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Study of Treating Wastewater with a Laboratory Benchtop Septic Systems

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Authors' contributions

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

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ABSTRACT

Efficient wastewater treatment technologies are needed to curb water scarcities and prevent the spread of diseases and contamination of water sheds. Decentralized wastewater treatment systems or respectively septic systems are easy to afford and handle – especially in rural areas. In this research a developed 19.9 l (5 gal.) laboratory septic system containing 15 l (3.96 gal.) of liquid was operated at a temperature of 18°C (64.4°F) with wastewater collected from a primary clarifier of a local wastewater treatment plant. The laboratory study included a hydraulic retention time of 30-, 10- and 5-day with and without addition of bacteria from an anaerobic sludge blanket reactor and commercially available bacteria for enhancement of septic systems.

Operating the laboratory septic system at a 10-day HRT showed the best performance for all system operations with and without enhancement bacteria in comparison n to 30- and 5-day HRT.

The developed laboratory septic system proved to be a valuable way to investigate septic systems performance on a laboratory scale.

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Keywords: Contaminants; decentralized water treatment system; remediation; septic system; sewage; wastewater.

1. INTRODUCTION

As climate change continues, water scarcity is becoming a common phenomenon in many parts of the world. According to Stanford Earth Matters Magazine, this is resulting not only in threats to human health on multiple levels but also in an increased incidence of wildfires and dust storms [1]. The southwestern US is already experiencing water shortages [2].

In addition to water-saving measures, it is also important to treat wastewater as efficiently as possible. However, the UN stats that "safely managed wastewater is an affordable and sustainable source of water, energy, nutrients and other recoverable materials" [3]. In a global scale, approximately 80% of the wastewater - produced in industry and by civilians - is released into the environment untreated which affects both, humans, and nature [4].

With the increased release phosphorus and other nutrient from agricultural operations and not proper functioning sewage systems into watersheds allows the grow of algae causing algae blooms [5], affecting local wildlife and us humans equally. We all should work on minimizing and perhaps eliminating waste and water pollution.

Continuously growing urban and suburban developments cannot be connected to existing WWTPs, because the distances in many areas of the United States are too long to be economical. This fosters the implementation of decentralized wastewater treatment systems, also known as septic systems. Therefore, especially rural, urban, and suburban governments face the burden that comes with decentralized water treatment systems and how to protect the beauty and quality of waterbodies in the affected areas [6,7].

Especially rural areas are not connected to municipal sewage systems, innovative solutions are needed. Therefore, septic systems can be used to ensure sufficient treatment of wastewater if operated properly. These systems are easy to manufacture, install and handle and can be a cost-efficient solution for the treatment of wastewater [8]. Septic systems are mainly used in urban and rural areas of the Global South. [9] In the US, according to the Environmental Protection Agency (EPA), more than one fifth of all households has got a septic system for wastewater treatment [6,8]. This helps minimizing pathogens transmitted through contaminated water. In addition, widespread wastewater infrastructure can be eliminated and the surrounding environment benefits from treated water [6].

A septic system consists of a tank in which biological processes ensure the degradation of contaminants. The polluted water is pumped into the tank through a pipe. It remains there for a long hydraulic retention period (HRT). Differences in density of the mixture's components lead to a division into phases. Those are the sinking sludge, the cleaned water, and the scum (oil and grease, etc.) floating on top. After the cleaning process, the water leaves the tank and then percolates through a drain field and adjunct soil layers till it reached the ground water table [10,11].

The laboratory research focuses on the improvement, understanding, and assessment of septic systems in order better utilize current septic systems and minimize the release of excess nutrients into the environment.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Septic systems

Wastewater was collected from the Village of Minoa Wastewater Treatment Plant (WWTP) primary clarifier in Minoa, New York. Both versions of the septic tank (one and two chambers arrangement) were developed by Dölle and Lex [6]. They are described in more detail in Section "2.2 Methods". Customary Septic System Enhancement Bacteria (SSEB), purchased from Amazon and bacteria from an Anaerobic Sludge Blanket Reactor (ASBR) from a nearby industrial WWTP used.

2.1.2 Analytical evaluation

For the analytic evaluation, a Denver Instrument SI-234 balance and a Thelco drying oven (set to 105°C = 221°F) as well as a Fisher Scientific Thermolyne 1.3 l (0.04 cuft) Muffle furnace (set to 525°C = 437°F) are being utilized.

