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

Investigating the characteristics of phosphate adsorption onto gypsum board fragments for wastewater treatment

De Oliveira Souza, A.*, Silva, L. C.*, Nagalli, A.**, Passig, F. H.*** and Carvalho, K. Q.**

*Federal University of Technology – Paraná (UTFPR) - Civil Engineering Graduate Program, Deputado Heitor de Alencar Furtado St., 5000, Ecoville, Curitiba, Paraná 81280-340, Brazil. Email: souza.2021@alunos.utfpr.edu.br; lucascarvalhosilva@alunos.utfpr.edu.br.

**Federal University of Technology – Paraná (UTFPR) - Civil Construction Academic Department, Deputado Heitor de Alencar Furtado St., 5000, Ecoville, Curitiba, Paraná 81280-340, Brazil. Email: nagalli@utfpr.edu.br; kaquerne@utfpr.edu.br.

***Federal University of Technology – Paraná (UTFPR) – Chemistry and Biology Academic Department, Deputado Heitor de Alencar Furtado St., 5000, Ecoville, Curitiba, Paraná 81280-340, Brazil. Email: fhpassig@utfpr.edu.br.

Highlights:

- the application of GA removed 54% to 64% of TP.
- kinetic studies and isotherms reached 56.84% and 92.94%, respectively.
- the composition of the plasterboard can be used in wetlands for wastewater treatment

Keywords: construction waste; Plastbooard; Adsorption.

INTRODUCTION

Increased phosphorus in water bodies can lead to eutrophication and cause serious environmental problems for water resources (Lürling et al., 2014). Several techniques have been successful in removing phosphorus (P) in wastewater, including physical (adsorption and filtration), chemical (chemical precipitation and ion exchange), and biological processes (plant uptake and microbial degradation) (Wang et al., 2016). Among them, adsorption stands out as a highly effective method for removing pollutants, characterized by operational simplicity, low costs, and the ability to perform effective removal without generating harmful by-products, with the possibility of reusing the adsorbent (Hoppen et al., 2019). Therefore, kinetic and equilibrium studies were conducted to evaluate phosphate adsorption onto gypsum plasterboard fragments and support the application of these wastes as filtering material in constructed wetlands treating wastewater.

METHODOLOGY

The gypsum plaster (GP) was obtained from losses and leftovers during production and was collected directly from the industry to avoid contamination. De Oliveira Souza et al. (2023) achieved 64% phosphate removal by applying this material in vertical subsurface flow constructed wetlands (VFCW) systems treating synthetic effluent. This study is the first approach to using gypsum waste in CW, indicating its potential as an adsorbent for reducing phosphate.

For the adsorption studies, masses of 2.16 g of GP (particle size of 6.35 mm) were added to 125 mL Erlenmeyer flasks containing 50 mL of synthetic effluent (TP initial concentration of 10 mg L^{-1}) and agitated at 150 rpm and 25 ºC in a shaker SOLAB, SL222. The samples were collected at 1, 3, 5, 8, 10, 12, 14, 16, 18, 20, 22, 24, 27, and 30 h. For the isotherm studies, 0.5, 1.0, 1.5, 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, and 5.5 g of the GP were added to Erlenmeyer flasks with 50 mL of 0.01 M NaOH at the same operational conditions of the kinetics studies for 24 h. Phosphorus concentrations were determined in a UV-Vis spectrophotometer, HACH DR 5000, using the ascorbic acid method (4500-P) (APHA, 2017). Pseudo-first order, pseudo-second order, and Elovich models (Lagergren, 1898; Ho and Mckay, 1999) for kinetics studies, and Langmuir, Freundlich, Liu, and Sips models (Freundlich, 1906; Langmuir, 1916; Sips, 1948; Liu, 2003) for equilibium studies were applied for the experimental data adjustments using Origin® 9.5.1 software.

