IWA 17th SWWS AND 9th ROS
10th–14th November, 2024
Curitiba-Brazil

Effect of the Variation of the Carbon/Nitrogen Ratio on the Removal of Organic Matter and Nitrogen from Effluents Generated in Dairy Industries

Correa, C.Z.*, Prates, K.V.M.C.**, Lopes, D.D.*** and Damianovic, M. H. R. Z.,****

*Prof. Dr. of the Department of Civil Engineering at the Federal Technological University of Paraná (UTFPR). Apucarana, Paraná, Brazil.
**Prof. Dr. of the Department of Environmental Engineering, Federal Technological University of Paraná Londrina, Paraná, Brazil.
*** Prof. Dr. of the Department of Civil Construction, State University of Londrina. Londrina, Paraná, Brazil.
****Prof. Dr. of the Department of Hydraulics and Sanitation at the School of Engineering of São Carlos University of São Paulo (EESC-USP). São Carlos, São Paulo, Brazil.

Highlights:

- Total nitrogen removal was reduced by changing the C/N ratio from 11 to 3.
- The oxidation of NH_4^+-N was compromised by the lack of alkalinity in the medium with a C/N ratio of 3 - organic loading rates of 1.2 kgCOD.m^{-3}d^{-1}.
- The composition of dairy wastewater influences the simultaneous removal of organic matter and nitrogen.

Keywords: intermittent aeration; simultaneous nitrification and denitrification (SND); structured bed reactor.

INTRODUCTION

Conventional nitrogen removal processes require much energy for aeration and additional carbon sources to sustain nutrient removal. Consequently, alternative approaches are desired to reduce the operational costs of industrial wastewater treatment plants and minimize pollutant discharges.

Given the above, the use of intermittent aeration (IA) in reactors with attached biomass, such as structured bed reactors (SBR), can be seen as a good alternative to reduce costs in wastewater treatment plants (SILVA et al., 2018). Since the concentrations of organic matter and nitrogen significantly affect the activity of nitrifying and denitrifying bacteria in the biological treatment of wastewater, this research aimed to evaluate the efficiency of organic matter and total nitrogen (TN) removal in a structured bed reactor operated with IA and recirculation when used for treating wastewater generated in dairies.

METHODOLOGY

The experiment was conducted on a bench scale, using a SBR with continuous flow, operated with intermittent aeration (2 hours with aeration on and 1 hour with aeration off), recirculation, and fed with wastewater generated by a dairy industry. The reactor was operated with a hydraulic retention time (HRT) of 16 hours and a recirculation flow rate of 3 times the influent flow rate, with its temperature maintained at 26±1°C. The study was conducted over 88 days, divided into three experimental conditions: Phase I - (organic loading rates (OLR) - 2.2 kgCOD.m^{-3}d^{-1} and C/N ratio (COD/TKN) = 11;

Phase II – OLR 1.0 $kgCOD.m^{-3}d^{-1}$ and C/N ratio = 3; and Phase III – OLR 1.0 $kgCOD.m^{-3}d^{-1}$ and C/N ratio = 3. The changes in the C/N ratios were achieved by adding NH_4Cl to the influent. To evaluate the system's performance, physical-chemical analyses were conducted on the influent and effluent from the reactor to determine pH, alkalinity, nitrogen series, Chemical Oxygen Demand (COD), total, and filtered (APHA, 2012).

RESULTS AND CONCLUSIONS

There was a reduction in the COD removal percentage in Phase III, with results statistically inferior to the others (Test: Kruskal-Wallis, level: 95%) (Table 01). From the data presented, it is also possible to note that the effluent COD in all conditions was close to 80 mg L^{-1}, demonstrating the reactor's stability in removing biodegradable organic matter.

From Phase I to Phase II, there was a significant reduction in TKN removal, resulting from the low removal of NH_4^+-N in the reactor. The removal of NH_4^+-N may have been affected by the lack of alkalinity in the effluent, necessitating the addition of an external alkalinity source ($NaHCO_3$) for the operation of Phases II and III. The results indicated that the composition of dairy wastewater influences the simultaneous removal of organic matter and nitrogen. It was observed that with a C/N ratio below 11, the amount of aerobically degraded organic matter was insufficient to buffer the system However, in higher ratios the existence of exogenous sources of alkalinity is not required (CORREA, 2021).

