

Iron oxide-based adsorbent for odor control in sewage treatment plants

Santos, J. M. B.*, Brandt, E. M. F.*, Ferreira, A. J. R.*, Leles, W. F.*, Costa, L. M. J.**

*Brandt Meio Ambiente. Alameda do Ingá, 89, Vale do Sereno, Nova Lima, Minas Gerais, Brazil.

**Óxido de Ferro Rio Acima. Fazenda do Viana, s/n, Morgan, Rio Acima, Minas Gerais, Brazil.

Highlights:

- The emission of odorous gases represents a serious socio-environmental problem.
- The adsorption technique is promising for odor treatment, especially for selective removal of H₂S.
- The Environ-Ox[®] adsorbent demonstrated high H₂S adsorption capacity, promoting efficiency and viability in odor treatment in STPs.

Keywords: odor; hydrogen sulfide; adsorption.

INTRODUCTION

The emission of odorous gases in sewage treatment plants (STPs) poses a serious socio-environmental problem. This is because H₂S, primarily responsible for the bad odor in STPs, is a toxic, corrosive gas and has a very low human olfactory perception limit (8 ppb_v) [1]. In this way, it compromises worker safety and generates dissatisfaction in the neighboring community, in addition to causing problems with corrosion of STP parts and structures [2, 3]. One option for managing fugitive H₂S emissions is the confinement and exhaustion of emission sources, generating waste gas streams that are directed to treatment [3]. Among the treatment techniques, adsorption with iron oxide-based products appears to be a promising alternative, mainly because it is a technique that is simple to implement and operate and allows the selective removal of H₂S with high efficiencies [4, 5]. The biofiltration technique also stands out, especially when considering the economic aspect [3], however, they generally demand large areas and operational complexity related to bed clogging. Still, when biofilters are used, layers of adsorbent are usually added to the filling material to ensure treatment efficiency. In this sense, the present study aimed to evaluate the efficiency of an iron oxide-based granular adsorbent in controlling odors in STPs.

METHODOLOGY

Adsorption tests were conducted using a commercial iron oxide-base adsorbent (Environ-Ox[®], supplied by Óxido de Ferro Rio Acima, Brazil) at both, bench scale and industrial scale. In the lab-scale tests, a fixed-bed column (DxH: 5x25 cm) was used with an inlet of a synthetic gas mixture of H₂S and CO₂, with N₂ as the balance gas. Various contact times (1, 5, and 95 seconds) and CO₂ concentrations (0%, 10%, and 50%) were tested. The contact times were chosen to address situations of area restriction and the adsorbent's use in biofilters. Meanwhile, the CO₂ concentration was varied to assess its impact on the adsorbent's capacity, as the manufacturer indicates a reaction with CO₂. The inlet flow rate was regulated by three thermal mass flow controllers for H₂S, CO₂, and N₂ (Figure 1). The H₂S concentration was measured at the inlet and outlet of the column using a portable gas sensor (AcrulogTM; 0-2000 ppm).

Initially, the study of adsorption equilibrium was conducted based on Langmuir experimental isotherms, obtained by calculating the adsorption capacity for each H₂S concentration (300 to 1,800 ppm) from the

breakthrough curve to the saturation point ($C/C_0 = 1$), as detailed by Santos et al., 2023. In this case, a contact time of 1 second and 0% CO_2 were used [5].

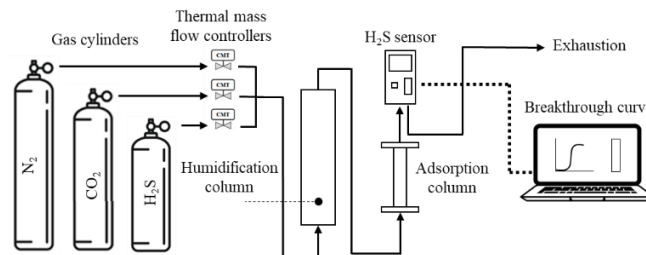


Figure 1 - Schematic representation of the experimental setup

For longer contact times (5 and 95 seconds) and higher CO_2 concentrations (10% and 50%), the H_2S concentration was fixed at 18,000 ppm to achieve the maximum estimated adsorption capacity at equilibrium. In this case, integration of the breakthrough curve was performed up to the breakthrough point ($C/C_0 = 0.05$, equivalent to 900 ppm), and subsequently, the adsorption capacity at saturation point was estimated considering the history of the results of the adsorption capacity ratio at the breakthrough and saturation points obtained in the previous step. Given that the adsorbent can be regenerated with atmospheric air, field conditions favor the concomitant occurrence of adsorption and regeneration processes (presence of air in the waste gas). However, for laboratory testing, introducing air into the gas flow (instead of N_2) would lead to impractical tests durations. Therefore, the tests were adapted to perform regeneration cycles after adsorption and, thus, estimate the maximum capacity of the adsorbent in the presence of O_2 . Regeneration cycles were conducted using air pumps, with the airflow passing through a humidification column.