For measuring the chemical oxygen demand, TNT 823 tests (Hach®) are used. Whatman® 934-AH glass microfiber filters having a 45 µm pore size are applied for the measurement of Total Suspended Solids (TSS)

2.2 Methods

Fig. 1 shows the Laboratory Benchtop Septic System with one single chamber (LBS1) as described by Dölle and Lex [6].

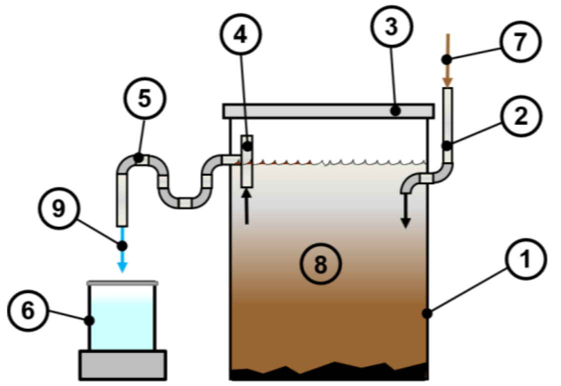

Fig. 1. Design of the Laboratory Benchtop Septic (LBS-1) System [7]: 1) 15 l-tank 2) liquid inlet 3) cover 4) Tee 5) Pig tail pipe 6) collecting beaker 7) influent wastewater 8) settling zone 9) effluent water [6]

The total capacity of the tank (1) is 19.9l (5 gal.). The tank is filled with 15l (3.96 gal.) liquid and has a freeboard of 4.9l (1.29 gal.). In this manner, the proportions of the tank are realistically reproduced, and overflow is avoided. An L-shaped pipe (2) with an inner diameter of 12.4mm (0.5 inch) forms the liquid inlet. On the opposite side, the outlet is formed by a Tee (5) connected to a pig tail pipe (6). The material and diameter of the outlet pipe is equal to the inlet pipe. The pig tail pipe, as well as the L-shaped inlet and the tanks cover (3) prevent odor from leaving the tank. A funnel is put into the inlet pipe to simplify filling the tank with municipal wastewater (7). The outflowing water (9) is collected in a beaker (6). In the settling zone (8) scum and sludge are separated from the water.

Fig. 2 shows the Laboratory Benchtop Septic System with two chambers (LBS2) as described by Dölle and Lex [7]. The tank, which is shown in Fig. 1 is modified by adding a 9.53 mm (3/8-inch) plywood divider (4) with two 25.4 mm (1.0-inch) holes located 76.2 mm (3-inch) above the bottom of the tank. In this way, the LBS2-tank is divided in two equal 7.50 liters (1.98 gal.) sized chambers (9,10); one for the settling of solids (9), and one called the effluent chamber (10). More detailed information about the design and development of the septic systems can be found in Dölle's and Lex': "Benchtop Septic System for Effluent Treatment - A Laboratory Development" [7].

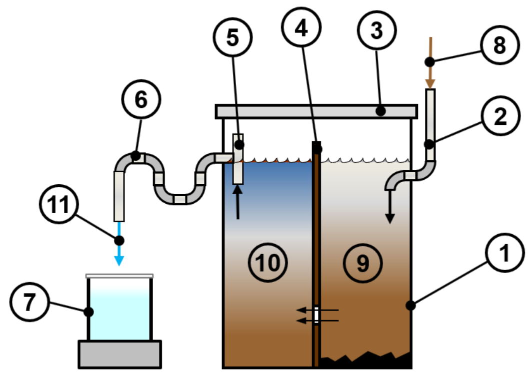

Fig. 2. Design of the Laboratory Benchtop Septic (LBS-2) System: 1) 15 l tank 2) liquid inlet 3) cover 4) wooden divider 5) Tee 6) Pig tail pipe 7) collecting beaker 8) influent wastewater 9) settling chamber 10) effluent chamber 11) effluent water [12]

2.3 Testing Procedures

The procedures to determine the Total Solids (TS) content and Total Suspended Solids (TSS) content, as well as Chemical Oxygen Demand (COD) are described in the following section. The tests for TS and TSS content are run triplicate and COD is performed single due to the Hach standardized testing vials used.

