

Effectiveness of a Desorption Chamber for the Removal of Dissolved Gases from Anaerobic Effluents

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Abstract

Emission of dissolved sulfide and methane present in anaerobic effluents can pose various problems, such as greenhouse effect, corrosion and odour nuisance in the vicinity of sewage treatment plants. Therefore, methods for removal of these gases from anaerobic effluents are needed. In this study we tested a pilot-scale desorption chamber (DC) for this purpose. The DC was operated under different air exhaustion rates and the results showed that good removal efficiencies of methane (around 60%) and sulfide (around 84% for the best condition) could be obtained. Considering the low cost and simplicity of the method, these efficiencies can be considered satisfactory.

Keywords

Desorption chamber, dissolved gases, methane, sulfide, UASB reactors

INTRODUCTION

When anaerobic UASB-type reactors are employed for the treatment of domestic sewage, the generation of gaseous by-products, notably methane and hydrogen sulfide, is unavoidable. The former is a greenhouse gas and the latter causes bad odours and corrosion. In addition, methane losses means less energy potential to be exploited. In this sense, high dissolved methane concentrations in the reactor effluent results in the decrease of the methane recovery efficiency (Giménez *et al.*, 2012), since only the methane effectively collected inside the three-phase separator can actually be considered as useful and available biogas for energy recovery purposes.

In relation to methane, despite its low water solubility, it is often dissolved in a supersaturated level and may escape along with the effluent from the UASB reactor. In this regard, Matsuura *et al.* (2015) emphasize that the amount of dissolved methane in the effluent depends on the partial pressure of methane in the biogas, temperature and degree of supersaturation. The same authors also claim that the recovery of dissolved methane has not yet been studied in details.

As related to hydrogen sulfide, Pagliuso *et al.*, (2002) report the emission of odorous compounds through a outlet structure located 6 m below the effluent exit of UASB reactors treating domestic sewage. This monitoring point was chosen due to the evidence that the odorous emissions were not related to the surface (upper part) of the anaerobic reactors, but from the turbulence produced by the free fall of the effluent. In fact, due to its high solubility in water (3.2 g/L as S₂ at 25° C), H₂S tends to remain in solution when the liquid effluent exits the reactor, being separated only when there is an increase in turbulence or a decrease in the pH. Inside the chamber where the effluent was discharged, the H₂S concentrations were greater than 500 ppm, due to the agitation promoted by the free drop.

Alternatives such as stripping and desorption techniques, which present low cost and operational simplicity for the removal of dissolved gases, are based on aeration (Khan *et al.*, 2011) and gas transfer conditions. Therefore, this study aimed to test the effectiveness of the desorption technique for the removal of methane and hydrogen sulfide dissolved in the effluent of a pilot-scale UASB reactor.

MATERIAL AND METHODS

The experimental apparatus was composed of one pilot-scale UASB reactor (useful volume of 360 L) and one desorption chamber (DC) for the removal of dissolved gases (methane and sulfide) contained in the anaerobic effluent, as depicted in Figure 1. The UASB reactor, fed on real domestic sewage taken from a chamber upstream of the primary clarifiers of a full-scale plant (Arrudas STP, Belo Horizonte, Brazil), after being subjected to preliminary treatment for solids and grit removal, was operated with the hydraulic detention time of 7h.



Figure 1: Schematic configuration of experimental apparatus.

The desorption chamber (DC), located immediately outside the UASB reactor, consisted of a 10 cm diameter cylindrical chamber, equipped with inlet and outlet tubes for the liquid effluent, and one vent tube to allow the extraction of the waste gases (Figure 2). The DC was operated at two different drop heights (0.5 and 1.0 m) and controlled air exhaustion rates, with the same hydraulic loading rate ($0.132 \text{ m}^3 \cdot \text{m}^{-2} \cdot \text{min}^{-1}$), comprising four operational phases, as shown in Table 1. The DC was installed immediately close to the UASB exit, therefore the drop heights were almost exclusively due to the desorption chamber itself.

