratory Benchtop Bioreactor System (LBB) system as described by Dölle & Lex et al. [12].

The LBTST system, as shown in Fig. 1., consists of the following main components: A 5-gallon (18.9 l) LBS system comprised of recirculation tank (1), with a liquid capacity of 15 liters (3.97 gal.), made from a High-Density Polyethylene (HDPE) 5-gallon (18.9 l) pail with cover (3). A 3/8-inch (9.53 mm) plywood divider (4) with two 1.0-inch (25.4 mm) holes in the middle, spaced 4.0 inch (101.6 mm) apart, and 3-inch (76.2 mm) above the bottom of the LBS. The divider (4) separates the LBS recirculation tank (1) in two equal sized chambers, a settling chamber (23) for solids, and the effluent chamber (24). Each chamber has a volume of 7.5-liter (1.99 gal.).

Connected through the LBS main tank (1) wall are: (i) the inlet pipe assembly (2), located 1.0-inch (25.4 mm) below the liquid level, which prevent odor to escape the LBS; (ii) the effluent Assembly (5); (iii) outlet pig tail pipe assembly (6), which seals the effluent line of the LBS from odor to the outside; and (iv) a 300 ml glass collection beaker (7) contains the systems effluent (25).

The LBB system part consists of: (i) a bioreactor glass tank (8) which is 900 mm (35.43 inch) long and has a inside diameter of 90 mm {3.54 inch); (ii) a distributor (9) made out of a 500 mml PVC pail with 50 holes with 2 mm in diameter equally spaced on the bottom to disperse equally the influent; (iii) Polypropylene (PP) bacteria growth media (10) on which the distributer (9) trickles the influent. The growth media (10) 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 [21] 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 volume of 0.138 ft^3 (0.004 m^3) and a surface area of 6.624 ft^2 (0.615 m^2). into the glass tank (8).

A fish tank air pump (11) provides airflow at 0.14 gal/min (0.5 l/min) into the bottom of the glass tank (8) LBBS using a fish tank air stone (12).

The influent feed system is comprised of a influent container (14) which serves as the reservoir for the influent substrate (21) for the LBTST system. Substrate (21) is pumped with a Jecod DP-2 peristaltic auto dosing pump (13) using ½” clear PVC hose (15) and (16) from the substrate reservoir (14) to the LBTST system inlet pipe assembly (2).

A 25 small 25-Watt pond pump (17) with a maximal flow rate of 4.40 gal/min (16.66 l/min) at a head of 5.5 ft. (1.67 m) recirculates the suspension from the recirculation tank (1) to the distributer (9). A valve 19 allows to adjust the liquid flow through a Polyvinyl Chloride (PVC) hose with a 10 mm inside diameter (18) to the distributer (8).

The suspension trickles through the distributor (9) onto the growth media (10). After the suspension made its way through the growth media (10), the suspension is collected in the collection chamber (21) in the lower part of the glass tank (8) and is transferred back with PVC hose (22) into the inlet pipe assembly (2) of recirculation tank (1).

2.1.3 Laboratory testing procedures

For determining the Chemical Oxygen Demand (COD), Hach HACH COD TNTplus® Spectrophotometer Vial Test (3-150.0 mg/L) were used following HACH Method 8000 [23]. A HACH DRB200 Reactor was used to treat TNTplus® test vials according to the HACH 8000 Method, followed by analyzing the COD using a HACH DR900 Spectrophotometer.

To investigate how much Total Solids (TS) are removed by the LSTBT system we measured the TS value. TS was measured in triplicate. Each test sample was measured using a 300 ml aluminum sample container, which was marked and weighted accordingly. Then approximately 200 ml to 220 ml of the prepared substrate was added to each of the three corresponding aluminum sample containers prepared for the given test sample. Weighting of the sample containers followed, before they were placed in a ~105°C oven to dry for 48 hours to evaporate the moisture. After drying, the samples were weight again to determine their dry weight measurement. The remaining solids were the TS content of the substrate.

