REDUCTION AND LIQUID-SOLID PARTITIONING OF VIRAL PATHOGENS PRESENT IN SEWAGE IN SPONGE-BED TRICKLING FILTERS AS POST-TREATMENT OF UASB REACTOR

Rosa-Machado, A.*, Lopes, B.*, Vassalle, L.*, Bressani-Ribeiro, T.* and Mota, C

* Federal University of Minas Gerais. e-mail: cesar@desa.ufmg.br

Highlights:

- The UASB reactor+DHS system is efficient for the removal of viruses present in the liquid phase;
- The SARS-CoV-2 of left the system in the UASB sludge only;
- More than 50% RV-A and HAdV of left the system in the UASB slud, scum and trickling filters.

Keywords: SARS-CoV-2; Rotavirus A; post-treatment UASB reactor.

INTRODUCTION

Enteric viruses are responsible for various waterborne infectious diseases, such as diarrhea and viral hepatitis, which primarily affect populations without adequate access to hygiene and sanitation conditions. During the Covid-19 pandemic, the presence of SARS-CoV-2 was detected in both raw sewage and treated effluents at wastewater treatment plants (WWTPs) (Abu Ali et al., 2020). Although there is no confirmed evidence of SARS-CoV-2 transmission through the fecal-oral route so far, research suggests this possibility.

In Brazil, anaerobic reactors represent 37% of wastewater treatment systems (ANA, 2020), typically followed by trickling filters for post-treatment of anaerobic effluents. In recent years, a widely studied alternative for improving trickling filters has been the use of polyurethane sponges as a support medium. Systems composed of upflow anaerobic sludge blanket (UASB) reactors and sponge-bed trickling filters (DHS) not only provide high efficiency in the removal of organic matter and nutrients (Bressani-Ribeiro et al., 2021), but also demonstrate good efficiency in removing pathogenic bacteria present in sewage (Miyaoka et al., 2017). Furthermore, the low production of excess sludge in these systems allows for operation without the need for secondary settlers, making them particularly suitable for decentralized systems (Bressani-Ribeiro et al., 2021).

Although advances have been made in improving DHS systems, there is still a significant gap in the literature regarding the use of this emerging system for the removal of SARS-CoV-2 and other viral pathogens in anaerobic effluents. In this context, this study aims to evaluate the removal, reduction, and solid-liquid partitioning of SARS-CoV-2, RV-A, and HAdV pathogens present in domestic sewage, using a system composed of a UASB reactor followed by an DHS, operating without the need for a secondary settling unit.

METHODOLOGY

Experimental design and samplings: The UASB reactor has a useful volume of 14.1 m^3, operated with a hydraulic detention time of 8.5 hours. The DHS has a useful height of 3.91 m, with a cross-sectional area of 0.25 m^2, the total volume of the reactor is 0.98 m^3 and 40.0% of this volume is filled with polyurethane sponges, the surface hydraulic loading rate in the DHS was 10.0 $m^3.m^{-2}.d^{-1}$. Unlike traditional systems, the system operated without a secondary settler.

The sampling and monitoring period of the experiment was between the months of Mar./2021 and Apr./2021 during the covid19 pandemic, totaling 10 samplings for the liquid phase (raw sewage, UASB reactor effluent and DHS effluent) and 5 samplings for the solid phase (scum and sludge from the UASB reactor, and biomass from the DHS).

Molecular quantification: The viral DNA/RNA concentration followed the method described by Ahmed et al. (2020b), an adaptation of the adsorption-elution method developed by Katayama et al. (2002). The analyses for detection and quantification of SARS-CoV-2, Rotavirus A (RV-A), and Human Adenovirus were performed using the quantitative polymerase chain reaction (qPCR) technique.

For the quantification of SARS-CoV-2 and Human Adenovirus, the assay described by Espinosa et al. (2022) was used. In the case of RV-A, a SYBR-green assay was employed, using primers recommended by Applied Biosystems™ (Forward: ACCCTCTATGAGCACAATA, Reverse: GGTCACATAACGCCCCTA). Reverse transcription was performed using the MasterMix Itaq Universal Probes One Step kit (Biorad).