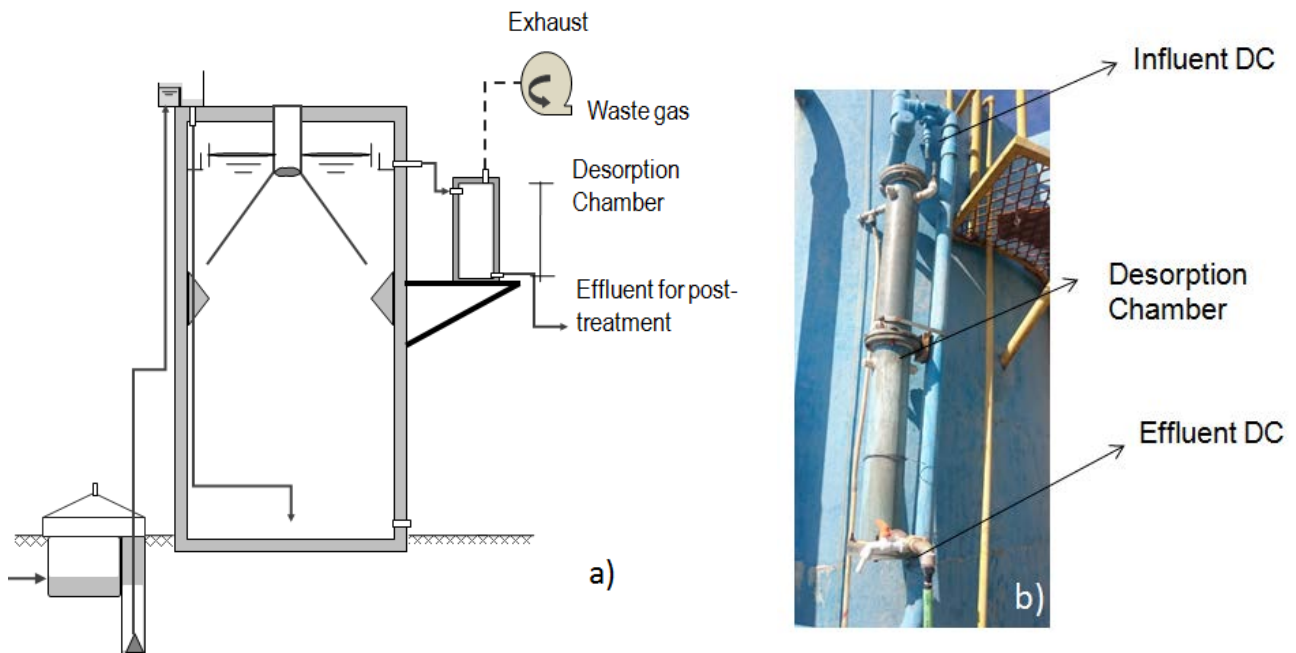


Figure 2: Schematic representation of the experimental apparatus: (a) Positioning of the Desorption Chamber; (b) View of the Desorption Chamber

Table 1: Operational phases of the experiments with the desorption chamber

Operational Phases	Exhaustion rate (L.min ⁻¹)	Exhaustion time (min)	Number of air renovations* (renews.h ⁻¹)	Free drop height inside DC (m)	Chamber volume (L)	RQ** (times)
1	1.2	3.3	18	0.5	4	1,1
2	1.6	2.5	24	0.5	4	1,5
3	1.6	5	12	1.0	8	1,5
4	3.2	2.5	24	1.0	8	3,1

(*) refers to headspace inside the desorption chamber unit; (**) refers to the air to wastewater flow ratio.