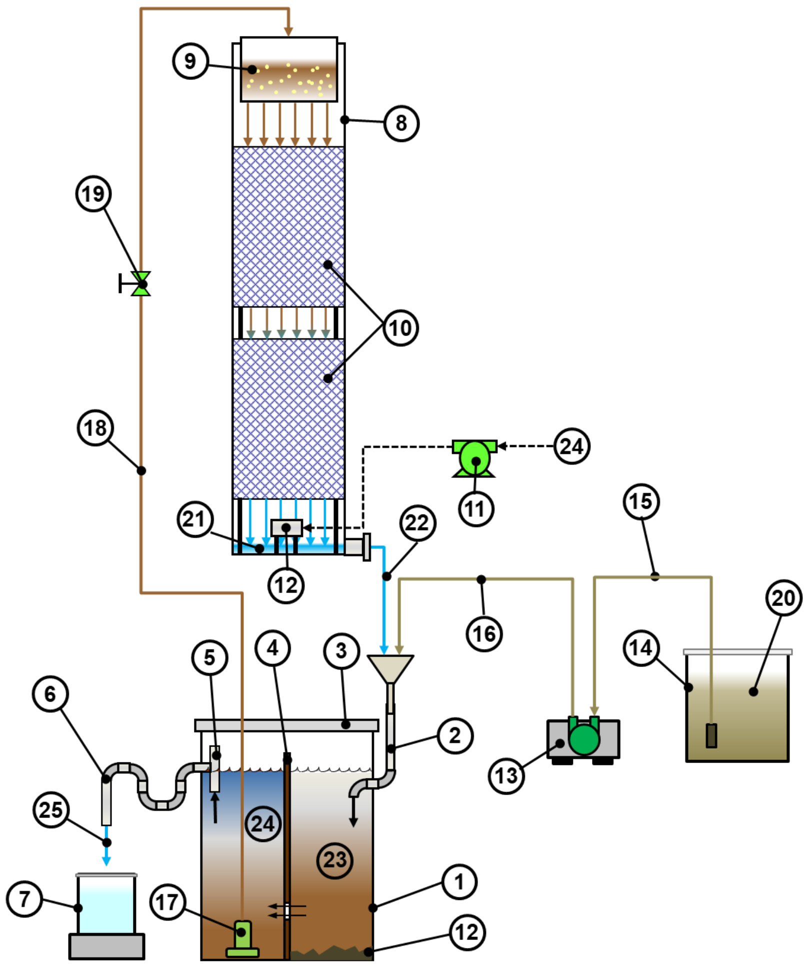

Fig. 1. Laboratory Septic Tank Biotower (LSTBT) System [22]

For measuring, the Total Suspended Solids (TSS) the Cole Parmer TSS Method and Procedure was used [24]. Each test was performed in triplicate. A sample of maximal 1000 ml was used. The sample was filtered using a 45 µm pore size glass fiber fabric filter (HACH, Be Right, grade: MGA, 47 mm). The solids which were retained on the filter and dried at 105 °C gave then the measurement for the TSS [24].

Temperature and pH measurements were conducted using a portable Milwaukee MW102 pH/temperature meter.

2.1.4 Preparation of selected influent substrates

For the LBTST system research WW and LCM were used as influent substrates.

The WW substrate was obtained from a primary clarifier at the Minoa wastewater treatment plant. It was used unfiltered Wastewater (UWW) and Filtered WW (FWW). Filtration was done using a Büchner funnel with a 100 mm diameter Whatmann, Grade 1 filter paper, that has a 11µm particle retention. However, WW can change its composition daily and is highly varying through the year, day and hour [Doelle Algae]. The reason of this lies in the nature of to the wastewater system connected homes and industries and the design of wastewater system itself. In addition, the WW might change its composition while in storage until it is used in the it LBS system.

The cow manure collected at the dairy operation at SUNY Morrisville had an original consistency of 13.2 ±0.2 %. To obtain the targeted influent quality the manure was diluted to a consistency of 5 % and then filtered using a T-Shirt fabric to remove large particles. To achieve an approximately COD level of 300mg/l, the manure was then diluted 1:50 with tap water, referred to as Liquid Cow Manure (LCM). The final achieved COD was 308 ±42 mg/l with a final TS of 0.041 ±0.002 %, and TSS of 0.0187 % compared to the wastewater.

