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RESEARCH ARTICLE

Efficient Adsorption of Chlortetracycline and Ibuprofen Onto Mg–Al Layered Double Hydroxide: Equilibrium, Kinetic, and Thermodynamic Studies

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ABSTRACT

Magnesium–aluminum layered double hydroxide (Mg–Al LDH) with a Mg/Al molar ratio of 2:1 was synthesized by a simple co-precipitation method and evaluated for the simultaneous removal of chlortetracycline (CTC) and ibuprofen (IBP) from aqueous solutions. SEM–EDX, FTIR, and XRD analyses confirmed the successful formation of a well-defined layered structure with a basal spacing of 7.65 Å and a pH_{pzc} of 6.15. Batch adsorption experiments showed rapid equilibrium within 30 min for CTC and 60 min for IBP, with removal efficiencies reaching 99% under optimal conditions (293 K, adsorbent dosage 2 g L^{−1}, initial concentration 50 mg L^{−1}, pH 7). The adsorption kinetics followed the pseudo-second-order model for CTC and the pseudo-first-order model for IBP, while equilibrium data were best described by the Langmuir isotherm, yielding maximum adsorption capacities of 121.61 mg g^{−1} for CTC and 100.41 mg g^{−1} for IBP.

Thermodynamic parameters indicated spontaneous and exothermic adsorption, with stronger interactions for CTC. The uncalcined Mg–Al LDH exhibited adsorption



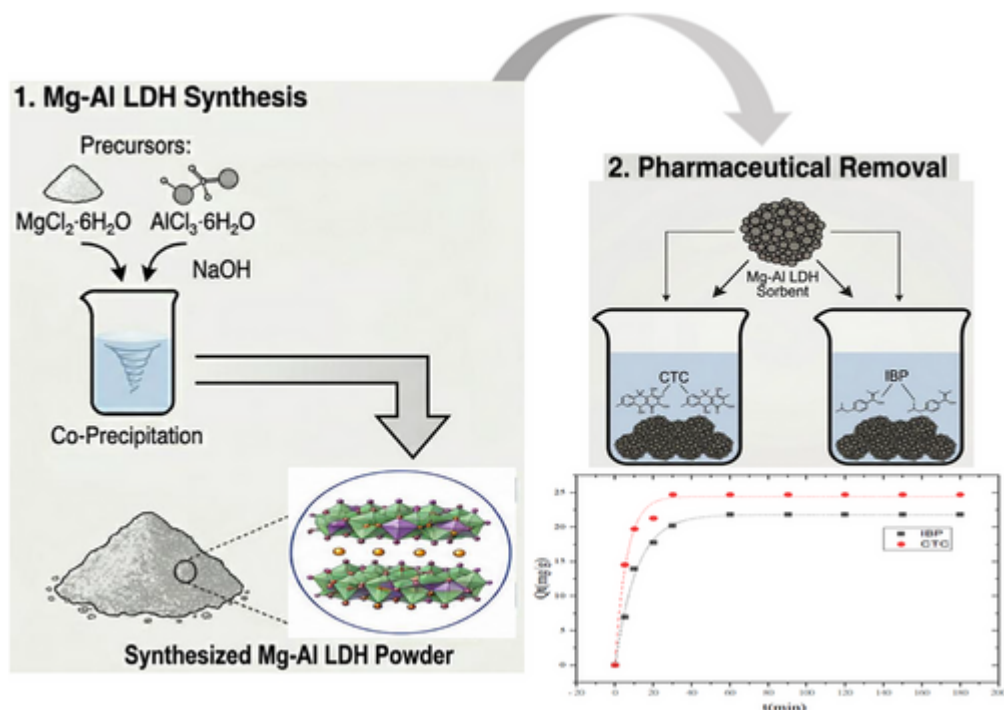
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An uncalcined Mg–Al layered double hydroxide synthesized by a simple co-precipitation method efficiently removes chlortetracycline and ibuprofen from water. Adsorption follows the pseudo-second-order model for CTC, the pseudo-first-order model for IBP, and the Langmuir isotherm, achieving up to 99% removal through a spontaneous and exothermic process.



Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

- 1 S. Manjunath, R. S. Baghel, and M. Kumar, "Antagonistic and Synergistic Analysis of Antibiotic Adsorption on Prosopis Juliflora Activated Carbon in Multicomponent Systems," *Chemical Engineering Journal* **381** (2020): 122713, <https://doi.org/10.1016/j.cej.2019.122713>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

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- 2 B. M. V. Gama, R. Selvasembian, D. A. Giannakoudakis, K. S. Triantafyllidis, G. McKay, and L. Meili, "Layered Double Hydroxides as Rising-star Adsorbents for Water Purification: A Brief Discussion,"

3 D. Balarak, A. H. Mahvi, S. Shahbaksh, M. A. Wahab, and A. Abdala, "Adsorptive Removal of Azithromycin Antibiotic From Aqueous Solution by Azolla Filiculoides-based Activated Porous Carbon," *Nanomaterials* 11 (2021): 3281, <https://doi.org/10.3390/nano11123281>.

[CAS](#) | [PubMed](#) | [Web of Science®](#) | [Google Scholar](#)

4 D. Montes-Grajales, M. Fennix-Agudelo, and W. Miranda-Castro, "Occurrence of Personal Care Products as Emerging Chemicals of Concern in Water Resources: A Review," *Science of the Total Environment* 595 (2017): 601–614, <https://doi.org/10.1016/j.scitotenv.2017.03.286>.

[CAS](#) | [PubMed](#) | [Web of Science®](#) | [Google Scholar](#)

5 C. Gadipelly, A. Pérez-González, G. D. Yadav, et al., "Pharmaceutical Industry Wastewater: Review of the Technologies for Water Treatment and Reuse," *Industrial & Engineering Chemistry Research* 53 (2014): 11571–11592, <https://doi.org/10.1021/ie501210j>.

[CAS](#) | [Web of Science®](#) | [Google Scholar](#)

6 M. Feizi-Dehnayebi, G. Mohammadi Ziarani, S. Reisi, et al., "Biological Evaluations and Biomolecular Interactions Along With Computational Insights of Arylidene Isatin Hydrazones Synthesized Using Nanocatalyst," *Scientific Reports* 15 (2025): 42705, <https://doi.org/10.1038/s41598-025-26721-7>.

[CAS](#) | [PubMed](#) | [Web of Science®](#) | [Google Scholar](#)

7 A. Gonzalez-Ospina, B. Domenjoud, E. Vulliet, S. Bony, and S. Baig, "Oxydation Biologique et Chimique à L'ozone Des Micropolluants Émergents en Station d'épuration," *Environnement, Risques & Santé* 17 (2018): 75–83.

[Google Scholar](#)

8 P. Kumari, B. Pal, and R. K. Das, "Superior Adsorptive Removal of Eco-toxic Drug Diclofenac Sodium by Zn–Al LDH-xBi₂O₃ Layer Double Hydroxide Composites," *Applied Clay Science* 208

 Have questions about this article?

Comptes Rendus Chimie 18 (2015): 1134–1142, <https://doi.org/10.1016/j.crci.2015.05.015>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#)  |

10 R. Yous, H. Cherifi, and R. Khalladi, “Kinetic Models of Competitive Adsorption of Cadmium–iron Mixture on Montmorillonite,” *Desalination and Water Treatment* 221 (2021): 207–217, <https://doi.org/10.5004/dwt.2021.27058>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#)  |

11 K. Addouch, S. Seddari, H. Cherifi, R. Yous, and R. Khalladi, “Raw Clay for Ibuprofen and Chlortetracycline Removal From Aqueous Solution,” *Desalination and Water Treatment* 265 (2022): 134–145, <https://doi.org/10.5004/dwt.2022.28605>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#)  |

12 G. Maia, J. Andrade, M. Oliveira, M. Vieira, and M. Silva, “Affinity Studies Between Drugs and Clays as Adsorbent Material,” *Chemical Engineering Transactions* 57 (2017): 583–588.