RESULTS AND CONCLUSIONS

De Oliveira Souza et al. (2023) verified CaO, SO_3, P_2O_5, Fe_2O_3, SiO_2, Al_2O_3, and SrO in the GP composition, with CW achieving TP removal efficiencies from 54 to 64% (fig.1). According to Han et al. (2022), materials rich in Fe, Al, Ca, and Mg are essential for the precipitation and adsorption of phosphorus and occur mainly through the formation of aluminum and iron phosphates, as well as adsorption on hydroxides and oxides of these elements. GP reached adsorption of 50.20% in the first 14 h of the kinetic studies and increased until reaching the equilibrium at 24 h with TP removal of 56.84%. Fittings of pseudo-first-order (R^2 0.992; Δq_e 0.90%), pseudo-second-order (R^2 0.994; Δq_e 0.07%) and Elovich models (R^2 0.995; Δq_e 0,51%) suggested the chemisorption process. Wu et al. (2007) state that a model fitting is considered valid for R^2 greater than 0.90 and Δq_e lower than 15% (fig.2a).

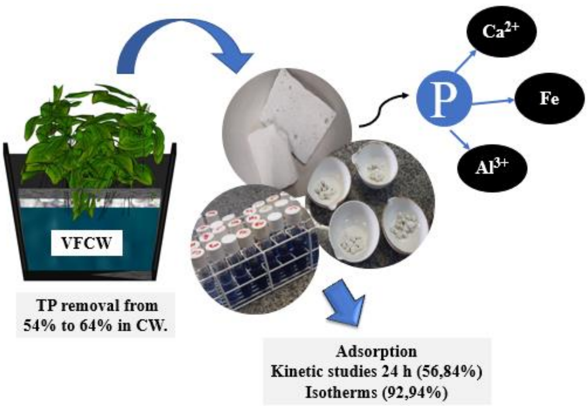
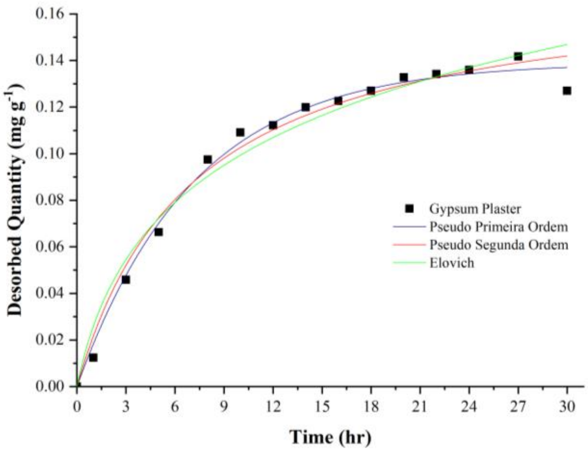


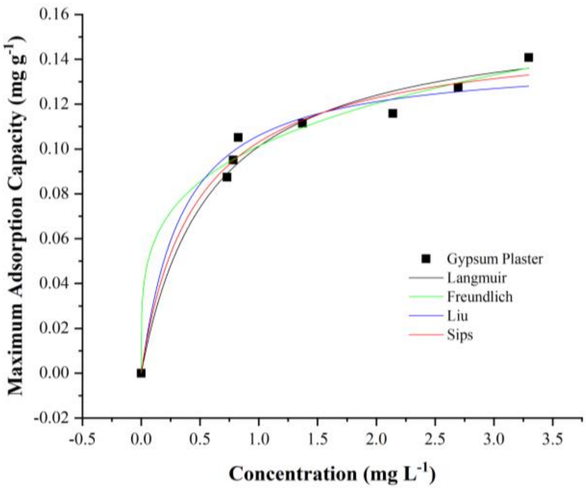
Fig. 1 - Scheme of the VFCW and details of the sorption studies

Langmuir, Freundlich, Liu, and Sips non-linear models fitted the experimental data with various initial concentrations of adsorbent mass, reaching 92.94% in the isotherms (fig.2b). The highest R^2 0.985 obtained for Freundlich model describes equilibrium on heterogeneous surfaces, indicating physisorption and the formation of multilayers (Ho; Mckay, 1999). Similar results for phosphate adsorption onto other construction wastes were verified by Kuhn et al. (2023), who obtained Freundlich model (R^2 0.99) in autoclaved aerated concrete; Cabral et al. (2021), who found Langmuir

(R^2 0.995), Freundlich (R^2 0.999) and Sips (R^2 0.998) models in unmodified red ceramics; and Wang et al. (2016), who observed Langmuir model (R^2 0.98) in autoclaved cellular concrete.



a)



b)

Fig. 2. - Fitings of a) kinetic models; b) equilibrium models

Thus, GP construction wastes can be an efficient alternative adsorbent to remove PO_4^{3-} from aqueous solutions.