Influent substrates were stored in a cold room at 5.0°C (41.0°F) until they were transferred to the room tempered 23.0°C (73.4°F) influent container (4).

2.1.5 Start-up of the laboratory biotower septic tank system

The Laboratory LBTST system was installed and a 9-day start-up phase with WW collect at the Mino, NY wastewater treatment plant from a primary clarifier. The WW was prepared according to 2.1.4. and 15.0 liter (3.97 gal.) of the filtered WW was filled in the recirculation tank (1) till the WW did enter glass collection beaker (7).

The LBB had already established a grown biofilm on the growth media (10) from previous experiments [20]. The biofilm was kept alive in between the experiments by constantly feeding the LBB with WW for several month.

During the entire start-up time the LBTST system was operated at a laboratory room temperature of 23.0±0.5°C (73.4±0.9°F). 16-liter (4.26 gal.) of WW (20) was stored in a in a 5 18.8 liter (5.0 gal.) influent container (14) and conditioned to room temperature prior to usage. The WW (20) is pumped with auto dosing pump (13) from the substrate reservoir (14) to the LBTST system inlet pipe assembly (2) trough PVC hose (15) and (16) at an hourly feed rate of 42 ml, representing a Hydraulic Retention Time (HRT) of 15 days.

The feed WW (20) enters the settling chamber (23) of the recirculation tank (1) which is closed with cover (3), and the heavy material, sludge (12), contained in the WW is settled out. The WW then moves through two 1.0-inch (25.4 mm) holes in the divider (4) into the effluent chamber (24).

Pond pump (17) pumps the effluent WW from effluent chamber (23) through PVC hose (18) to the distributer (9) of the of the bioreactor tank (8) at an flow rate 416 ml/min (0.11 gal/min) adjusted with flow control valve (19). This represents a recirculation of the recirculation tank volume of 40 times per day.

The WW suspension then trickles through the distributor (8) onto the growth media (10) covered with biofilm. After the suspension made its way through the growth media (10 covered with biofilm (10), the suspension is collected in the collection chamber (21) in the lower part of the glass tank (8) and is then transferred back with PVC hose (22) into the inlet pipe assembly (2) of recirculation tank (1). Air (24) to foster the biofilms bacteria growth and life is supplied by air pump (11) at a flow rate of 0.5 l/min (0.14 gal/min) (0.5 l/min) into the bottom of the glass tank (8) using a fish tank air stone and PVC hose (12).

The LBTST system effluent (25) flows through effluent assembly (5) and pig tail pipe assembly

(6) into the collection beaker (7) based on the LBTST system HRT/feed rate.

3. RESULTS AND DISCUSSION

The following chapter summarize and compares the degradation processes and effluent qualities of the LBTST systems during laboratory operation. For the research work, filtered wastewater and Liquid filtered cow manure (LCM), prepared as described in Section 2.1.5, was used.

After the start-up of the LBS system with wastewater and the 9-day adaption time, the LBS system was operated like described in Section 2.1.6., first with FWW at an HRT of 5, 10 and 20 days with a corresponding feed rate of 3,000 ml/d, 1,500 ml/d, and 750 ml/d.

The second research with LCM was used at a HRT of 5, 10, and 15 days, corresponding to a feed rate of 3,000 ml/d, 1,500 ml/d, and 1000 ml/d respectively.

The LBTST system operated automatically with a peristaltic auto dosing pump under a feed rate of 3,000 ml/d, 1,500 ml/d, and 750 ml/d which corresponds to an HRT rate of 5, 10, and 20 days accordingly. The operation of the peristaltic auto dosing pump was tested prior to usage of FWW and LCM. This test showed that the influent liquid (FWW and LCM) had to be filtered, prior to application, in order to not plug the peristaltic auto dosing pump.

The UWW collected for the 9-day start-up phase had initially a TS of 340 ± 26 mg/l. Due to larger particles present in the influent line, it was decided to collect the WW for the operational trials at the end of the primary clarifier to avoid these larger contaminating particles. The TS of the prepared FWW was 212±4 mg/l, with a TSS of 24.1 ± 0.5 mg/l and a COD of 80 mg/l.