To carry out TS content analysis, a sample of 40-50g is dried at 105°C (221°F) for 24h. To obtain the TS content value, the mass of dried product is divided by the mass of the undried material. The value is expressed as a percentage. It is estimated that the weight loss is caused by moisture evaporating. The used method is modified and based on TAPPI test T412 om-06 "Moisture in pulp, paper and paperboard" [13].

For performing the TSS, 200ml of the sample are filtered through the microfiber glass filter under vacuum. The filter is weighted before filtration, dried at 105°C (221°F) for 24h and weighted again. The difference in weight can be attributed to the suspended solids and be extrapolated to one liter using the factor five [14].

The chemical oxygen demand (COD) is performed according to Hach's HACH COD TNTplus® Spectrophotometer Vial Test (3-150.0 mg/L) following HACH Method 8000 [15].

2.4 Experimental Procedure

After a start-up phase of two weeks, in which the tanks are fed with 0.5 l (0.13 gal.) wastewater each day, 2 g of anaerobic bacteria based on dry mass are added to two LBS-1-systems run at an HRT of 30-, 10- and 5 days. 2 g of ASBR bacteria based on dry mass are added to one LBS-2-tank operated at an HRT of 10- and 5 days. One LBS-1-system and one LBS-2-system do not receive any bacteria for enhancement and were run at an HRT of 30-, 10- and 5 days.

For a hydraulic retention period of 30 days, the tanks are fed with 0.5 l (0.13 gal.) wastewater daily. Next, 1.5 l (0.40 gal.) wastewater are added each day for a hydraulic retention time of ten days. For a hydraulic retention period of 5 days, 3 l (0.80 gal.) of wastewater is added daily, creating the respectively daily overflow.

Both, tanks and wastewater are hold on a constant temperature of 18°C (64.4°F). Variations in the wastewater's composition are to assume [16,17]. They are underlying the design of the wastewater system itself as well as the water being in laboratory storage [6].

3. RESULTS AND DISCUSSION

Unclarified wastewater is compared to treated wastewater within the different modified LBS-systems. All results for TSC, TSS and COD are shown in Fig. 3.

3.1 Clarified Wastewater

Because of the daily changes in wastewater condition and samples taken for research during different time periods from the primary clarifier during the 30 HRT, 10 HRT and 5 HRT research period. TS content of the wastewater influent varied between a minimum of 17.2 mg/l and a maximum of 84.9 mg/l, with an average of 60.2 mg/l. TSS content of the wastewater influent varied between a minimum of 6.7 mg/l and a maximum of 38.0 mg/l, with an average of 18.8 mg/l. COD value of the collected wastewater had an minimum of 352 mg/l and a maximum of 516 mg/l with an average of 434 mg/l.

3.2 LBS-1 System with Septic System Enhancement Bacteria

The LBS-1 systems operated with customary SSEB showed for an HRT of 30 days in the effluent 244.4 mg/l for the TS, 2.7 mg/l for the TSS and 268.5 mg/l for the COD. For an HRT of 10 days the effluent had a TS was 33.6 mg/l, the TSS was 1.5 mg/l and the COD was 322.0 mg/l. For a HRT of 5 days the TS was 36.0 mg/l, the TSS was 7.3 mg/l and the COD was below 300 mg/l in the effluent.

Effluent values for an HRT of 10- and 5 days are similar. However, values for a 30-day HRT are significant higher. This could be cause by additional biological growth I the LBS-1 system due to the 30-day HRT and discharging the bacteria through the effluent. In addition, wastewater influent inconsistencies could have triggered a higher discharge value. Based on the results using SSEB showed the best performance for an HRT of 10- and 5 days, reducing the influent values of the wastewater by approximately 50% for the TS, between 53.2% to 92.0% for the TS and between 26.8% to 30.9% for the COD.

3.3 LBS-2 System with Anaerobic Sludge Blanket Reactor Bacteria

The LBS-2 systems operated with customary ASBR bacteria showed for an HRT of 10 days in the effluent 34.9 mg/l for the TS, 12.5 mg/l for the TSS and 200.0 mg/l for the COD. For an HRT of 5 days the effluent had a TS was 30.3 mg/l, the TSS was 17.5 mg/l and the COD was 380.0 mg/l.

Effluent values for an HRT of 10- and 5 days are very similar. However, COD value of the 5-day HRT shows only a reduction of 12.4% compared to the 10-day HRT which shows a reduction of 53.9% for the COD value. Reduction of TS and TSS for the 5-day and 10 day HRT are similar between 42.0% to 50.3% for the TS and between 33.5% to 9.0% for the TSS respectively.