ACKNOWLEDGEMENTS

The authors thank the support of the Coordination for the Improvement of Higher Education Personnel (Capes) [Finance Code 001], National Health Foundation (FUNASA) [grant number 25100.011.282/2014-87], and National Institutes of Science and Technology Program - National Institute of Science and Technology in Nature-Based Solutions (INCT SbN) [58/2022].

REFERENCES

APHA, Standard Methods for the Examination of Water and Wastewater, 23rd ed, American Public Health Association, Washington DC, 2017.

L.L. Cabral, I.C. Pereira, F. Perretto, A. Nagalli, R.C.P. Rizzo-Domingues, F. H. Passig, K.Q. Carvalho, Adsorption and desorption of phosphate onto chemically and thermochemically pre-activated red ceramic waste: characteristics, batch studies, and mechanisms, J. Environ. Chem. Eng. 9 (2021), 106695, https://doi.org/10.1016/j.jece.2021.106695.

H. Freundlich, Over the adsorption in solution, J. Phys. Chem. 57 (1906) 1100–1107.

M. Han, Y. Wang, Y. Zhan, J. Lin, X. Bai, Z. Zhang, Efficiency and mechanism for the control of phosphorus release from sediment by the combined use of hydrous ferric oxide, calcite and zeolite as a geo-engineering tool, Chem. Eng. J. 428 (2022), 131360, https://doi.org/10.1016/j.cej.2021.131360.

Y.S. Ho, G. McKay, A kinetic study of dye sorption by biosorbent waste product pith, Resour. Conserv. Recycl. 25 (1999) 171–193, https://doi.org/10.1016/ S0921-3449(98)00053-6.

M.I. Hoppen, K.Q. Carvalho, R.C. Ferreira, F.H. Passig, I.C. Pereira, R.C. P. RizzoDomingues, M.K. Lenzi, R.C.R. Bottini, Adsorption and desorption of acetylsalicylic acid onto activated carbon of babassu coconut mesocarp, J. Environ. Chem. Eng. 7 (2019), 102862, https://doi.org/10.1016/j.jece.2018.102862.

D.C. Kuhn, L.L. Cabral, I.C. Pereira, A.J. Gonçalves, G.M. Maciel, C.W.I. Haminiuk, A. Nagalli, F.H. Passig, K.Q. Carvalho, Development of aerated concrete waste/ white cement composite for phosphate adsorption from aqueous solutions: Characterization and modeling studies, Chem. Eng. Process. Process Intensif. 184 (2023) 109284, https://doi.org/10.1016/j.cep.2023.109284.

S. Lagergren, Zur Theorie der sogenannten adsorption geloster stoffe, Handlingar 24 (1898) 39–49.

I. Langmuir, The dissociation of hydrogen into atoms. III. The mechanism of the reaction, J. Am. Chem. Soc. 38 (1916) 1145–1156, https://doi.org/10.1021/ ja02263a001.

Liu, You et al. A general model for biosorption of Cd^{2+}, Cu^{2+} and Zn^{2+} by aerobic granules. Journal of Biotechnology, v. 102, p. 233–239, 2003.

Lürling, M., Waajen, G., van Oosterhout, F., 2014. Humic substances interfere with phosphate removal by lanthanum modified clay in controlling eutrophication. Water Res. 54, 78–88.

De Oliveira Souza, A., Bernardelli, J.K.B., de Carvalho Silva, L., Perretto, F., Nagalli, A., Mymrin, V., Passig, F.H., de Carvalho, K.Q., 2023. Plasterboard sheet applied in vertical-flow constructed wetlands: nutrients removal, microbial diversity, and mechanisms. J. Water Process Eng. 53, 103811 https://doi.org/10.1016/j.jwpe.2023.103811.

R. Sips, On the structure of a catalyst surface, J. Chem. Phys. 16 (1948) 490–495, https://doi.org/10.1063/1.1746922.

Y. Wang, Y. Yu, H. Li, C. Shen, Comparison study of phosphorus adsorption on different waste solids: fly ash, red mud and ferric–alum water treatment residues, J. Environ. Sci. 50 (2016) 79–86, https://doi.org/10.1016/j.jes.2016.04.025.

C.H. Wu, Adsorption of reactive dye onto carbon nanotubes: equilibrium, kinetics and thermodynamics, J. Hazard. Mater. 144 (2007) 93–100, https://doi.org/10.1016/j.jhazmat.2006.09.083.