[Google Scholar](#)  |

13 V. Yousefi, V. Tarhriz, S. Eyvazi, and A. Dilmaghani, “Synthesis and Application of Magnetic@ Layered Double Hydroxide as an Anti-inflammatory Drugs Nanocarrier,” *Journal of Nanobiotechnology* 18 (2020): 155, <https://doi.org/10.1186/s12951-020-00718-y>.

[CAS](#)  | [PubMed](#)  | [Web of Science®](#)  | [Google Scholar](#)  |

14 A. Ait Ichou, M. Abali, M. Chiban, et al., “Élaboration et Caractérisation D'argiles Synthétiques de Type HDL et Leur Application pour L'adsorption Des Ions Cu^{2+} (Development and Characterization of Synthetic Clay LDH Type and Their Application on the Adsorption of Cu^{2+} ions),” *Journal of Materials and Environmental Science* 5 (2014): 2444–2448.

[Google Scholar](#)  |

 Have questions about this article?

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016/j.chemosphere.2019.124369.

16 G. Mishra, B. Dash, and S. Pandey, "Layered Double Hydroxides: A Brief Review From Fundamentals to Application as Evolving Biomaterials," *Applied Clay Science* 153 (2018): 172–186, <https://doi.org/10.1016/j.clay.2017.12.021>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

17 E. H. Mourid, M. Lakraimi, L. Benaziz, E. H. Elkhatabi, and A. Legrouri, "Wastewater Treatment Test by Removal of the Sulfamethoxazole Antibiotic by a Calcined Layered Double Hydroxide," *Applied Clay Science* 168 (2019): 87–95, <https://doi.org/10.1016/j.clay.2018.11.005>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

18 Y. Chen, H. Xu, M. S. Khan, S. Han, and S. Zhu, "Recent Advances in Layered Double Hydroxides for Pharmaceutical Wastewater Treatment: A Critical Review," *Critical Reviews in Environmental Science and Technology* 55 (2025): 1097–1123, <https://doi.org/10.1080/10643389.2025.2488808>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

19 F. G. Corrêa, R. J. Araujo, V. N. Campos, et al., "Layered Double Hydroxides Modified With Carbon Quantum Dots as Promising Materials for Pharmaceutical Removal," *Minerals* 15 (2025): 899.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

20 C. Yang, L. Wang, Y. Yu, et al., "Highly Efficient Removal of Amoxicillin From Water by Mg-Al Layered Double Hydroxide/Cellulose Nanocomposite Beads Synthesized Through In-situ Coprecipitation Method," *International Journal of Biological Macromolecules* 149 (2020): 93–100, <https://doi.org/10.1016/j.ijbiomac.2020.01.096>.

[CAS](#) [PubMed](#) [Web of Science®](#) [Google Scholar](#)

21 C. Xia, H. Huang, D. Liang, et al., "Adsorption of Tetracycline Hydrochloride on Layered Double Hydroxide Loaded Carbon Nanotubes and Site Energy Distribution Analysis," *Chemical Engineering Journal* 443 (2022): 136398, <https://doi.org/10.1016/j.cej.2022.136398>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

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Simultaneous Removal of Ibuprofen, Carbamazepine, Sulfamethoxazole, and Diclofenac From

[CAS](#) [Web of Science®](#) [Google Scholar](#)

23 Y. Li, H. Zhang, G. Qu, et al., "Efficient Removal of Antibiotics From Wastewater by Chitosan/Polyethyleneimine/Ti3C2 MXene Composite Hydrogels: Synthesis, Adsorption, Kinetics and Mechanisms," *Colloids and Surfaces A: Physicochemical and Engineering Aspects* 702 (2024): 135111, <https://doi.org/10.1016/j.colsurfa.2024.135111>.