Based on the results using ASBR bacteria showed the best performance for an HRT of 10-days. However the TS and was slightly lower for the 5-day HRT which could be caused by influent wastewater influent inconsistencies.

3.4 LBS-system without Bacteria

Both, a LBS-1- and a LBS-2-system are used in this part of the investigation without addition of any bacteria for system enhancement.

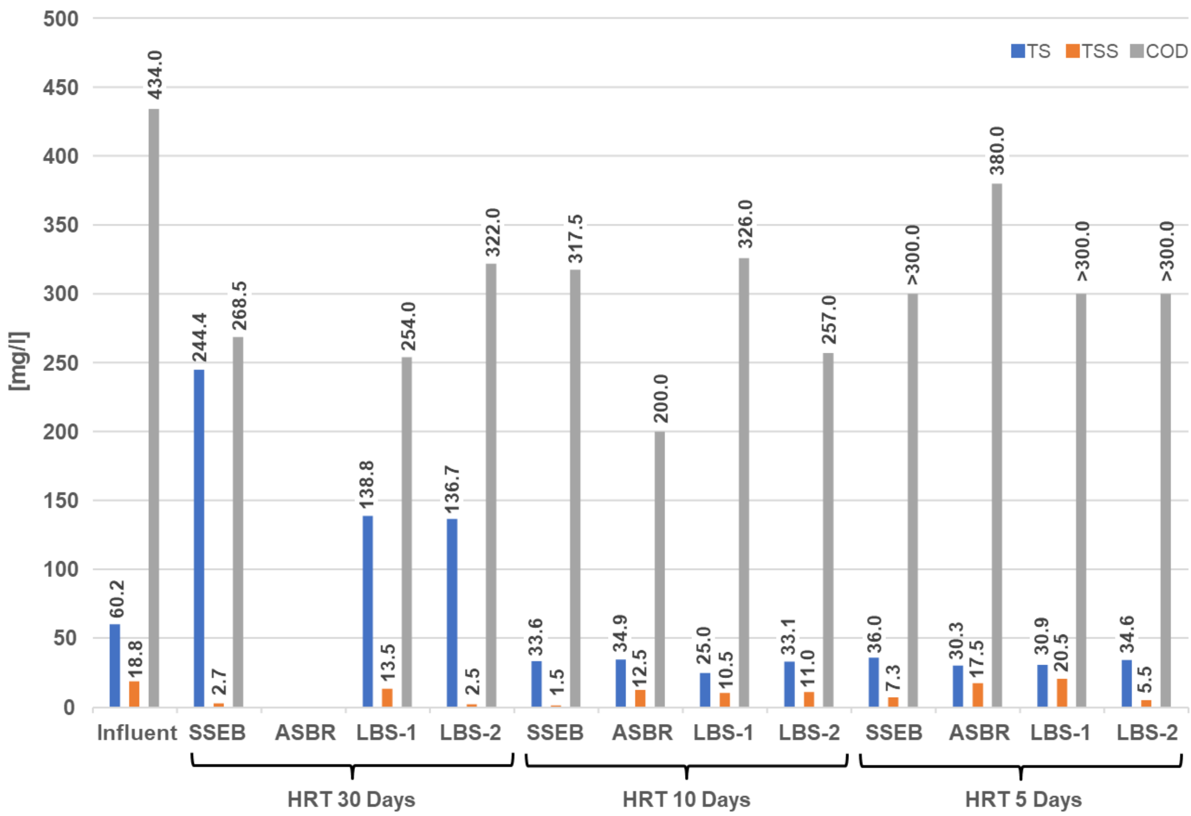

Fig. 3. Influent and Effluent values of the different modified LBS-systems

The LBS-1 and LBS-2 system operation showed respectively for an HRT of 30 days in the effluent 138.8 mg/l and 136.7 mg/l for the TS, 13.5 mg/l and 2.5 mg/l for the TSS and 254.0 mg/l and 322.0 mg/l for the COD. For an HRT of 10 days the effluent for the LBS-1 and LBS-2 system showed respectively a TS of 25.0 mg/l and 33.1 mg/l. The TSS was 10.5 mg/l and 11.0 mg/l. The COD was 326.0 mg/l and 257 mg/l. For the HRT of 5 days the LBS-1 and LBS-2 system has respectively a TS of 30.9 mg/l and 34.6 mg/l, with a TSS of 20.5 mg/l and 5.5 mg/l. The COD was below for both systems below 300 mg/l in the effluent.

