

SYNTHESIS OF NEW TRIAZOLYL STARCH DERIVATIVES FOR HEAVY METALS REMOVAL

ASAAD H. ANEED, HAYDER M. KAMAL, DHURGHAM AZIZ, NUHA S. KAREEM,
MARYAM M. MAHDI, ZAHRAA H. MUSLIM, ZAHRAA H. HAMID

References:

1. Crini, G. Recent Developments in Polysaccharide-Based Materials Used as Adsorbents in Wastewater Treatment. *Prog. Polym. Sci.* **2005**, 30 (1), 38–70. <https://doi.org/10.1016/j.progpolymsci.2004.11.002>.
2. Khoramzadeh, E.; Nasernejad, B.; Halladj, R. Mercury Biosorption from Aqueous Solutions by Sugarcane Bagasse. *J. Taiwan Inst. Chem. Eng.* **2013**, 44 (2), 266–269. <https://doi.org/10.1016/j.jtice.2012.09.004>.
3. Yargıç, A. Ş.; Yarbay Şahin, R. Z.; Özbay, N.; Önal, E. Assessment of Toxic Copper(II) Biosorption from Aqueous Solution by Chemically-Treated Tomato Waste. *J. Clean. Prod.* **2015**, 88, 152–159. <https://doi.org/10.1016/j.jclepro.2014.05.087>.
4. Wan Ngah, W. S.; Hanafiah, M. A. K. M. Removal of Heavy Metal Ions from Wastewater by Chemically Modified Plant Wastes as Adsorbents: A Review. *Bioresour. Technol.* **2008**, 99 (10), 3935–3948. <https://doi.org/10.1016/j.biortech.2007.06.011>.
5. Fu, F.; Wang, Q. Removal of Heavy Metal Ions from Wastewaters: A Review. *J. Environ. Manage.* **2011**, 92 (3), 407–418. <https://doi.org/10.1016/j.jenvman.2010.11.011>.
6. Nasrollahzadeh, M.; Sajjadi, M.; Iravani, S.; Varma, R. S. Starch, Cellulose, Pectin, Gum, Alginate, Chitin and Chitosan Derived (Nano)Materials for Sustainable Water Treatment: A Review. *Carbohydr. Polym.* **2021**, 251, 116986. <https://doi.org/10.1016/j.carbpol.2020.116986>.
7. Olivera, S.; Muralidhara, H. B.; Venkatesh, K.; Guna, V. K.; Gopalakrishna, K.; Kumar, Y. K. Potential Applications of Cellulose and Chitosan Nanoparticles/Composites in Wastewater Treatment: A Review. *Carbohydr. Polym.* **2016**, 153, 600–618. <https://doi.org/10.1016/j.carbpol.2016.08.017>.
8. Xu, C.; Nasrollahzadeh, M.; Sajjadi, M.; Maham, M.; Luque, R.; Puente-Santiago, A. R. Benign-by-Design Nature-Inspired Nanosystems in Biofuels Production and Catalytic Applications. *Renewable Sustainable Energy Rev.* **2019**, 112, 195–252. <https://doi.org/10.1016/j.rser.2019.03.062>.
9. Yusof, Y. M.; Kadir, M. F. Z. Electrochemical Characterizations and the Effect of Glycerol in Biopolymer Electrolytes Based on Methylcellulose–Potato Starch Blend. *Mol. Cryst. Liq. Cryst.* **2016**, 627 (1), 220–233. <https://doi.org/10.1080/15421406.2015.1137115>.
10. Kweon, D.-K.; Choi, J.-K.; Kim, E.-K.; Lim, S.-T. Adsorption of Divalent Metal Ions by Succinylated and Oxidized Corn Starches. *Carbohydr. Polym.* **2001**, 46 (2), 171–177. [https://doi.org/10.1016/S0144-8617\(00\)00300-3](https://doi.org/10.1016/S0144-8617(00)00300-3).
11. Soto, D.; Urdaneta, J.; Pernía, K.; León, O.; Muñoz-Bonilla, A.; Fernández-García, M. Heavy Metal (Cd^{2+} , Ni^{2+} , Pb^{2+}) Adsorption in Aqueous Solutions by Oxidized Starches. *Polym. Adv. Technol.* **2015**, 26 (2), 147–152. <https://doi.org/10.1002/pat.3439>.
12. Igura, M.; Okazaki, M. Selective Sorption of Heavy Metal on Phosphorylated Sago Starch-Extraction Residue. *J. Appl. Polym. Sci.* **2012**, 124 (1), 549–559. <https://doi.org/10.1002/app.34899>.
13. Zhang, H.; Reynolds, M. Cadmium Exposure in Living Organisms: A Short Review. *Sci. Total Environ.* **2019**, 678, 761–767. <https://doi.org/10.1016/j.scitotenv.2019.04.395>.
14. Naseem, R.; Tahir, S. S. Removal of Pb(II) from Aqueous/Acidic Solutions by Using Bentonite as an Adsorbent. *Water Res.* **2001**, 35 (16), 3982–3986. [https://doi.org/10.1016/S0043-1354\(01\)00130-0](https://doi.org/10.1016/S0043-1354(01)00130-0).
15. Hiroki, A.; Tran, H. T.; Nagasawa, N.; Yagi, T.; Tamada, M. Metal Adsorption of Carboxymethyl Cellulose/Carboxymethyl Chitosan Blend Hydrogels Prepared by Gamma Irradiation. *Radiat. Phys. Chem.* **2009**, 78 (12), 1076–1080. <https://doi.org/10.1016/j.radphyschem.2009.05.003>.
16. Calace, N.; Di Muro, A.; Nardi, E.; Petronio, B. M.; Pietroletti, M. Adsorption Isotherms for Describing Heavy-Metal Retention in Paper Mill Sludges. *Ind. Eng. Chem. Res.* **2002**, 41 (22), 5491–5497. <https://doi.org/10.1021/ie011029u>.
17. Li, Y.; Tan, Y.; Ning, Z.; Sun, S.; Gao, Y.; Wang, P. Design and Fabrication of Fluorescein-Labeled Starch-Based Nanospheres. *Carbohydr. Polym.* **2011**, 86 (1), 291–295. <https://doi.org/10.1016/j.carbpol.2011.04.049>.
18. Wang, C.; et al. Super Wettable Porous Spheres Prepared by Recyclable Pickering Emulsion Polymerization for Multifarious Oil/Water Separations. *Green Chem.* **2021**, 23 (6), 2372–2381. <https://doi.org/10.1039/D0GC04147E>.
19. Kamal, H. M.; et al. New Hydrophilic Grafting Cellulose Based on Amino-Carboxylic Acid: Synthesis and Antibacterial Evaluation. *J. Biosci. Appl. Res.* **2025**, 11 (1), 214–222. <https://doi.org/10.21608/jbaar.2025.353637.1140>.

