Structured Bed Reactors for Sewage Treatment: Remote Monitoring and Key Parameter Analysis

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Highlights:

- Remote monitoring system developed using Raspberry Pi and ADS1115 ADCs for structured bed reactors.
- Strong correlations identified between NH_4^+-N, NO_3^--N, pH, and ORP parameters.
- Potential for remote operation and predictive modeling using correlated variables.
- Efficient total nitrogen removal despite parameter fluctuations during aeration cycles.

Keywords: Remote Monitoring; Structured Bed Reactors; Wastewater Treatment

INTRODUCTION

The treatment of domestic sewage remains a significant challenge, especially in developing countries. In Brazil, only 52.2% of the generated sewage is treated, requiring substantial investments in the sector (SNIS, 2022). In this context, the structured bed reactor with intermittent aeration (SBRIA) has proven to be a promising technology. Unlike conventional systems, the SBRIA can promote the simultaneous removal of organic matter and nitrogen in a single reaction unit, making it advantageous in both constructive and operational aspects (Moura et al., 2018; Oliveira et al., 2023) .

Furthermore, research focused on the remote monitoring of the reactor and its operational control is of great importance. By associating this monitoring with an easy-to-build and operate system, it becomes possible to improve sanitary conditions even in less developed regions, as the entire control of the system can be carried out remotely. Thus, the automation of these processes is essential to ensure the efficiency of sewage treatment.

Therefore, this work aims to develop a monitoring system for key parameters in an SBRIA reactor, with the goal of enabling its future control through Machine Learning techniques.

METHODOLOGY

The reactor was made of acrylic, cylindrical in shape, with an internal diameter of 14.6 cm, a height of 61 cm, and a conical base, totaling a volume of approximately 10.8 L. A total volume of 3.8 L of support material was added to the reactor, resulting in a bed porosity of 64%.

Vernier sensors for dissolved oxygen, pH, redox potential, temperature, ammonia nitrogen, and nitrate were installed to monitor the reactor. A data acquisition and logging system was developed to simultaneously use up to 8 different analog probes from Vernier that utilize BTA connectors. The system includes a Raspberry Pi 2W and two 16-bit ADS1115 analog-to-digital converter ICs. An HTTP server was programmed on the Raspberry Pi to allow configuration of the acquisition system and access to recorded probe data via a website.

Reactor monitoring was conducted from 20/05/2024 to 24/05/2024, operating with a Hydraulic Retention Time (HRT) of 10 hours, temperature of 30 °C, air flow rate of 4.5 L/min, and aeration and non-aeration periods of 1h45min and 45min, respectively. Data was collected every 30 seconds.

RESULTS AND CONCLUSIONS

The data acquisition by the probes occurred without interruption throughout the experimental period. The Figure 1 illustrates the behavior of the parameters as a function of the aeration and non-aeration periods. The ammonium nitrogen (NH_4^+-N) data exhibited greater stability, while the nitrite nitrogen (NO_3^--N) data showed more fluctuations. Despite these oscillations, a good total nitrogen removal efficiency was observed, as the reactor was fed with an NH_4^+-N concentration of 30 mg/L. Oliveira et al., (2020) concluded that this reactor model presented flow characteristics like a completely mixed reactor when operated with intermittent aeration. However, it is possible to note in Figure 1 that there is an oscillation of the data during the aeration and non-aeration periods, which may interfere with the concentration of the nitrogen species in the reactor effluent.

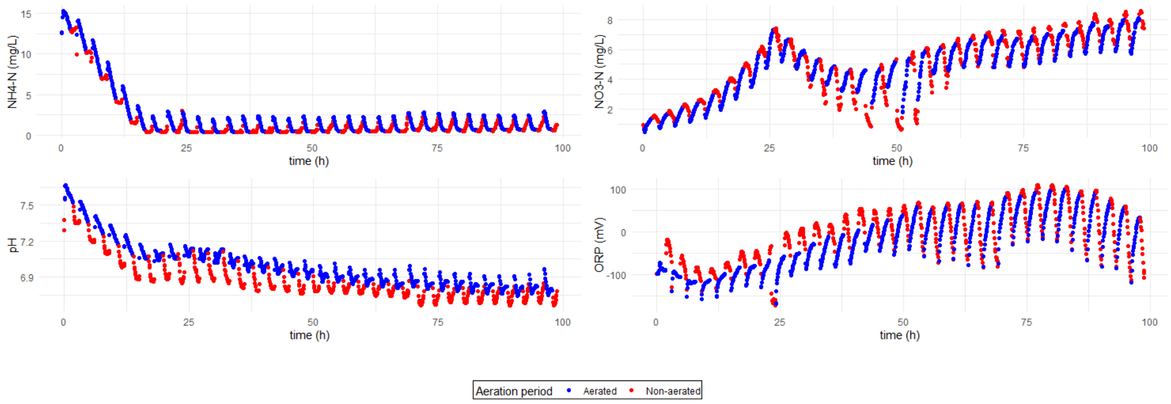

Figure 1 - Temporal profile of the parameter monitored in the SBRIA.

The Spearman correlation analysis results are presented in Figure 2. Stronger correlations were observed between the NH_4^+-N and ORP (Oxidation-reduction potential) parameters, NO_3^--N and pH, and between pH and ORP. The correlations found between the variables can become a key factor when seeking remote reactor operation, as multiple variables can be monitored, reducing the risks of failures due to probe malfunctions. Furthermore, with increased experimental data acquisition, it may be possible to develop a predictive model of reactor efficiency as a function of different measured parameters, given the correlation between a simple monitoring parameter, such as pH, and a parameter that is more difficult to monitor, such as NO_3^--N.

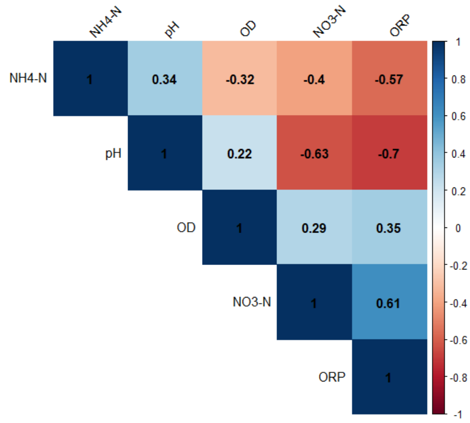

Figure 2 - Spearman correlation between the parameter monitored in the SBRIA

ACKNOWLEDGMENTS

The authors would like to acknowledge the financial support provided by Fundação de Amparo à Pesquisa do Estado de Minas Gerais (FAPEMIG), Instituto Mineiro de Gestão das Águas – IGAM and Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq).

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