JWARP> Vol.3 No.10, October 2011

OPEN ACCESS

Influence of Physical and Chemical Parameters on the Treatment of Heavy Metals in Polluted Stormwater Using Zeolite—A Review

PDF (Size:179KB) PP. 758-767 DOI: 10.4236/jwarp.2011.310086

Author(s)

Abdul M. Ziyath, Parvez Mahbub, Ashantha Goonetilleke, Moses O. Adebajo, Serge Kokot, Adekunle Oloyede

ABSTRACT

Zeolite-based technology can provide a cost effective solution for stormwater treatment for the removal of toxic heavy metals under increasing demand of safe water from alternative sources. This paper reviews the currently available knowledge relating to the effect of properties of zeolites such as pore size, surface area and Si:Al ratio and the physico-chemical conditions of the system such as pH, temperature, initial metal concentration and zeolite concentration on heavy metal removal performance. The primary aims are, to consolidate available knowledge and identify knowledge gaps. It was established that an in-depth understanding of operational issues such as, diffusion of metal ions into the zeolite pore structure, pore clogging, zeolite surface coverage by particulates in stormwater as well as the effect of pH on stormwater quality in the presence of zeolites is essential for developing a zeolite-based technology for the treatment of polluted stormwater. The optimum zeolite concentration to treat typical volumes of stormwater and initial heavy metal concentrations in stormwater should also be considered as operational issues in this regard. Additionally, leaching of aluminium and sodium ions from the zeolite structure to solution were identified as key issues requiring further research in the effort to develop cost effective solutions for the removal of heavy metals from stormwater.

KEYWORDS

Zeolite, Heavy Metals, Stormwater, Leaching, Stormwater Reuse

Cite this paper

A. Ziyath, P. Mahbub, A. Goonetilleke, M. Adebajo, S. Kokot and A. Oloyede, "Influence of Physical and Chemical Parameters on the Treatment of Heavy Metals in Polluted Stormwater Using Zeolite—A Review," *Journal of Water Resource and Protection*, Vol. 3 No. 10, 2011, pp. 758-767. doi: 10.4236/jwarp.2011.310086.

References

[1] WHO, "Global Water Supply and Sanitation Assessment 2000 Report," World Health Organization, USA, 2000.

[2] WHO, "Progress on Drinking Water and Sanitation: Special Focus on Sanitation," UNICEF, New York and WHO, Geneva, 2008.

[3] S. Begum, M. Rasul and R. J. Brown, "A Comparative Review of Stormwater Treatment and Reuse Techniques with a New Approach: Green Gully," WSEAS Transactions on Environment and Development, Vol. 4, 2008, pp. 1002-1013.

[4] M. Burns and V. Mitchell, "An Evaluation of the Design, Implementation and Operation of 3 Stormwater Reuse Systems across Melbourne," Proceedings of the 13th International Rainwater Catchment Systems Conference, Sydney, Australia, 2007,

[5] B. Hatt, A. Deletic and T. Fletcher, "Stormwater Reuse: Designing Biofiltration Systems for Reliable Treatment," Water Science and Technology, Vol. 55, No. 4, 2007, p. 201. doi:10.2166/wst.2007.110

[6] S. R. Carpenter, N. F. Caraco, D. L. Correll, R. W. Howarth, A. N. Sharpley and V. H. Smith, "Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen," Ecological Applications, Vol. 8, No. 3, 1998, pp. 559-568. doi:10.1890/1051-0761(1998)008[0559:NPOSWW]2.0.CO;2

[7] V. A. Tsihrintzis and R. Hamid, "Modeling and Management of Urban Stormwater Runoff Quality: A Review," Water Resources Management, Vol. 11, No. 2, 1997, pp. 136-164. doi:10.1023/A:1007903817943

[8] B. Sun, M. Sato and J. Clements, "Use of a Pulsed High-Voltage Discharge for Removal of Organic Compounds in Aqueous Solution," Journal of Physics D: Applied Physics, Vol. 32, No. 15, 1999, p. 1908. doi:10.1088/0022-3727/32/15/319

[9] C. Tanner, J. Clayton and M. Upsdell, "Effect of Loading Rate and Planting on Treatment of Dairy Farm Wastewaters in Constructed Wetlands-I. Removal of Oxygen Demand, Suspended Solids and Faecal Coliforms," Water Research, Vol. 29, No. 1, 1995, pp. 17-26. doi:10.1016/0043-1354(94)00139-X

[10] M. Tomaszewska and S. Mozia, "Removal of Organic Matter from Water by PAC/UF System," Water Research, Vol. 36, No. 16, 2002, pp. 4137-4143. doi:10.1016/S0043-1354(02)00122-7