The LBS-1 and LBS-2 system showed the best performance at an HRT of 10 day in regard to TS, TSS and COD measurements of the effluent. The TS was reduced between 58.5.% to 45.0%, the TSS between 44.1% and 41.4%, and the COD between 53.9% and 24.8%.

4. CONCLUSION

Tests conducted on a developed 19.9 l (5 gal.) laboratory septic system containing 15 l (3.96 gal.) liquid was operated at a HRT of 30-, 10- and 5 days at an temperature of 18°C (64.4°F) with and without enhancement bacteria. The influent wastewater collected from a primary clarifier at a nearby WWTP had a TS content minimum of 17.2 mg/l and a maximum of 84.9 mg/l, with an average of 60.2 mg/l. The TSS content varied between a minimum of 6.7 mg/l and a maximum of 38.0 mg/l, with an average of 18.8 mg/l. COD influent was at a minimum of 352 mg/l and a maximum of 516 mg/l.

Operating the laboratory septic system at an 10-day HRT showed the best performance for all system operations with and without enhancement bacteria in comparison n to 30- and 5-day HRT.

Addition of ASBR bacteria outperformed the SSEB addition and operation without bacteria in regard to COD reduction while TS and TSS reduction were at similar values. A 30-day HRT showed higher TS values for all operation modes while the TS in the effluent was similar for the 5-day HRT.

wastewater influent inconsistencies could have triggered a higher discharge value. Based on the results using SSEB showed the best performance for an HRT of 10- and 5 days, reducing the influent values of the wastewater by approximately 50% for the TS, between 53.2% to 92.0% for the TS and between 26.8% to 30.9% for the COD.

The developed laboratory septic system proved to be valuable to investigate septic systems performance on a laboratory scale and will be used in further studies.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Josie Garthwaite. The effects of climate change on water shortages. Stanford Earth Matters magazine; 2019.
   Accesson 18 August 2022.
   Available:https://earth.stanford.edu/news/effects-climate-change-water-shortages#gs.8y2l5l
2. Olivia Lai. US Drought: What are the causes, effects and solutions. EARTH.ORG; 2021.
   Accesson 18 August 2022.
   Available:https://earth.org/us-drought/
3. Water and climate change. UN Water.
   Access on 26 September 2022.
   Available:https://www.unwater.org/water-facts/water-and-climate-change
4. Kamble PS, Kamble AC. Health effects of water pollution. EPRA International Journal of Economic and Business Review; 2022.
5. Doelle K, Watkins C. Application of algae as biomass feedstock source at a waste water treatment facility. British Journal of Advances in Biology & Biotechnology (BJABB). 2015;4(3):1-9.
6. Dölle K, Lex S. Benchtop septic system for effluent treatment - A laboratory development. Journal of Engineering Research and Reports. 2022;22(10):34-40.
7. 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.
8. Environmental Protection Agency (EPA).
   Accesson December 15, 2022.
   Available:https://www.epa.gov/septic
9. Herrera E, Meneses-Jácome A. Nature-based wastewater treatment – Overview and current common systems. in: bumbac c, clifford e, dussaussois jb, schaal a, tompkins d, editors. innovative wastewater treatment technologies – The INNOQUA project. Hanover: Now Publishers Inc; 2021.
10. Godfrey E, Woessner WW, Benotti MJ. Pharmaceuticals in on-site sewage effluent and ground water, Western Montana. Ground Water. 2007;45(3): 263e271.
11. 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.
12. Dölle K. Design of the laboratory benchtop chamber septic system. Pdf-file.
13. TAPPI T412 om-06. Moisture in pulp, paper and paperboard.
14. Cole Parmer. Total Suspended Solids (TSS) method and procedure. ColeParmer. 2019;10–12.
15. HACH Method 8000 - Oxygen Demand, Chemical.

16. Doelle K, Watkins C. Algae to remove phosphorous in a trickling filter. British Journal of Advances in Biology &Biotechnology (BJABB). 2017;11(2): 1-9.
17. Doelle K. Water treatment and remediation using a bioreactor. Unites States Golf Association (USGA), Turfgrass and Environmental Research. 2015;14(1): 12-14.

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