Analysis of removal, reduction, and partitioning of the virus: The removal, reduction, and liquid-solid partitioning of the viruses were calculated based on the model proposed by Espinosa et al. (2022).

RESULTS AND CONCLUSIONS

The geometric mean concentrations of SARS-CoV-2, RV-A, and HAdV in the influent raw sewage were 4.25, 3.61, and 4.16 log copies.L^{-1}, respectively. After treatment in the UASB reactor, a removal of 0.80 log copies of SARS-CoV-2 genetic material was observed. However, this removal was not statistically significant ($p>0.05$). Espinosa et al. (2022) reported a removal of 0.16 log copies of SARS-CoV-2 in UASB reactors, corroborating the observed inefficiency. In the case of RV-A, no significant removal was detected in the UASB reactor.

After post-treatment of the anaerobic effluent by the DHS, no genetic material of SARS-CoV-2 was detected in the final treated effluent, suggesting a possible removal of 4.25 log copies. For RV-A and HAdV, the DHS efficiency was 1.18 and 3.13 log copies, respectively.

Regarding the liquid-solid partitioning of viruses in the UASB reactor + DHS system (Figure 1), it was observed that SARS-CoV-2 left the system adsorbed only to the UASB reactor sludge. In the case of enteric viruses, approximately 52.5% of RV-A was removed along with the UASB reactor sludge. For HAdV, about 77.5% of the virus was removed adsorbed to the solid phase, that is, to the UASB reactor sludge and scum, as well as to the total suspended solids (TSS) present in the DHS effluent.

Finally, in terms of overall virus reduction (considering both the liquid and solid phases) in the UASB reactor + DHS system, significant removal was observed only for SARS-CoV-2 and HAdV ($p<0.05$).

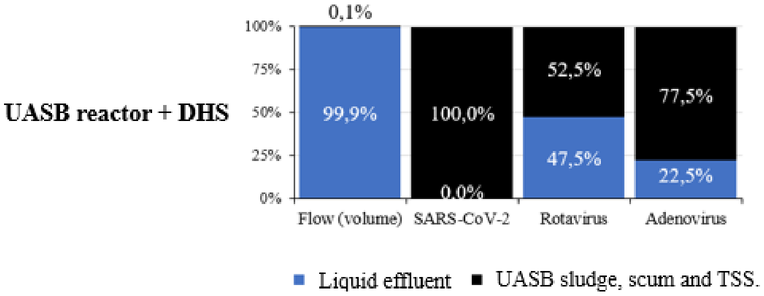

Figure 1: Liquid-solid partitioning of the virus.

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REFERENCES

ABU ALI, Hala et al. Tracking SARS-CoV-2 RNA through the wastewater treatment process. ACS ES&T Water, v. 1, n. 5, p. 1161-1167, 2021.

Ahmed, W. et al. First confirmed detection of SARS-CoV-2 in untreated wastewater in Australia: A proof of concept for the wastewater surveillance of COVID-19 in the community. Science of the Total Environment, v. 728, p. 138764, 2020b.

ANA–National Water Agency, 2017. Watershed Sewage Depollution Atlas. Available at: http://atlasesgotos.ana.gov.br.

Bressani-Ribeiro, T. et al. Inorganic carbon limitation during nitrogen conversions in sponge-bed trickling filters for mainstream treatment of anaerobic effluent. Water Research, v. 201, n. March, p. 117337, 2021.

Espinosa, M. F. et al. Reduction and liquid-solid partitioning of SARS-CoV-2 and adenovirus throughout the different stages of a pilot-scale wastewater treatment plant. Water research, p. 118069, 2022.

Miyaoka Y, et al. Eukaryotic Community Shift in Response to Organic Loading Rate of an Aerobic Trickling Filter (Down-Flow Hanging Sponge Reactor) Treating Domestic Sewage. Microb Ecol. 2017;73(4): 801–14.

Katayama, H., Shimasaki, A., Ohgaki, S., 2002. Development of a virus concentration method and its application to detection of enterovirus and Norwalk virus from coastal seawater. Appl. Environ. Microbiol. 68, 1033–1039. https://doi.org/10.1128/AEM.68.3.1033-1039.2002.