[CAS](#) [Google Scholar](#)

24 M. Sui, Y. Zhou, L. Sheng, and B. Duan, "Adsorption of Norfloxacin in Aqueous Solution by Mg–Al Layered Double Hydroxides With Variable Metal Composition and Interlayer Anions," *Chemical Engineering Journal* 210 (2012): 451–460, <https://doi.org/10.1016/j.cej.2012.09.026>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

25 M. Daud, A. Hai, F. Banat, et al., "A Review on the Recent Advances, Challenges and Future Aspect of Layered Double Hydroxides (LDH)—Containing Hybrids as Promising Adsorbents for Dyes Removal," *Journal of Molecular Liquids* 288 (2019): 110989, <https://doi.org/10.1016/j.molliq.2019.110989>.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

26 M. El-Abboubi, N. Taoufik, F. Mahjoubi, A. Oussama, F. Kzaiber, and N. Barka, "Sorption of Methyl Orange Dye by Dodecyl-sulfate Intercalated Mg–Al Layered Double Hydroxides," *Materials Today: Proceedings* 37 (2021): 3894–3897.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

27 K. Benazouz, N. Bouchelkia, H. Moussa, et al., "Efficient Removal of Cu (II) From Wastewater Using Chitosan Derived From Shrimp Shells: A Kinetic, Thermodynamic, Optimization, and Modelling Study," *Water* 17 (2025): 851.

[CAS](#) [Web of Science®](#) [Google Scholar](#)

29 H. Zhang, J. Wang, B. Zhang, et al., "Synthesis of a Hydrotalcite-Like Compound from Oil Shale Ash and Its Application in Uranium Removal," *Colloids and Surfaces A: Physicochemical and Engineering Aspects* **444** (2014): 129–137, <https://doi.org/10.1016/j.colsurfa.2013.12.054>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

30 R. Mahmoud, S. A. Moaty, F. Mohamed, and A. Farghali, "Comparative Study of Single and Multiple Pollutants System Using Ti–Fe Chitosan LDH Adsorbent With High Performance in Wastewater Treatment," *Journal of Chemical & Engineering Data* **62** (2017): 3703–3722, <https://doi.org/10.1021/acs.jced.7b00453>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

31 M. Lakraimi, A. Legrouri, A. Barroug, A. De Roy, and J. P. Besse, "Preparation of a New Stable Hybrid Material by Chloride–2,4-dichlorophenoxyacetate Ion Exchange Into the Zinc–aluminium–chloride Layered Double Hydroxide," *Journal of Materials Chemistry* **10** (2000): 1007–1011, <https://doi.org/10.1039/a909047i>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

32 N. Hamri, A. Imessaoudene, N. Bouchelkia, et al., "Innovative Surface Modification of Kaolinite by Direct Grafting of an Anionic Surfactant to Improve Pollutant Adsorption and Effluent Decontamination," *Journal of Dispersion Science and Technology* **47** (2024): 1610–1629, <https://doi.org/10.1080/01932691.2024.2448761>.

[Web of Science®](#)  | [Google Scholar](#) 

33 A. Othmani, I. Hammouche, A. Selatnia, and N. Bouchelkia, "Surfactant-Activated Pharmaceutical Waste Biomass for Efficient Removal of Basic Violet 14: Experimental Investigation, Machine-Learning Optimization, and Mechanistic Validation by DFT Calculations," *Waste Management* **216** (2026): 115470, <https://doi.org/10.1016/j.wasman.2026.115470>.

[CAS](#)  | [PubMed](#)  | [Web of Science®](#)  | [Google Scholar](#) 

34 A. Othmani, I. Hammouche, and A. Selatnia, "From Batch to Fixed-bed Biosorption of Congo Red

 Have questions about this article?