Analyses of sulfide in the liquid samples (influent and effluent of the DC) were performed according to the protocol adapted by Plas *et al.* (1992), a colorimetric method that uses a standard curve obtained with the reagent sodium sulfide. Procedures for pre-treatment and collection of samples followed the recommendations contained in the Standard Methods for the Examination of Water and Wastewater (APHA, 2005), method 4500. As related to dissolved methane, sampling and analysis followed the procedures described by Alberto *et al.* (2000) and Hartley and Lant (2006). Waste gas (oxygen, nitrogen, CO₂ and H₂S) analysis were carried out with a portable analyzer LANDTEC type GEMTM 5000. Quantification of methane in the waste gas was conducted via gas chromatography (chromatograph Perkin Elmer, FID detector, flow 17 ml.min⁻¹, Helium as carrier gas, carbowax packed column).

RESULTS

The results presented in Figure 3 show similar methane removal efficiencies, around 40%, for the first three phases, however with a slight tendency of increase along the phases. Important to note that the higher air to wastewater flow (RQ) and exhaustion ratios applied in phase 4 were crucial to improve the removal efficiency of dissolved methane, which was close to 60% in the last operational phase. Statistical differences were achieved only between phases 4 and 1 and 4 and 2 (non parametric method, Kruskal-Wallis, independent samples, with significance level of 5%). The dissolved methane removal efficiencies verified in the present study were lower than the ones obtained with the same experimental apparatus in previous studies, when the efficiencies ranged from 62 to 73% (Glória *et al.*, 2016). Nevertheless, in the previous studies the desorption chamber was installed 3 m below the UASB exit, providing an important additional free drop height. The lower free drop heights tested in the present study resulted in smaller kinetic energy and interfacial contact time between the gaseous and liquid phases, and this seems to be the main factor to contribute to the lower removal efficiencies. In contrast, internal parameters, like air to liquid flow ratios (RQ), number of air renovations and free drop height, showed lower significance, in this comparison.

Figure 4 shows the median methane concentrations in the generated waste gas, which varied from 1.0 to 0.3% along phases 1 to 4. In this graphic it can be observed that the higher exhausting rates applied in phase 4 resulted in the dilution of waste gas, lowering the methane concentration.