The prepared LCM as described in section 2.1.5. had a final COD of 308 ± 42 mg/l and a final TS of 410±2 mg/l and TSS of 25 mg/l.

Both influent substrates (FWW and LCM) were stored in a cold room at 5.0°C (41.0°F) until they were used. Prior to usage they were slowly tempered to laboratory room temperature of 23.0°C (73.4°F), and then stored in influent container of the SBTST system.

3.1 Operation of the Laboratory Benchtop Septic System

The operation of the LBTST system was initiated using first FWW and second LCM.

To characterize biological processes and to follow the reactor stability pH-value is used as an indicator [25]. It can show changes of organic acids and hydrate formation in the degradation process of organic material via bacteria. Therefore, a reactor at stable state would show a stable pH-value and inhibitions in degradation routs could lead to a drift of the pH-vallue.

3.1.1 Change of pH-value

While operating the laboratory LBTST system with municipal wastewater, the pH kept stable at 7.5 ±0.1. The slight decrease from the influent pH of 8.0 ±0.1 might be related to the activity of acidifying bacteria in the reactor.

Compared to the operation with municipal WW, the laboratory LBTST system effluent had a similar stable pH- value (7.3 ±0.1) using separated LCM cow manure as influent. The influent pH was slightly higher at 7.5 ±0.1.

3.1.2 Change of temperature

Temperature could also influence biological processes. For this reason, measurements of the temperature in the LBTST system were kept at a laboratory room temperature of 23.0 ± 0.5°C (73.4 ± 0.9°F). Influent values of WW systems are operated at ambient conditions and WW influent temperatures fluctuate over the year. Average influent temperatures of WW systems can be based on own experience between 12°C and 23°C. Some systems might have higher fluctuations and can reach up to 35°C. [26].

3.1.3 Change of total solids and total suspended solids

The TS in the effluent showed an increasing trend for the FWW and the LCM. The FWW had an effluent TS of 55 mg/l, 60 mg/l, and 71 mg/l for a HRT of 5, 15 and 20 days respectively. The LCM had an effluent TS of 25 mg/l, 40 mg/l and 53 mg/l for a HRT of 5, 10 and 15 days respectively. The TSS for both the FWW and LCM was below the 4mg/l mark, except for the TSS for the LCM at 5-day HRT which was at a value of 20 mg/l.

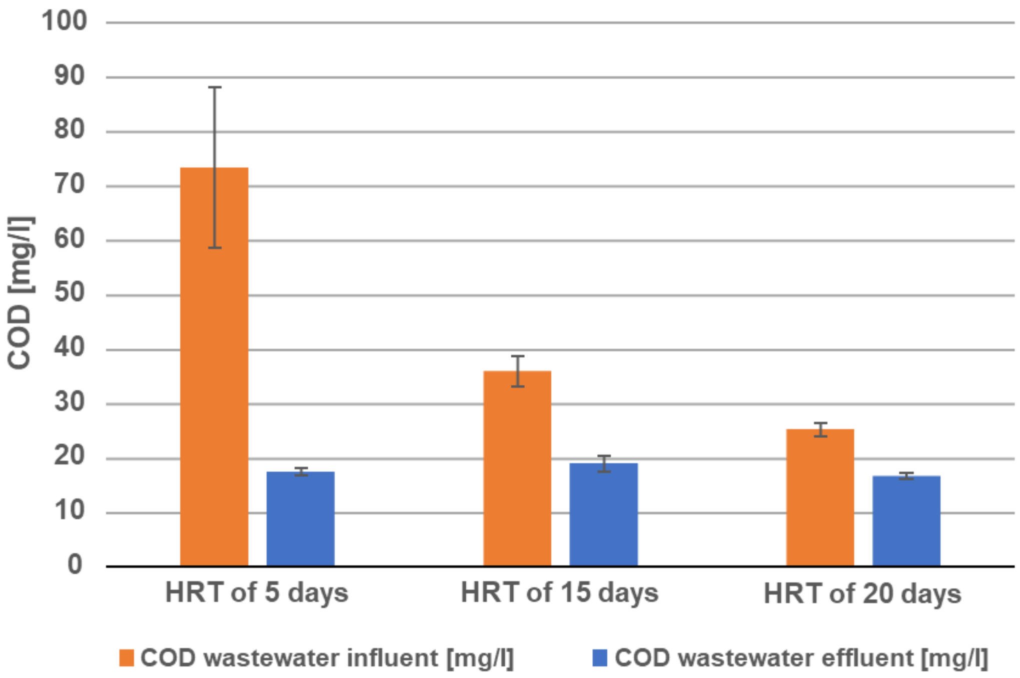

Fig. 2. Chemical Oxygen demand (COD) of Filtered Wastewater (FWW) at a hydraulic Retention time (HRT) of 5-, 15-, and 20 days