20. Xu, S.-M.; Feng, S.; Peng, G.; Wang, J.-D.; Yushan, A. Removal of Pb(II) by Crosslinked Amphoteric Starch Containing the Carboxymethyl Group. *Carbohydr. Polym.* **2005**, *60* (3), 301–305. <https://doi.org/10.1016/j.carbpol.2005.01.018>.
21. Na, Y.; Lee, J.; Lee, S. H.; Kumar, P.; Kim, J. H.; Patel, R. Removal of Heavy Metals by Polysaccharide: A Review. *Polym.-Plast. Technol. Mater.* **2020**, *59* (16), 1770–1790. <https://doi.org/10.1080/25740881.2020.1768545>.
22. Wannous, A.; Milaneh, S.; Said, M.; et al. New Approach for Starch Dialdehyde Preparation Using Microwave Irradiation for Removal of Heavy Metal Ions from Water. *SN Appl. Sci.* **2022**, *4*, 133. <https://doi.org/10.1007/s42452-022-05024-w>.
23. Salisu, A.; Usman, A.; Halliru, H.; Danjani, A. Removal of Co(II), Pb(II) and Zn(II) Ions by Dialdehyde Starch Aminopyrazole Schiff Base from Aqueous Solution. *IOSR J. Appl. Chem.* **2016**, *9* (6), 61–67. <https://doi.org/10.9790/5736-0906016167>.
24. Keleş, S.; Güçlü, G. Competitive Removal of Heavy Metal Ions by Starch-Graft-Acrylic Acid Copolymers. *Polym.-Plast. Technol. Eng.* **2006**, *45* (3), 365–371. <https://doi.org/10.1080/03602550600553291>.
25. Xiang, B.; Fan, W.; Yi, X.; Wang, Z.; Gao, F.; Li, Y.; Gu, H. Dithiocarbamate Modified Starch Derivatives with High Heavy Metal Adsorption Performance. *Carbohydr. Polym.* **2016**, *136*, 30–37. <https://doi.org/10.1016/j.carbpol.2015.08.065>.
26. Basri, S. N.; et al. Preparation and Characterization of Irradiated Carboxymethyl Sago Starch-Acid Hydrogel and Its Application as Metal Scavenger in Aqueous Solution. *Carbohydr. Polym.* **2016**, *138*, 34–40. <https://doi.org/10.1016/j.carbpol.2015.11.028>.
27. Xie, G.; Shang, X.; Liu, R.; Hu, J.; Liao, S. Synthesis and Characterization of a Novel Amino Modified Starch and Its Adsorption Properties for Cd(II) Ions from Aqueous Solution. *Carbohydr. Polym.* **2011**, *84*, 430–438. <https://doi.org/10.1016/j.carbpol.2010.12.003>.