[11] B. Tryba, A. Morawski and M. Inagaki, "Application of Tio2-Mounted Activated Carbon to the Removal of Phenol from Water," Applied Catalysis B: Environmental, Vol. 41, No. 4, 2003, pp. 427-433. doi:10.1016/S0926-3373(02)00173-X

[12] J. Vymazal, "Removal of Nutrients in Various Types of Constructed Wetlands," Science of the Total Environment, Vol. 380, No. 1-3, 2007, pp. 48-65. doi:10.1016/j.scitotenv.2006.09.014

[13] Z. Xie, "Electrochemical Wastewater Treatment for Denitrification and Toxic Organic Degradation Using Titanium-based Tin Oxide and Ruthenium Oxide Electrodes," Ph.D. Thesis, The University of Hong Kong, Hong Kong, 2006.

[14] D. Dayan and A. J. Paine, "Mechanisms of Chromium Toxicity, Carcinogenicity and Allergenicity: Review of the Literature from 1985 to 2000," Human and Experimental Toxicology, Vol. 20, No. 9, 2001, pp. 439-451. doi:10.1191/096032701682693062

[15] R. M. Jacobs, M. R. S. Fox and M. H. Aldridge, "Changes in Plasma Proteins Associated with the Anemia Produced by Dietary Cadmium in Japanese Quail," Journal of Nutrition, Vol. 99, No. 2, 1969, pp. 119-128.

[16] G. Nicholson, J. Fynn and N. Coroneos, "Cadmium Poisoning in a Crematorium Worker," Anaesthesia and Intensive Care, Vol. 25, No. 2, 1997, pp. 163-165.

[17] N. W. Revis, A. R. Zinsmeister and R. Bull, "Atherosclerosis and Hypertension Induction by Lead and Cadmium Ions: An Effect Prevented by Calcium Ion," Proceedings of the National Academy of Sciences of the United States of America, Vol. 78, No. 10, 1981, pp. 6494-6498. doi: 10.1073/pnas.78.10.6494

[18] S. Satarug and R. M. Michael, "Adverse Health Effects of Chronic Exposure to Low-Level Cadmium in Foodstuffs and Cigarette Smoke," Environmental Health Perspectives, Vol. 112, No. 10, 2004, pp. 1099-1103. doi:10.1289/ehp.6751

[19] P. A. Terry and W. Stone, "Biosorption of Cadmium and Copper Contaminated Water by Scenedesmus Abundans," Chemosphere, Vol. 47, No. 3, 2002, pp. 249-255. doi:10.1016/S0045-6535(01)00303-4

[20] P. Bose, M. Aparna Bose and S. Kumar, "Critical Evaluation of Treatment Strategies Involving Adsorption and Chelation for Wastewater Containing Copper, Zinc and Cyanide," Advances in Environmental Research, Vol. 7, No. 1, 2002, pp. 179-195. doi: 10.1016/S1093-0191(01)00125-3

[21] E. H. Martin, "Effectiveness of an Urban Runoff Detention Pond-Wetlands System," Journal of Environmental Engineering, Vol. 114, No. 4, 1988, pp. 810-827. doi:10.1061/(ASCE)0733-9372(1988)114:4(810)

[22] J. W. Patterson, H. E. Allen and J. J. Scala, "Carbonate Precipitation for Heavy Metals Pollutants," Journal of the Water Pollution Control Federation, Vol. 49, No. 12, 1977, pp. 2397-2410.

[23] V. Inglezakis and S. Poulopoulos, "Adsorption, Ion Exchange and Catalysis: Design of Operations and Environmental Applications", Elsevier Science Ltd, 2006.

[24] J. E. Baker, S. J. Eisenreich and B. J. Eadie, "Sediment Trap Fluxes and Benthic Recycling of Organic Carbon, Polycyclic Aromatic Hydrocarbons, and Polychlorobiphenyl Congeners in Lake Superior," Environmental Science & Technology, Vol. 25, No. 3, 1991, pp. 500-509. doi:10.1021/es00015a019

[25] G. M. Ayoub, L. Semerjian, A. Acra, M. El Fadel and B. Koopman, "Heavy Metal Removal by Coagulation with Seawater Liquid Bittern," Journal of Environmental Engineering, Vol. 127, No. 3, 2001, pp. 196-207. doi:10.1061/(ASCE)0733-9372(2001)127:3(196)