35 N. Bouchelkia, H. Tahraoui, K. Benazouz, et al., "Optimizing Adsorption Efficiency: A Novel Application of SVM_Boosting_IGWO for Methylene Blue Dye Removal Using Low-cost Fruit Peels Adsorbents," *Chemometrics and Intelligent Laboratory Systems* 261 (2025): 105377, <https://doi.org/10.1016/j.chemolab.2025.105377>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

36 Z. Zhang, L. Tang, J. Luo, J. Tan, and X. Jiang, "Comparative Study of Mg/Al-LDH and Mg/Fe-LDH on Adsorption and Loss Control of 2, 4-dichlorophenoxyacetic Acid," *Advanced Biotechnology* 3 (2025): 4, <https://doi.org/10.1007/s44307-024-00055-3>.

[PubMed](#)  | [Google Scholar](#) 

37 N. Boukhalfa, M. Boutahala, and N. Djebri, "Synthesis and Characterization of ZnAl-layered Double Hydroxide and Organo-K10 Montmorillonite for the Removal of Diclofenac From Aqueous Solution," *Adsorption Science & Technology* 35 (2017): 20–36, <https://doi.org/10.1177/026361741666548>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

38 V. O. Shikuku and T. Mishra, "Adsorption Isotherm Modeling for Methylene Blue Removal Onto Magnetic Kaolinite Clay: A Comparison of Two-parameter Isotherms," *Applied Water Science* 11 (2021): 103, <https://doi.org/10.1007/s13201-021-01440-2>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

39 S. Talbi, A. E. Khanchaoui, L. Bouissane, et al., "The High Performance of Multi-metal Layered Double Hydroxides (LDHs) in the Removal of Organic Dyes," *Chemistry Proceedings* 14 (2023): 99.

[Google Scholar](#) 

40 V. O. Shikuku, R. Zanella, C. O. Kowenje, F. F. Donato, N. M. Bandeira, and O. D. Prestes, "Single and Binary Adsorption of Sulfonamide Antibiotics Onto Iron-modified Clay: Linear and Nonlinear Isotherms, Kinetics, Thermodynamics, and Mechanistic Studies," *Applied Water Science* 8 (2018): 175, <https://doi.org/10.1007/s13201-018-0825-4>.



Have questions about this article?

Wastewater,” *Environmental Nanotechnology, Monitoring & Management* 15 (2021): 100455.

[CAS](#)  | [Google Scholar](#) 

42 H. Cherifi, S. Hanini, and F. Bentahar, “Adsorption of Phenol From Wastewater Using Vegetal Cords as a New Adsorbent,” *Desalination* 244 (2009): 177–187, <https://doi.org/10.1016/j.desal.2008.05.022>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

43 C. R. Girish, “Determination of Thermodynamic Parameters in Adsorption Studies: A Review,” *Chemical Papers* 79 (2025): 5687–5706, <https://doi.org/10.1007/s11696-025-04218-x>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

44 D. Somashekara and L. Mulky, “Sequestration of Contaminants From Wastewater: A Review of Adsorption Processes,” *ChemBioEng Reviews* 10 (2023): 491–509, <https://doi.org/10.1002/cben.202200050>.

[CAS](#)  | [Web of Science®](#)  | [Google Scholar](#) 

45 M. S. Manzar, P. Palaniandy, J. Georgin, et al., “Synthesis of LDH-MgAl and LDH-MgFe Composites for the Efficient Removal of the Antibiotic From Water,” *Environmental Science and Pollution Research* 31 (2024): 55577–55596, <https://doi.org/10.1007/s11356-024-34837-y>.

[CAS](#)  | [PubMed](#)  | [Google Scholar](#) 

46 H. Mkaddem, E. Rosales, M. Pazos, H. B. Amor, M. Sanromán, and J. Meijide, “Anti-inflammatory Drug Diclofenac Removal by a Synthesized MgAl Layered Double Hydroxide,” *Journal of Molecular Liquids* 359 (2022): 119207, <https://doi.org/10.1016/j.molliq.2022.119207>.

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