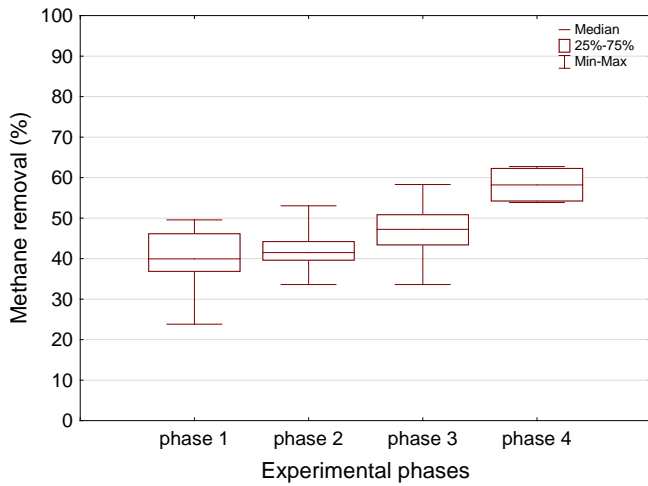


Figure 3: Dissolved methane removal efficiencies

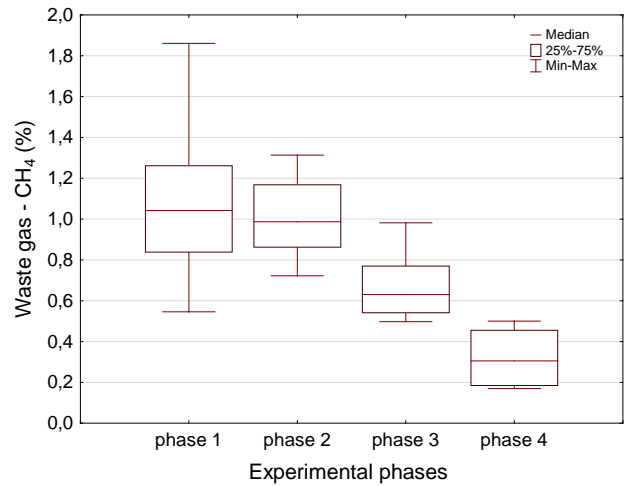


Figure 4: Methane concentration in the waste gas

As related to dissolved sulfide removal (Figure 5), the median efficiencies varied between 40 and 60% for phases 1, 2 and 3, with no statistical differences observed between these phases. Much higher efficiencies were obtained in phase 4 (median of 84%), possibly due to the higher RQ ratio used in this phase. The efficiencies obtained in phase 4 were statistically different from phases 1, 2 and 3 (non parametric method, Kruskal-Wallis, independent samples, with significance level of 5%). Overall, it seems that the position of the DC close to the UASB exit did not considerably interfere with the removal efficiencies of dissolved sulfide, as compared to the results obtained in previous studies with the same experimental apparatus (but located 3 m below the UASB exit), when the efficiencies ranged from 57 to 97% (Glória et al., 2016). Altogether, these results suggest that no additional free drop height is necessary in the case of sulfide removal.

As related to sulfide concentration in the generated waste gas, the concentrations varied from 280 to 600 ppm (Figure 6). It was also noted that the higher exhausting rate was responsible to the waste gas dilution in phases 2, 3 and 4, although only the later phase presented higher dissolved sulfide removal efficiency.

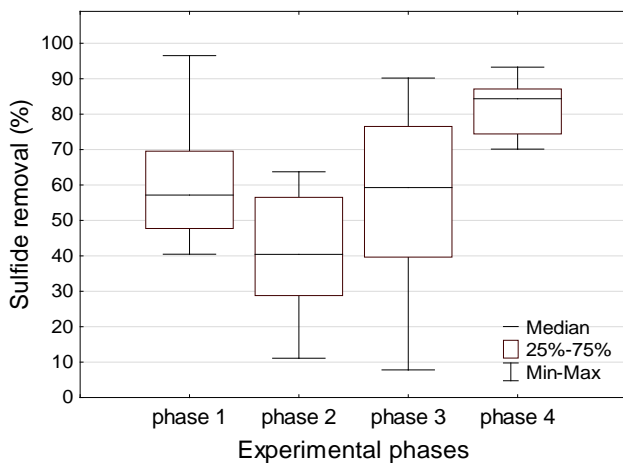


Figure 5: Dissolved sulfide removal efficiencies

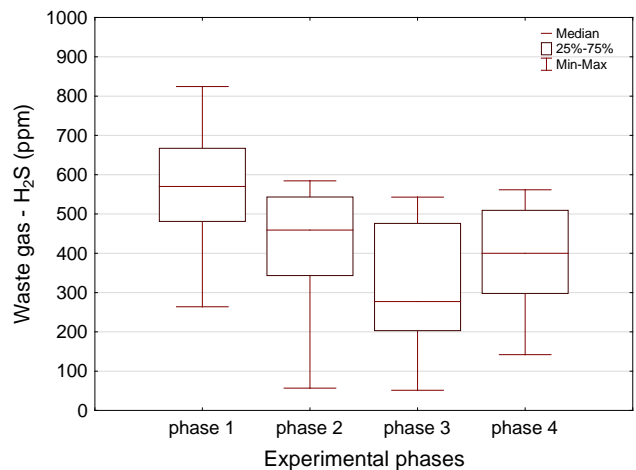


Figure 6: Sulfide concentration in the waste gas

CONCLUSION

The use of the Desorption Chamber (DC) allowed good removal efficiencies of the dissolved gases (methane and hydrogen sulfide) contained in the effluent of the UASB reactor. For the best operating conditions (free fall of 1.0 m, air to wastewater flow ratio of 3.1, and 24 renews per hour), the dissolved methane removal efficiency was close to 60%. As related to the removal of dissolved hydrogen sulfide, efficiencies as high as 80% were achieved for the same operating conditions. Overall, these results prove that simple devices such as the DC tested in this research can effectively contribute for the control of methane and hydrogen sulfide emissions in anaerobic-based sewage treatment plants.

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