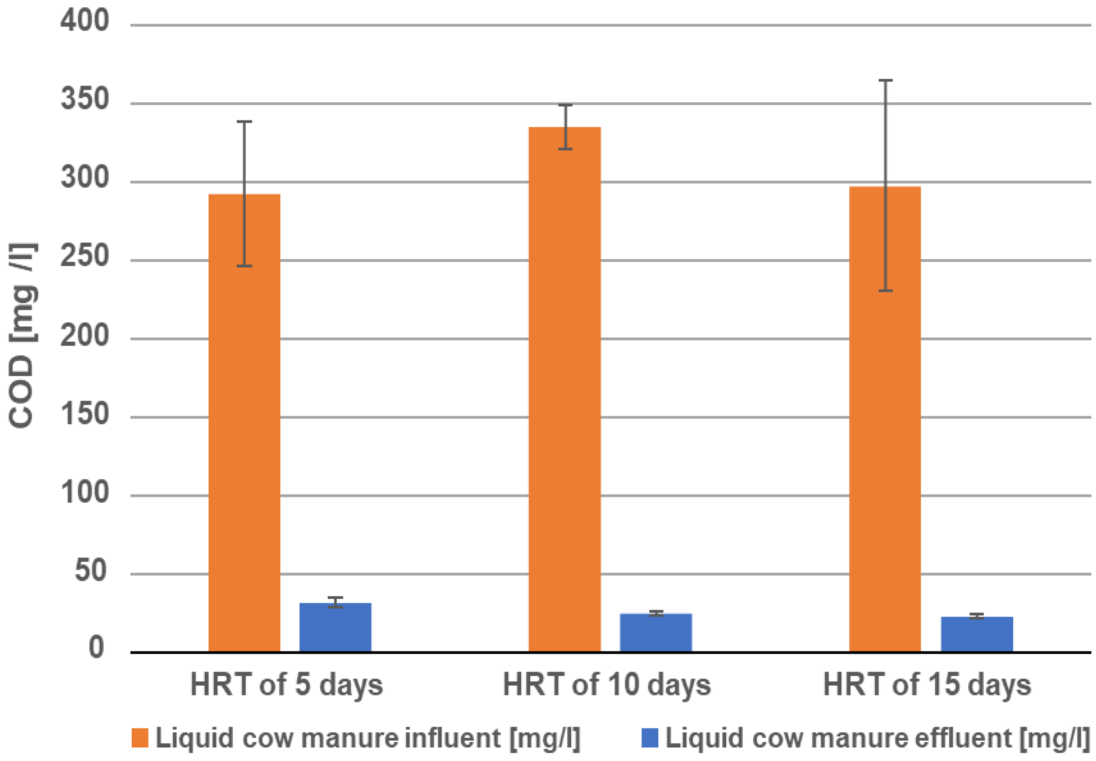

Fig. 3. Chemical Oxygen demand (COD) of Liquid Cow Manure (LCM) at a Hydraulic Retention Time (HRT) of 5, 10 and 15 days

The reason for the increasing TS of the FWW and LCM may be in a to high recirculation flow in the bioreactor which tends to wash out bacteria from the biofilm and cause a larger suspended bacteria amount in the recirculation tank. At higher HRT more bacteria are suspended in the discharged liquid.