With the reduction of the C/N ratio from 11 to 3 (Phase II), the denitrification percentage remained close to 80%. In Phase III, the concentration of oxidized forms of nitrogen increased by approximately 2.5 times, with an increase, mainly in NO_3^--N, which resulted in a reduction in the percentage of denitrification. The removal of TN was 53±6%, 37±6% and 22±9% in Phases I, II and III, respectively.

The reduction in the removal percentage of TN from Phase I to Phase II is explained by the low removal of NH_4^+-N, caused by the lack of alkalinity in the medium. In Phase III, this percentage was affected by the reduction in denitrification, which was influenced by the low availability of organic matter in the effluent.

From the results, it was possible to conclude that with the decrease in the C/N ratio from 11 to 3, the average TN removal efficiency decreased by approximately 30% from Phase I to Phase II and about 40% from Phase II to Phase III. This decrease was associated with the lack of alkalinity in the medium for Phase II and the reduction in the denitrification percentage for Phase III. During system operation, there was no accumulation of oxidized forms of nitrogen in the reactor, indicating the occurrence of SND.

Table 01 - COD influent (IN) and effluent (EF), organic loading rates (OLR) and percentage of COD removal obtained in the phases studied.

Phase	COD_T		COD_F		OLR		Removal	
	IN	EF	IN	EF	Aplicada	Removida	COV_T	COV_F
	mg L^{-1}				kgCOD $m^{-3}d^{-1}$		%	
I	1552±52	154±54	1210±86	84±56	2,2±0,3	2,0±0,4	91±3[a]	92±5[a]
II	936±48	138±124	779±159	75±74	1,2±0,2	0,8±0,6	88±14[a]	98±2[a]
III	455±128	112±80	300±145	84±33	0,7±0,2	0,5±0,2	71±11[b]	67±7[b]

Note: Equal letters = statistically equal values; Different letters= statistically different values at the 95% level - Test: Kruskall-Wills.

Table 02 - Influent (IN) and effluent (EF) concentration of TKN, NH_4^+-N, NO_2^--N, NO_3^--N and removal percentage of TKN and NH_4^+-N and denitrification

Phase	TKN		NH_4^+-N		NO_2^--N	NO_3^--N	Removal		*DN
	IF	EF	IF	EF	EF	EF	TKN	NH_4^+-N	
	mg L^{-1}						%		
I	126,4±0,9	41,5±8,6	92,9±1,4	39,0±6,9	2,2±1,8	16,1±3,6	67±7	60±8	78±4
II	363,4±5,2	212,3±1,3	284,8±44,4	185,7±85,4	7,2±7,2	23,3±10,0	42±0,4	38±32	77±12
III	171,5±8,4	71,8±48,4	160,3±13,1	64,7±53,7	12,9±11,4	62,8±31,9	57±26	58±38	43±14

*DN = Percentage of denitrified.

ACKNOWLEDGMENTS

The Authors would like to thank the Coordination for the Improvement of Higher Education Personnel (CAPES) and the State University of Londrina (UEL) for the support received.

REFERENCES

AMERICAN PUBLIC HEALTH ASSOCIATION (APHA). **Standards Methods for the Examination of Water e Wastewater**. Washington, D.C; 2012.

CORREA, C, Z. **Remoção de matéria carbonácea e nitrogenada de efluente de laticínios em reator de leito estruturado operado com aeração intermitente**. 171f. Tese (Doutorado em Engenharia Civil) – Universidade Estadual de Londrina, Centro de Tecnologia e Urbanismo, Programa de pós-graduação em Engenharia Civil, 2021.

SILVA, B. G.; DAMIANOVIC, M. H. R. Z.; FORESTI, E. Effects of intermittent aeration periods on a structured-bed reactor continuously fed on the post-treatment of sewage anaerobic effluent. **Bioprocess and Biosystems Engineering**., v. 41, p. 1115-11120, ago. 2018. https://doi.org/10.1007/s00449-018-1940-1