[26] T. A. Kurniawan, G. Y. S. Chan, W. H. Lo and S. Babel, "Physico-Chemical Treatment Techniques for Wastewater Laden with Heavy Metals," Chemical Engineering Journal, Vol. 118, No. 1-2, 2006, pp. 83-98. doi:10.1016/j.cej.2006.01.015

[27] S. Babel and T. A. Kurniawan, "Low-Cost Adsorbents for Heavy Metals Uptake from Contaminated Water: A Review," Journal of Hazardous Materials, Vol. 97, No. 1-3, 2003, pp. 219-243. doi:10.1016/S0304-3894(02)00263-7

[28] Kesraoui-Ouki, C. R. Cheeseman and R. Perry, "Natural Zeolite Utilisation in Pollution Control: A Review of Applications to Metals' Effluents," Journal of Chemical Technology & Biotechnology, Vol. 59, No. 2, 1994, pp. 121-126. doi:10.1002/jctb.280590202

[29] S. Wang and Y. Peng, "Natural Zeolites as Effective Adsorbents in Water and Wastewater Treatment," Chemical Engineering Journal, Vol. 156, No. 1, 2010, pp. 11-24. doi:10.1016/j.cej.2009.10.029

[30] J. Weitkamp, "Zeolites and Catalysis," Solid State Ionics, Vol. 131, No. 1-2, 2000, pp. 175-188. doi:10.1016/S0167-2738(00)00632-9

[31] H. Ghobarkar, O. Sch?f, and U. Guth, "Zeolites-from Kitchen to Space," Progress in Solid State Chemistry, Vol. 27, No. 2-4, 1999, pp. 29-73. doi:10.1016/S0079-6786(00)00002-9

[32] S. Ouki and M. Kavannagh, "Performance of Natural Zeolites for the Treatment of Mixed Metal-Contaminated Effluents," Waste Management & Research, Vol. 15, No. 4, 1997, pp. 383-394. doi:10.1177/0734242X9701500406

[33] K. S. Hui, C. Y. H. Chao and S. C. Kot, "Removal of Mixed Heavy Metal Ions in Wastewater by Zeolite 4A and Residual Products from Recycled Coal Fly Ash," Journal of Hazardous Materials, Vol. 127, No. 1-3, 2005, pp. 89-101. doi:10.1016/j.jhazmat.2005.06.027

[34] B. Bi?kup and B. Subotic, "Kinetic Analysis of the Exchange Processes between Sodium Ions from Zeolite A and Cadmium, Copper and Nickel Ions from Solutions," Separation and Purification Technology, Vol. 37, No. 1, 2004, pp. 17-31. doi:10.1016/S1383-5866(03)00220-X

[35] M. I. Panayotova, "Kinetics and Thermodynamics of Copper Ions Removal from Wastewater by Use of Zeolite," Waste Management, Vol. 21, No. 7, 2001, pp. 671- 676. doi:10.1016/S0956-053X(00)00115-X

[36] W. Mozgawa and T. Bajda, "Spectroscopic Study of Heavy Metals Sorption on Clinoptilolite," Physics and Chemistry of Minerals, Vol. 31, No. 10, 2005, pp. 706- 713. doi:10.1007/s00269-004-0433-8

[37] V. J. Inglezakis, M. D. Loizidou and H. P. Grigoropoulou, "Equilibrium and Kinetic Ion Exchange Studies of Pb2+, Cr3+, Fe3+ and Cu2+ on Natural Clinoptilolite," Water Research, Vol. 36, No. 11, 2002, pp. 2784-2792. doi:10.1016/S0043-1354(01)00504-8

[38] E. álvarez-Ayuso, A. García-Sánchez and X. Querol, "Purification of Metal Electroplating Waste Waters Using Zeolites," Water Research, Vol. 37, No. 20, 2003, pp. 4855-4862. doi:10.1016/j.watres.2003.08.009

[39] V. K. Jha, M. Nagae, M. Matsuda and M. Miyake, "Zeolite Formation from Coal Fly Ash and Heavy Metal Ion Removal Characteristics Of thus-Obtained Zeolite X in Multi-Metal Systems," Journal of Environmental Management, Vol. 90, No. 8, 2009, pp. 2507-2514. doi:10.1016/j.jenvman.2009.01.009

[40] T. Mishra and S. K. Tiwari, "Studies on Sorption Properties of Zeolite Derived from Indian Fly Ash," Journal of Hazardous Materials, Vol. 137, No. 1, 2006, pp. 299-303. doi:10.1016/j.jhazmat.2006.02.004