To validate these estimates, a scale-up test was conducted at a STP with an inflow rate of 95 l.s^{-1} , using anaerobic treatment with UASB reactors followed by trickling filters. This system processes waste gas from the exhaust of the headworks at an Odor Treatment Unit (OTU) based on adsorption processes. For this purpose, 1,485kg of Environ-OX[®] was used, and its adsorption capacity was compared to that of 1,000kg of activated carbon, which was previously used at the OTU. Both adsorbents were evaluated at two different time periods. Initially, activated carbon was assessed with a contact time of 2.5 seconds for 130 days, followed by Environ-OX[®], which was evaluated with a contact time of 1.9 seconds for 135 days. These differences in contact time were attributed to variations in mass and load loss. H_2S concentration was monitored using a portable analyzer (Instrutemp; 0 - 100 ppm) at both the inlet and outlet of the filter filled with the adsorbent. Additionally, gas flow rate at the filter outlet was calculated using wind speed readings from an anemometer (Kestrel 5500). The data on gas flow rate, H_2S concentration, mass of adsorbent, and operational time were employed to calculate the adsorption capacities of both activated carbon and Environ-OX[®].

RESULTS AND CONCLUSIONS

The maximum H_2S adsorption capacity of the Environ-Ox[®] adsorbent in the equilibrium, considering adsorption/regeneration, a contact time of 1.9 seconds and 0% CO_2 , was $0.10 \text{ kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$. For tests with contact times of 5 and 95 seconds and 10% CO_2 , the maximum adsorption capacities were 0.10 and $0.17 \text{ kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$, respectively. When the CO_2 concentration is increased to 50%, the maximum

adsorption capacities decrease to 0.06 and 0.14 $\text{kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$ (Figure 2). However, these results are still competitive compared to those found in the literature for activated carbons and other commercial adsorbents (0.02 to 0.20 $\text{kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$) [6].

Although the adsorption capacity is impacted by the CO_2 concentration, this effect is attenuated with increasing contact time. For example, for a 10-fold increase in CO_2 concentration, only an approximately 5-fold increase in contact time would be required. Considering that the CO_2 concentration in waste gas treatment systems is close to atmospheric (0.04%), the performance of the adsorbent can be significantly improved by prolonging the contact time.

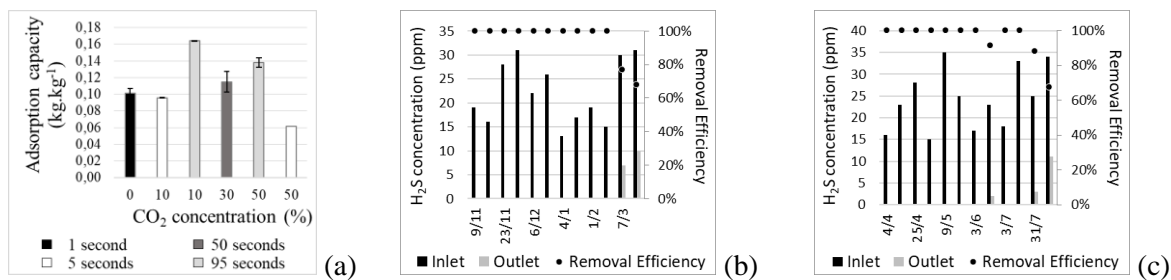


Figure 2 – (a) H₂S adsorption capacities for the tested conditions in the laboratory; H₂S concentrations and removal efficiencies for activated carbon (b) and Environ-OX[®] (c) during the scale-up tests.

