Applicability of the Equilibrium Adsorption Isotherms and the Statistical Tools on to them: A Case Study for the Adsorption of Fluoride onto Mg-Fe-CO3 LDH

Tanuj Mahajan1, Susanta Paikaray1 and Pooja Mahajan2\*

1Environmental Geochemistry Group, Department of Geology, Panjab University. Chandigarh, India—160014

2Department of Applied Sciences, Chitkara University Institute of Engineering and Technology, Chitkara University, Punjab, India-140401

pooja.mahajan@chitkara.edu.in

**Abstract**. The demand for a low-cost, easy-to-use, low-maintenance system of adsorbents for detoxifying wastewater effluents is growing. A proper understanding of adsorption mechanisms, their controls, and adsorbate-adsorbent behaviour is essential. Hence, the present study deals with the required understanding of linear equilibrium adsorption isotherm models. The data on fluoride adsorption by Mg-Fe-CO3 LDH are fitted to isotherm models. The two-parameter models discussed are Langmuir, Freundlich, Dubinin-Radushkevich, and Temkin, whereas the three-parameter model cited is Redlich-Peterson. To identify the best-fitting model(s) in an equilibrium isotherm study to quantitatively represent the relevant sorption system, various error functions and statistical tools, such as average relative error deviation (ARED), hybrid relative error function (HYBRID), sum of square errors (ERRSQ or SSE),, sum of absolute errors (EABS), Marquardt’s percent standard error deviation (MPSD), sum of normalized errors (SNE), correlation coefficient of Pearson (r), coefficient of determination (r2), student’s T-test, chi-square test (χ2), and F-test were applied. It is found that the Temkin model best fits the isotherm data, and the sorption process occurs over multiple layers as per the Freundlich isotherm and was found to be more promising than Langmuir’s monolayer sorption process. The physisorption course for the adsorbate-absorbent interactions is deduced from the isotherm parameters.

Keywords: isotherms, adsorption, fluoride, linear equilibrium model, Mg-Fe-CO3, LDH

References:

[1] Al-Ghouti, M. A., & Da'ana, D. A. (2020). Guidelines for the use and interpretation of adsorption isotherm models: A review. Journal of hazardous materials, 393, 122383. https://doi.org/10.1016/j.jhazmat.2020.122383

[2] Imamura, K., Ikeda, E., Nagayasu, T., Sakiyama, T., & Nakanishi, K. (2002). Adsorption behaviour of methylene blue and its congeners on a stainless steel surface. Journal of Colloid and Interface Science, 245(1), 50-57. https://doi.org/10.1006/jcis.2001.7967

[3] Al-Degs, Y., Khraisheh, M. A. M., Allen, S. J., & Ahmad, M. N. (2000). Effect of carbon surface chemistry on the removal of reactive dyes from textile effluent. Water Research, 34(3), 927-935.https://doi.org/10.1016/S0043-1354(99)00200-6

[4] Pirbazari, M., Badriyha, B. N., & Miltner, R. J. (1991). GAC adsorber design for removal of chlorinated pesticides. Journal of environmental engineering, 117(1), 80-100. https://doi.org/10.1061/(ASCE)0733-9372(1991)117:1(80)

[5] Danis, T. G., Albanis, T. A., Petrakis, D. E., & Pomonis, P. J. (1998). Removal of chlorinated phenols from aqueous solutions by adsorption on alumina pillared clays and mesoporous alumina aluminum phosphates. Water research, 32(2), 295-302. https://doi.org/10.1016/S0043-1354(97)00206-6

[6] Cusack, P. B., Healy, M. G., Ryan, P. C., Burke, I. T., O'Donoghue, L. M., Ujaczki, É., & Courtney, R. (2018). Enhancement of bauxite residue as a low-cost adsorbent for phosphorus in aqueous solution, using seawater and gypsum treatments. Journal of Cleaner Production, 179, 217-224. https://doi.org/10.1016/j.jclepro.2018.01.092

[7] Lavecchia, R., Medici, F., Piga, L., Rinaldi, G., & Zuorro, A. (2012). Fluoride removal from water by adsorption on a high alumina content bauxite. Chem. Eng, 26, 225-230

[8] Sah, R. P., Choudhury, B., & Das, R. K. (2015). A review on adsorption cooling systems with silica gel and carbon as adsorbents. Renewable and Sustainable Energy Reviews, 45, 123-134. https://doi.org/10.1016/j.rser.2015.01.039

[9] Wang, S., & Peng, Y. (2010). Natural zeolites as effective adsorbents in water and wastewater treatment. Chemical engineering journal, 156(1), 11-24. https://doi.org/10.1016/j.cej.2009.10.029

[10] Bansal, R. C., & Goyal, M. (2005). Activated carbon adsorption. CRC press. https://doi.org/10.1201/9781420028812

[11] Mahajan, T., & Paikaray, S. (2022). Fluoride Retention Kinetic and Equilibrium Studies on Layered Double Hydroxides under Ambient Conditions: Implications on Pond-Stream-Hot Spring-Well Water Remediation. Water Environment Research. https://doi.org/10.1002/wer.10804

[12] Paikaray, S., & Hendry, M. J. (2013). In situ incorporation of arsenic, molybdenum, and selenium during precipitation of hydrotalcite-like layered double hydroxides. Applied clay science, 77, 33-39. https://doi.org/10.1016/j.clay.2013.03.016

[13] Sadegh, H., Ali, G. A., Gupta, V. K., Makhlouf, A. S. H., Shahryari-Ghoshekandi, R., Nadagouda, M. N., ... & Megiel, E. (2017). The role of nanomaterials as effective adsorbents and their applications in wastewater treatment. Journal of Nanostructure in Chemistry, 7(1), 1-14. https://doi.org/10.1007/s40097-017-0219-4

[14] Ayawei, N., Ebelegi, A. N., & Wankasi, D. (2017). Modelling and interpretation of adsorption isotherms. Journal of Chemistry, 2017. https://doi.org/10.1155/2017/3039817

[15] El-Khaiary, M. I. (2008). Least-squares regression of adsorption equilibrium data: comparing the options. Journal of Hazardous Materials, 158(1), 73-87. https://doi.org/10.1016/j.jhazmat.2008.01.052

[16] Allen, S. J., Mckay, G., & Porter, J. F. (2004). Adsorption isotherm models for basic dye adsorption by peat in single and binary component systems. Journal of Colloid and Interface Science, 280(2), 322-333. https://doi.org/10.1016/j.jcis.2004.08.078

[17] Faust, S. D., & Aly, O. M. (1987). Adsorption Models. Adsorption Processes for Water Treatment, 25–64. https://doi.org/10.1016/b978-0-409-90000-2.50005-4

[18] Kapoor, A., & Yang, R. T. (1989). Correlation of equilibrium adsorption data of condensible vapours on porous adsorbents. Gas Separation & Purification, 3(4), 187-192. https://doi.org/10.1016/0950-4214(89)80004-0

[19] Marquardt, D. W. (1963). An algorithm for least-squares estimation of nonlinear parameters. Journal of the society for Industrial and Applied Mathematics, 11(2), 431-441. https://doi.org/10.1137/0111030