[41] H.-L. Chang and W.-H. Shih, "Synthesis of Zeolites A and X from Fly Ashes and Their Ion-Exchange Behavior with Cobalt Ions," Industrial & Engineering Chemistry Research, Vol. 39, No. 11, 2000, pp. 4185-4191. doi:10.1021/ie990860s

[42] H. Leinonen and J. Lehto, "Purification of Metal Finishing Waste Waters with Zeolites and Activated Carbons," Waste Management Research, Vol. 19, No. 1, 2001, pp. 45-57. doi:10.1177/0734242X0101900106

[43] G. Purna Chandra Rao, S. Satyaveni, A. Ramesh, K. Seshaiah, K. S. N. Murthy and N. V. Choudary, "Sorption of Cadmium and Zinc from Aqueous Solutions by Zeolite 4a, Zeolite 13x and Bentonite," Journal of Environmental Management, Vol. 81, No. 3, 2006, pp. 265-272. doi:10.1016/j.jenvman.2005.11.003

[44] J. Groen, L. Peffer, J. Moulijn and J. Pérez-Ramírez, "On the Introduction of Intracrystalline Mesoporosity in Zeolites upon Desilication in Alkaline Medium," Microporous and Mesoporous Materials, Vol. 69, No. 1-2, 2004, pp. 29-34. doi:10.1016/j.micromeso.2004.01.002

[45] K.-H. Lee and B.-H. Ha, "Characterization of Mordenites Treated by HCl/Steam or HF," Microporous and Mesoporous Materials, Vol. 23, No. 3-4, 1998, pp. 211- 219. doi:10.1016/S1387-1811(98)00118-8

[46] L. Herngren, A. Goonetilleke and G. A. Ayoko, "Understanding Heavy Metal and Suspended Solids Relationships in Urban Stormwater Using Simulated Rainfall," Journal of Environmental Management, Vol. 76, No. 2, 2005, pp. 149-158. doi:10.1016/j.jenvman.2005.01.013

[47] IZASC (International Zeolite Association Structure Commission), Accessed on 3 April 2009. http://izasc.ethz.ch/fmi/xsl/IZA-SC/ ft.xsl

[48] E. R. Nightingale, "Phenomenological Theory of Ion Solvation. Effective Radii of Hydrated Ions," The Journal of Physical Chemistry, Vol. 63, No. 9, 1959, pp. 1381- 1387. doi:10.1021/j150579a011

[49] M. El-Kamash, A. A. Zaki and M. A. El Geleel, "Modeling Batch Kinetics and Thermodynamics of Zinc and Cadmium Ions Removal from Waste Solutions Using Synthetic Zeolite A," Journal of Hazardous Materials, Vol. 127, No. 1-3, 2005, pp. 211-220. doi:10.1016/j.jhazmat.2005.07.021

[50] C. Wang, J. Li, X. Sun and L. Wang, "Evaluation of Zeolites Synthesized from Fly Ash as Potential Adsorbents for Wastewater Containing Heavy Metals," Journal of Environmental Sciences, Vol. 21, No. 1, 2009, pp. 127-136. doi:10.1016/S1001-0742(09)60022-X

[51] P. Wu and Y.-S. Zhou, "Simultaneous Removal of Coexistent Heavy Metals from Simulated Urban Stormwater Using Four Sorbents: A Porous Iron Sorbent and Its Mixtures with Zeolite and Crystal Gravel," Journal of Hazardous Materials, Vol. 168, No. 2-3, 2009, pp. 674- 680. doi:10.1016/j.jhazmat.2009.02.093

[52] H. Oren and A. Kaya, "Factors Affecting Adsorption Characteristics of Zn2+ on Two Natural Zeolites," Journal of Hazardous Materials, Vol. 131, No. 1-3, 2006, pp. 59-65. doi:10.1016/j.jhazmat.2005.09.027

[53] R. Leyva-Ramos and G. Aguilar-Armenta, L. V. Gonzalez-Gutierrez, R. M. Guerrero-Coronado, and J. Mendoza-Barron, "Ammonia Exchange on Clinoptilolite from Mineral Deposits Located in Mexico," Journal of Chemical Technology & Biotechnology, Vol. 79, No. 6, 2004, pp. 651-657. doi:10.1002/jctb.1035

[54] A. H. Ali and R. El-Bishtawi, "Removal of Lead and Nickel Ions Using Zeolite Tuff," Journal of Chemical Technology & Biotechnology, Vol. 69, No. 1, 1997, pp. 27-34. doi:10.1002/(SICI)1097-4660(199705)69:1<27::AID-JCTB682>3.0.CO;2-J