For the scale-up tests, the calculated adsorption capacity for the activated carbon was 0.24 $\text{kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$, while for Environ OX[®] it was 0.14 $\text{kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$. When comparing these results with those obtained in the laboratory, it is observed that the field adsorption capacity of Environ-OX[®] was 40% higher. This suggests that the adsorbent performed better in the field conditions than in the controlled laboratory environment. Therefore, field tests are crucial for validating technology scalability, while standardized lab adsorption tests ensure accurate comparisons and optimizations. Considering the total time of each test, the masses of adsorbent used, and the prices of the products (\$1.84.kg⁻¹ for activated carbon and \$1.25.kg⁻¹ for the Environ OX[®] tested), the monthly treatment costs are \$428.82 for activated carbon and \$416.83 for Environ OX[®]. Thus, despite the adsorption capacity of Environ OX[®] being approximately 40% lower than that of activated carbon, it still presents a competitive cost/efficiency ratio. Given that the efficiency of the adsorbent improves with longer contact times, this ratio could be even better if both adsorbents are tested under the same contact time.

However, during the testing period, Environ OX[®] underwent changes in its composition and manufacturing process to improve its performance. According to the manufacturer, the new version of the product has an adsorption capacity approximately 4 times greater than its previous version used in the test, with an adsorption capacity of about 0.55 $\text{kg}_{\text{H}_2\text{S}}.\text{kg}_{\text{adsorbent}}^{-1}$. Under these conditions, the cost/efficiency ratio of Environ OX[®] is approximately 3 times better than that of activated carbon.

Therefore, due to its high adsorption capacity and possibility of regeneration, the Environ-Ox[®] adsorbent is applicable both for adsorption waste gas treatment systems, in STPs that have area restrictions (shorter contact time), and in systems of odor treatment by biofiltration, which demand large areas and, consequently, provide longer contact times (15 to 180 seconds) [3, 7]. This way, it is a product with great cost/benefit and high H₂S removal efficiency.

ACKNOWLEDGMENTS

The authors extend their sincere gratitude to Óxido de Ferro Rio Acima for generously providing the Environ-Ox[®] product for testing, which greatly facilitated the effective conduct of this research. We also wish to express our deep appreciation to COPASA for their invaluable support and for allowing us to conduct real-scale testing of the adsorbent at their odor treatment unit. The collaboration and assistance from both Óxido de Ferro Rio Acima and COPASA have been instrumental in the success of this study. We are truly thankful for their partnership and support.

REFERENCES

1. Andrade, C. L., Lacerda, L. A. B. G., Ribeiro, T. B., Chernicharo, C. A. L., & Brandt, E. M. F. (2023). Estratégias para detecção, espacialização e controle de odores em estações de tratamento de esgoto. In *Anais do 32º Congresso da ABES, CBESA – Congresso Brasileiro de Engenharia Sanitária e Ambiental, XXXII*. Associação Brasileira de Engenharia Sanitária e Ambiental (ABES). <https://congressoabes.com.br/anais/>
2. Water Environment and Reuse Foundation (WERF). (2007). *Minimization of odors and corrosion in collection systems (phase 1)* (Report No. 04-CTS-1). Water Environment Research Foundation.
3. Brandt, E. M. F., Souza, C. L., Centeno-Mora, E., Bianchetti, F. J., Santos, J. M. B., & Chernicharo, C. A. L. (2021). Nota Técnica 1 – Tópicos de interesse: Avanços nas técnicas de controle de emissões gasosas em ETEs com reatores anaeróbios. *Cadernos Técnicos de Engenharia Sanitária e Ambiental, 1*, 5-22.
4. Chernicharo, C. A. L., Stuetz, R. M., Souza, C. L., & Melo, G. C. B. (2010). Alternativas para o controle de emissões odorantes em reatores anaeróbios tratando esgoto doméstico. *Engenharia Sanitária e Ambiental, 15*(3), 229-236.
5. Santos, J. M. B., Ferreira, A. J. R., Brandt, E. M. F., Costa, L. M. J., & Costa, R. G. W. (2023). Teste de adsorção de H₂S em fase gasosa para adsorventes a base de óxido de ferro. In *Anais do 32º Congresso da ABES, CBESA – Congresso Brasileiro de Engenharia Sanitária e Ambiental, XXXII*. Associação Brasileira de Engenharia Sanitária e Ambiental (ABES). <https://congressoabes.com.br/anais/>
6. Wasajja, H., Lindebooma, R. E. F., Van Lier, J. B., & Aravind, P. V. (2020). Techno-economic review of biogas cleaning technologies for small scale off-grid solid oxide fuel cell applications. *Fuel Processing Technology, 197*. <https://doi.org/10.1016/j.fuproc.2019.106215>.
7. Chernicharo, C. A. L., Stuetz, R. M., Souza, C. L., & Melo, G. C. B. (2014). Contribuição para o projeto de biofiltros aplicados ao tratamento de emissões odorantes provenientes de reatores anaeróbios. *Revista DAE, 186*, 56-62.