3.1.4 Reduction of chemical oxygen demand

The LBTST system was at first operated with FWW as influent. Fig. 2 shows, that the Chemical Oxygen Demand (COD) of the influent differs between 74 ±15 mg/l, 36 ±3 mg/l and 25 ±1 mg/l within the operation modes of the three hydraulic retention times of 5 days, 15 days, and 20 days respectively. The COD of the effluent kept stable at 18 ±1 mg/l, 19 ±1 mg/l, and 17 ±1 mg/l for a HRT of 5-, 15-, and 20 days. This shows that the LBTST system was able to reduce the highly fluctuating inlet COD content to a stable effluent level by 75.7%, 47.2%, and 32.0% for a HRT of 5, 15 and 20 days.

Fig. 3. shows that compared to the FWW, the influent COD of the LCM had a higher concentration of 293 ±46 mg/l, 335 ±14 mg/l, and 298 ±67 mg/l for the 5-, 10-, and 15-day HRT respectively. The COD of the effluent kept stable at 32 ±3 mg/l, 25 ±1 mg/l, and 23 ±1 mg/l or a reduction of the highly fluctuating influent LCM COD concentration by 89.1%, 92.5%, and 92.3% for a HRT of 5, 15 and 20 days respectively.

This shows that the LBTST system can reduce the effluent COD to a stable level among highly varying influent COD levels of FWW and LCM.

4. CONCLUSION

A Laboratory LBTST system was designed, installed, started up with UWW during a 9-day start-up phase. The LBTST was then operated at a HRT of 5, 10 and 20 days with a corresponding feed rate of 3,000 ml/d, 1,500 ml/d, and 750 ml/d for the FWW and at a HRT of HRT of 5, 10, and 15 days corresponding to a feed rate of 3,000 ml/d, 1,500 ml/d, and 1000 ml/d for the LCM respectively using a peristaltic auto dosing pump.

LBTST system were kept at a laboratory room temperature of 23.0 ± 0.5°C (73.4 ± 0.9°F) during the start-up and operational phase.

The LBTST system operated with UWW had an influent pH of 7.5 ±0.1 and a slightly higher pH of 8.0 ± 0.1 for the effluent. The operation with LCM had an influent pH of 7.3 ±0.1 and a slightly increased effluent pH of 7.5 ±0.1.

The TS in the effluent of the LBTST system showed an increase for the FWW and LCM influent with increasing HRT from of 55 mg/l to 71 mg/l and from 25 mg/l to 53 mg/l for the FWW and LCM respectively.

TSS for both the FWW and LCM was below the 4mg/l mark, except for the LCM 5-day HRT at a value of 20 mg/l.

The LBTST system was operated with FWW with and influent COD between 25 ±1 mg/l and 74 ±15 mg/l and 293 ±46 mg/l to 335 ±14 mg/ for the LCM. Both influent types resulted in a stable effluent COD reduction between 17 ±1 mg/l, and 19 ±1 mg/l for a HRT between 5-, and 20 days for the FWW, and between 23 ±1 mg/l and 32 ±3 mg/l for a HRT between 5-, and 15 days for the LCM.

92.3% for a HRT of 5, 15 and 20 days respectively.

This research showed that the LBTST system can reduce the effluent COD to a stable level among highly varying influent COD levels of FWW and LCM. TS showed and increased level of up to 71 mg/l and 53 mg/l for the FWW and LCM respectively. TSS values below 4 mg/l for both the FWW and LCM.

Future research should focus if different recirculation rates have an increasing or decreasing effect on the TS, TSS and COD value of the effluent. In addition, future research on the remediation potential of the LBTST system should include influent types with higher and lower contamination such as agricultural residues, milk waste, food processing and industrial effluents.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Dölle K, Wang Q. Application of subsurface bioreactor for wastewater treatment. International Journal for Earth and Environmental Sciences. 2017; 2(132):1-6.