[55] V. J. Inglezakis, M. D. Loizidou and H. P. Grigoropoulou, "Ion Exchange of Pb2+, Cu2+, Fe3+, and Cr3+ on Natural Clinoptilolite: Selectivity Determination and Influence of Acidity on Metal Uptake," Journal of Colloid and Interface Science, Vol. 261, No. 1, 2003, pp. 49-54. doi:10.1016/S0021-9797(02)00244-8

[56] T. Motsi, N. A. Rowson and M. J. H. Simmons, "Adsorption of Heavy Metals from Acid Mine Drainage by Natural Zeolite," International Journal of Mineral Processing, Vol. 92, No. 1-2, 2009, pp. 42-48. doi:10.1016/j.minpro.2009.02.005

[57] Y. S. Ok, J. E. Yang, Y. S. Zhang, S. J. Kim and D. Y. Chung, "Heavy Metal Adsorption by a Formulated Zeolite-Portland Cement Mixture," Journal of Hazardous Materials, Vol. 147, No. 1-2, 2007, pp. 91-96. doi:10.1016/j.jhazmat.2006.12.046

[58] M. Wark, W. Lutz, G. Schulz-Ekloff and A. Dyer, "Quantitative Monitoring of Side Products During High Loading of Zeolites by Heavy Metals Via pH Measurements," Zeolites, Vol. 13, No. 8, 1993, pp. 658-62. doi:10.1016/0144-2449(93)90139-T

[59] S. K. Pitcher, R. C. T. Slade and N. I. Ward, "Heavy Metal Removal from Motorway Stormwater Using Zeolites," Science of The Total Environment, Vol. 334-335, 2004, pp. 161-166. doi:10.1016/j.scitotenv.2004.04.035

[60] M. Vaca Mier, R. López Callejas, R. Gehr, B. E. Jiménez Cisneros and P. J. J. Alvarez, "Heavy Metal Removal with Mexican Clinoptilolite: Multi-Component Ionic Exchange," Water Research, Vol. 35, No. 2, 2001, pp. 373- 378. doi:10.1016/S0043-1354(00)00270-0

[61] G. M. Haggerty and R. S. Bowman, "Sorption of Chromate and Other Inorganic Anions by Organo-Zeolite," Environmental Science & Technology, Vol. 28, No. 3, 1994, pp. 452-458. doi:10.1021/es00052a017

[62] NHMRC (National Health and Medical Research Council), "Australian Drinking Water Guidelines", 2004.

[63] V. J. Inglezakis, M. M. Loizidou and H. P. Grigoropoulou, "Ion Exchange Studies on Natural and Modified Zeolites and the Concept of Exchange Site Accessibility," Journal of Colloid and Interface Science, Vol. 275, No. 2, 2004, pp. 570-576. doi:10.1016/j.jcis.2004.02.070

[64] M. Barros, P. A. Arroyo, E. F. Sousa-Aguiar and C. R. G. Tavares, "Thermodynamics of the Exchange Processes between K+, Ca2+ and Cr3+ in Zeolite NaA," Adsorption, Vol. 10, No. 3, 2004, pp. 227-235. doi:10.1023/B:ADSO.0000046359.58855.9f

[65] T. M. Seward, C. M. B. Henderson, J. M. Charnock and T. Driesner, "An EXAFS Study of Solvation and Ion Pairing in Aqueous Strontium Solutions to 300?C," Geochimica et Cosmochimica Acta, Vol. 63, No. 16, 1999, pp. 2409-2418. doi:10.1016/S0016-7037(99)00200-8

[66] A. Ismail, R. M. Mohamed, I. A. Ibrahim, G. Kini and B. Koopman, "Synthesis, Optimization and Characterization of Zeolite A and Its Ion-Exchange Properties," Colloids and Surfaces A: Physicochemical and Engineering Aspects, Vol. 366, No. 1-3, 2010, pp. 80-87. doi:10.1016/j.colsurfa.2010.05.023

[67] M. A. Stylianou, M. P. Hadjiconstantinou, V. J. Inglezakis, K. G. Moustakas and M. D. Loizidou, "Use of Natural Clinoptilolite for the Removal of Lead, Copper and Zinc in Fixed Bed Column," Journal of Hazardous Materials, Vol. 143, No. 1-2, 2007, pp. 575-581. doi:10.1016/j.jhazmat.2006.09.096

[68] S. Wang, M. Soudi, L. Li and Z. H. Zhu, "Coal Ash Conversion into Effective Adsorbents for Removal of Heavy Metals and Dyes from Wastewater," Journal of Hazardous Materials, Vol. 133, No. 1-3,