ASSESSMENT OF THE IMPACT OF POLY-ALUMINIUM CHLORIDE ON THE METABOLISM OF ACTIVATED SLUDGE

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ABSTRACT

The evaluation of the impact of poly-aluminium chloride (PAC) on the metabolism of microorganisms in activated sludge (AS) systems, commonly used in wastewater treatment, is important for the optimization and control of treatment systems. Analyses, including microscopy, phosphorus concentration, and respirometry, were conducted to understand how PAC affects the characteristics and performance of these biological systems. The results obtained indicated that PAC did not exhibit inhibitory effects on microorganisms up to the tested concentrations, and an increase in oxygen consumption rates were observed in the presence of the chemical additive. However, higher concentrations of PAC resulted in a proportional increase in the volume of excess sludge, suggesting potential implications for the operation and maintenance of these systems. Although no toxic effect was observed within the tested concentrations, the study raises the possibility of adverse effects in situations of excessive accumulation of PAC.

Keywords: Poly-Aluminium Chloride; Activated Sludge; Respirometry.

1 INTRODUCTION

The Activated Sludge (AS) system is a biological process with an aerobic reactor followed by a settling tank, aiming to remove carbonaceous and nitrogenous matter. Advanced AS configurations for efficient nutrients removal (i.e. nitrate and phosphorus) have been developed to avoid their disposal in natural water bodies. In tropical countries like Brazil, the relevance of phosphorus is relatively higher, as eutrophication is favoured by climatic conditions. Phosphorus removal is a challenging task due to design and operational conditions in the wastewater treatment plants (WWTP). In this regard, the use of chemical additives like poly-aluminium chloride (PAC) has been adopted for phosphorus removal through co-precipitation with the excess sludge. Besides this is a common operational practice, it was hypothesized that chemicals may inhibit the microbial ecology of the system, Li et al (2018)[5] highlights that the addition of chemical additives to the AS system has significant influences on the structure of microbial cells, flocs and bacterial metabolism (autotrophic and heterotrophic) of the activated sludge, especially at different dosages and contact times.

The oxygen uptake rate (OUR) also known as respirometry, is a measuring of the oxygen consumption velocity during the aerobic bacterial respiration due the consumption of carbonaceous and nitrogenous matter. One mol of glucose requires 1.42 mol of oxygen while one mol of ammonium requires 4.57 mol of oxygen for its oxidation. Higher OUR results reveal higher microbial activity against the substrate. Also, this method allows the biomass partitioning between heterotrophic and autotrophic biomass, responsible for the carbon and nitrogen matter removal, respectively. The microscopy is another monitoring tool to support the OUR results, revealing the AS floc structure and the microbial diversity.

In this sense, evaluation techniques of the activated sludge system through respirometry and microscopy can provide important information about the potential impact of adding products to the biological process aiming the phosphorus removal This study aimed to assess the impact of PAC on the microbial respiration of AS samples collected from a full-scale WWTP located in Florianópolis, Brazil.

2 MATERIAL & METHODS

The mixed liquor was collected from the AS reactor (oxidation ditch). Respirometry was determined following the methodology of Andreottola et al. (2007)[1]. Firstly, the sample underwent aeration for 24 hours without the addition of exogenous substrate. A YSI PRO 1020 multiparameter probe was used for dissolved oxygen measurement along with an aeration pump. This process was divided into three stages: endogenous respiration by oxygen saturation through aeration, autotrophic nitrifying respiration by the addition of ammonium chloride (NH_4Cl), heterotrophic respiration with ATU (allylthiourea) solution to inhibit autotrophic nitrifying respiration, and acetate solution addition.

Microscopic analysis was conducted using a binocular optical microscope (Olympus model BX-41). Initially, the general appearance of the floc and the presence of organisms were assessed according to Eikelboom et al. (2000)[3]. Gram staining was performed using a method adapted from the classical method and the modified Hucker method.

Polysaccharide concentration in the sludge was determined using the colorimetric method of Dubois et al (1956)[6]. The series of solids and SVI (Sludge Volume Index) were determined according to APHA et al. (2012)[2]. Total phosphorus concentration of effluent from the reactor was determined using the colorimetric method of Vanamolybdophosphoric acid according to APHA et al. (2012)[2].

The previous methodology was replicated with the addition of PAC on one side. The impact of PAC was analysed based on the methods of Gendig et al. (2003)[4]. PAC was not added to one of the samples to serve as a blank, and 5 mg of K_2PO_4 was added to achieve approximately 5 mg.L^{-1} of total phosphorus, presumably removed in the WWTP.

3 RESULTS & DISCUSSION

The SVI result indicated poor settling, with most microorganisms being Gram-negative, potentially contributing to the open and dispersed structure of the biological floc. Neisser staining indicated the possible presence of phosphorus adhered to PAC, as the presence of phosphorus-accumulating bacteria was not investigated by other methodologies. Endogenous, autotrophic, and heterotrophic respiration rates were 7.33, 3.33 and 6.44 mgO$_2$.gVSS^{-1}.h^{-1}. Although the addition of substrate did not increase the respiration rate (Figure 1), heterotrophic biomass had the highest percentage in relation to the total biomass partition according to data obtained in the distribution of active biomass expressed in Figure 2.