2. Dölle K, Giarrusso S. Bio-tower application for improvement of a decentralized waste water treatment system for residential applications-reduction of nonpoint source pollution by nitrogen. Asian Journal of Environment and Ecology (AJEE). 2021;14(3):1-7.
3. McDowell W, Brick C, Clifford M, Frode-Hutchins M, Harvala J, Knudsen K. Septic Systems Impact on Surface Waters – A Review for the Inland Northwest. Tri-State Water Quality Council; 2005.
4. Environmental Protetection Agency (EPA). Accessed June 7, 2022. Available:https://www.epa.gov/septic/septic-systems-overview
5. Environmental Protetection Agency (EPA). Accessed June 7, 2022. Available:https://www.epa.gov/nutrientpollution/sources-and-solutions
6. Doelle K, Watkins C. Application of Algae as a Biomass Feedstock Source at a Waste Water Treatment Facility. Journal of Advances in Biology & Biotechnology. 2015; 4(3):1-9.
7. Bootsma H, Young EB, Berges JA. Cladophra abudance and physical/chemical conditions in the Milwaukee Region of Lake Michigan, Milwaukee Metropololitan Sewage District; 2006. 10. October 2016. Available:http://www.mmsd.com/-/media/MMSD/Documents/Water%20Quality/Reports/cladophora_report.pdf.
8. Cost estimate of Phosphorous removal at waste Water treatment plants. Ohio Environmental Protection Agency; 2013. 10 October 2016. Available:http://epa.ohio.gov/Portals/35/wqs/nutrient_tag/OhioTSDNutrientRemovalCostEstimate_05_06_13.pdf
9. Environmental Defense Canada. Clean Not Green. Freshwater Future. 2014;(8).
10. Dölle K, Watkins C. Application of algae as a biomass feedstock source at a waste water treatment facility. Journal of Advances in Biology & Biotechnology. 2015;4(3):1-9.
11. Doelle K, Wang Q. Municipal wastewater treatment using a packed bio-tower approach. Asian J. Environ. Ecol. 2020; 13(2):42–50.
12. Dölle K, Lex, S. Benchtop septic system for effluent treatment - a laboratory development. Journal of Engineering Research and Reports. 2022;(10):34- 40.
13. Godfrey E, Woessner WW, Benotti MJ. Pharmaceuticals in on-site sewage effluent and ground water, Western Montana. Ground Water. 2007;45(3):263e271.
14. Phillips PJ, Schubert C, Argue D, Fisher I, Furlong ET, Foreman W, Gray J, Chalmers A. Concentrations of hormones, pharmaceuticals and other micropollutants in groundwater affected by septic systems in New England and New York. Sci. Total Environ. 2015;43e54:512-513.
15. Dölle K, Wang Q, Tong J. Pharmaceuticals in surface water and waste water plant effluent around the world – a review. Asian Journal of Environment and Ecology (AJEE). 2017:3(3);1-17.
16. Dölle K, Wang Q. Application of subsurface bioreactor for wastewater treatment. International Journal for Earth and Environmental Sciences. 2017; 2(132):1-6.
17. Siegrist RL, Lowe KS, Geza M, McRay JE. Soil treatment units used for effluent infiltration and purification within onsite wastewater systems: science and technology highlights. International Symposium on Domestic Wastewater Treatment and Disposal Systems. Dublin, Ireland; 2002.
18. Gill, L, Johnston P, Misstear B, O'Suilleabhain C. An investigation into the performance of subsoils and stratified sand filters for the treatment of wastewater from onsite systems. Project 2000-MS-15-M1. Report Prepared for the Environment Protection Agency; 2004.
19. Wilhelm SR, Schiff SL, Cherry JA. Biogeochemical evolution of domestic waste water in septic systems: 1. Conceptual model. Ground Water. 1994; 32(6):905–916.
20. Doelle K, Qin Y, Wang Q. Bio-tower application for wastewater treatment. Journal of Engineering Research and Reports. 2020;11(1):1-7.
21. Cross Flow Media. Brentwood Industries, Inc.: Datasheet BT006-1_09-14_EN.
22. Dölle K. Laboratory Septic Tank Biotower (LSTBT) System. pdf-file
23. HACH Method 8000 - Oxygen Demand, Chemical.
24. Cole Parmer. Total Suspended Solids (TSS) method and procedure. Cole-Parmer. 2019;10–12.
25. Dölle K, Hughes T, Kurzmann DE. From fossil fuels to renewable biogas production

from biomass based feedstock- a review of anaerobic digester Systems. Journal of Energy Research and Reviews. 2020; 5(3):1-37.

26. Tchobanoglous G, Burton FL, Stensel H. Wastewater engineering treatment and reuse. 4th Edition: Metcalf & Eddy Inc.; 2003.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/89870