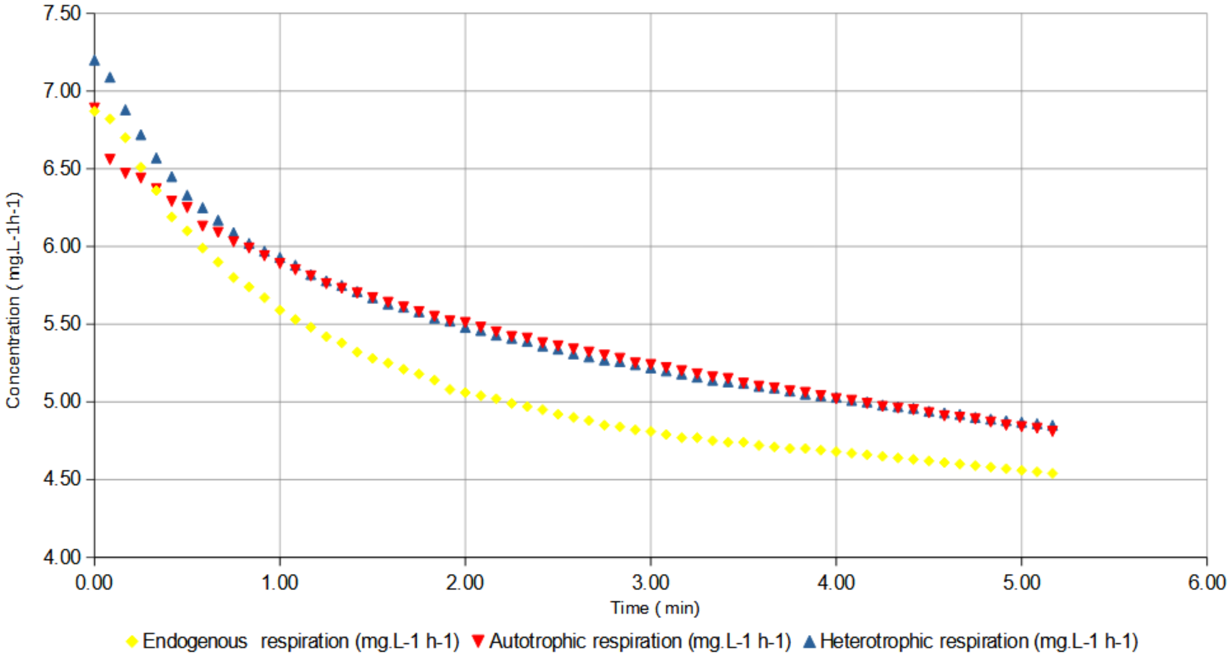

Figure 1 Respirometry graph of endogenous, autotrophic and heterotrophic respiration, without PAC addition

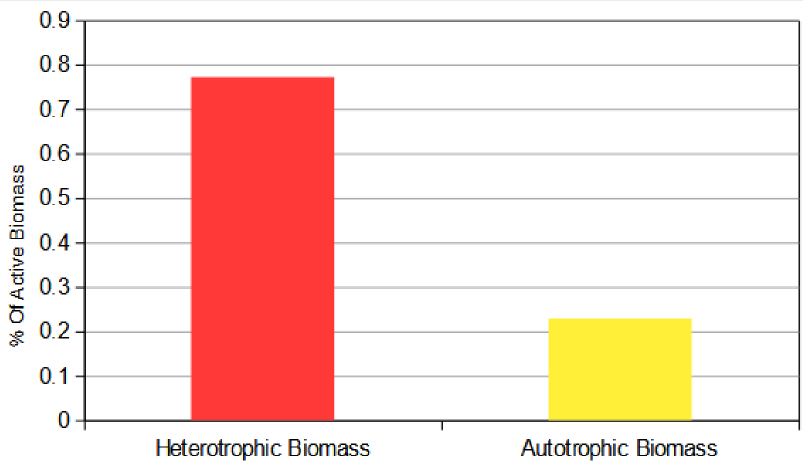

Figure 2 Distribution of active biomass according to the respirometric analysis.

The evaluated PAC concentrations did not inhibit microorganisms and instead led to increased oxygen consumption rates, with the highest obtained at a PAC concentration of 0.182 mLL^{-1} resulting in a total OUR of 50.68 mg O$_2$L^{-1}h^{-1}, 25.67mg O$_2$L^{-1}h^{-1} for heterotrophic rate, and 25.05 mg O$_2$L^{-1}h^{-1} for autotrophic rate. PAC may have agglomerated nutrient particles (organic matter and nitrogenous compounds), favouring the activity of microorganisms. PAC concentrations above 0.182 mLL[1] resulted in reduction of OUR (Table 1). The addition of PAC at its lowest concentration (0.083 $mL.L^{-1}$) resulted in a phosphorus removal efficiency of 91.66%, however, the higher the concentration of PAC used, higher the volume of sludge produced.

Table 1 Oxygen consumption rates with different PAC concentrations applied.

PAC Concentration ($mL.L^{-1}$)	Total OUR ($mgO_2.L^{-1}.h^{-1}$)	Heterotrophic OUR ($mgO_2.L^{-1}.h^{-1}$)	Autotrophic OUR ($mgO_2.L^{-1}.h^{-1}$)
Blank	6.19	4.30	1.88
0.083	10.61	7.05	3.56
0.182	50.68	25.67	25.02
0.500	34.89	15.22	19.66
1.000	37.93	21.60	16.33

4 CONCLUSION

According to this study, PAC does not exhibit an inhibitory effect between 0.083 mL. L^{-1} (105.00 $mg.L^{-1}$) and 1.00 $mL.L^{-1}$ (1265.00 $mg.L^{-1}$). On the contrary, it resulted in higher oxygen consumption rates. One hypothesis for this is that PAC may aggregate nutrient particles, making them easier for microorganisms to consume. Additionally, physicochemical effects on the diffusion of oxygen in the liquid medium might have impacted the results in some way. However, this result does not rule out the possibility of toxic effects in cases where PAC accumulation exceeds these concentrations, since higher PAC concentrations led to OUR reduction.

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