Nanoporous Adsorbents Based on Zeolitic Imidazolate Frameworks for the Removal of Heavy Metals

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Abstract

There are growing concerns regarding the water pollution caused by the toxic heavy metal contaminants such as lead. Currently, the process of adsorption-based physical separation is the most practical and economic approach to remove heavy metals from water. However, the conventional adsorbents such as activated carbons are shown to have low effectiveness towards heavy metals; and this challenge has motivated the development of new materials with improved sorption efficiency. This presentation will discuss the synthesis, structure and adsorption properties of new adsorbents based on ZIF-8, a type of metal-organic framework nanoporous materials. ZIF-8 powders with two different crystal sizes were synthesized by a solvothermal method. Their phase structure and morphology were characterized by X-ray powder diffraction (XRD) and scanning electron microscope (SEM), respectively. In batch adsorption experiments, these ZIF-8 adsorbents showed excellent removal efficiency towards lead ions. The effect of crystal size on the lead adsorption properties will also be discussed in this presentation. Our findings have demonstrated the great potential of ZIF-8 as an effective adsorbent for the capture of heavy metals from water.

APPROACH

- A common approach to testing sorption properties is to conduct batch adsorption experiments.
- Batch adsorption experiments are done by introducing a quantity of adsorbent into a solution that contains contaminants.
- The adsorption experiments should be run with multiple data points at different time intervals in order to obtain a graph of the adsorbent's properties over time.

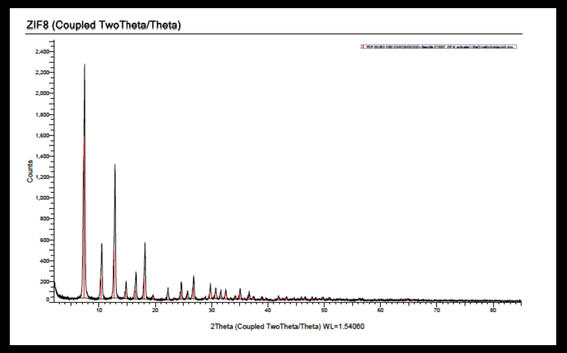

Figure 1. *XRD spectrum of ZiF-8*

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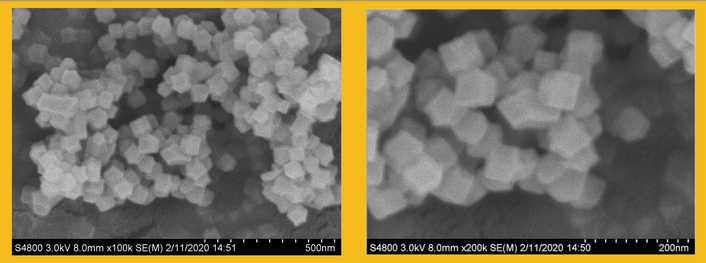

Figure 2. ZiF-8 crystal structure at (left) 500nm and (right) 200nm.

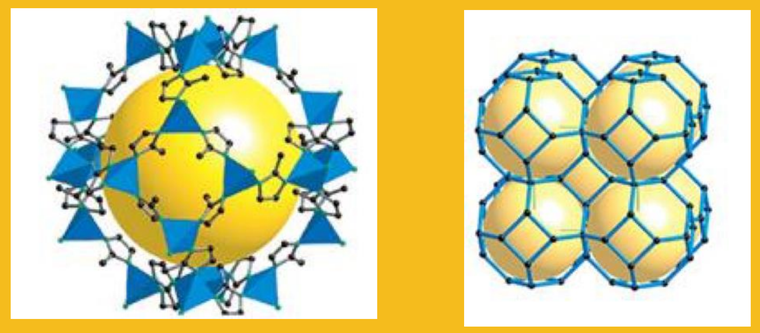

Figure 3. *(left) single crystal and (right) multiple crystal structure of ZiF-8.*

METHODOLOGY

- Step 1: Synthesize ZiF-8 using the methods described in He[1] and Cravillon[3]
- Step 2: X-ray powder diffraction (XRD) analysis to confirm the identity of ZiF-8.
- Step 3: Scanning electron microscopy (SEM) analysis to determine the size of the crystals. Two different crystal sizes were studied in this experiment. One crystal size around 1 micron and the other is around 50nm
- Step 4: Prepare stock solutions of contaminant. In this case, lead solutions were made. One containing 50 parts per million (ppm) of lead and the other, 100 parts per million (ppm) of lead.
- Step 5: Begin batch adsorption by placing ZiF-8 into lead solution, 4 solutions total (two for each crystal size and two for each lead concentration).
- Step 6: Stir solutions and remove a small amount of solution in two hour intervals for 8 hours.
- Step 7: Prepare inductive coupled plasma mass spectrometry (ICP) samples and test in ICP machine.
- Step 8: Analyze data.

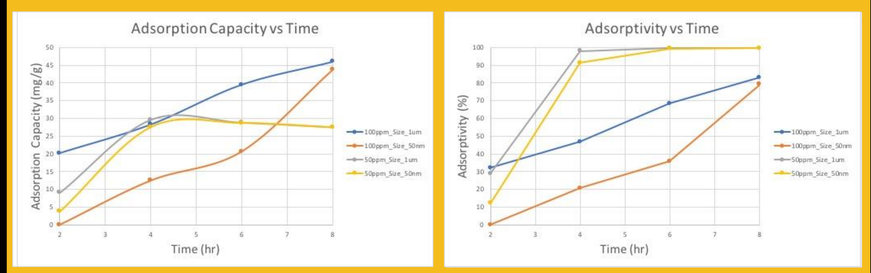

Figure 4. *(left) Adsorption Capacity and (right) adsorptivity of ZiF-8 in lead at 50ppm and 10ppm.*

RESULTS

- The ZiF-8 crystal structure was confirmed by comparing the XRD spectrum from Figure 1 with ZiF-8 spectra from literature.
- SEM provided the results for the crystal sizes as shown in Figure 2.
- The ICP analysis shows really good adsorptivity at 50ppm and not too bad at 100ppm, shown in Figure 4.
- ZiF-8 also shows good adsorption capacity at both lead concentrations, shown in Figure 4.

CONCLUSION

- ZiF-8 is a very promising material for lead removal from water.
- The bigger crystals have a higher adsorption capacity, likely due to their higher surface area available for adsorption visible by the structure in Figure 3.
- The difference in the adsorption is not that big but is is visible.
- One last thing that is interesting is that at higher concentrations, the adsorptivity slows down but the capacity increases.
- Overall, ZiF-8 is a effective adsorbent of heavy ions in water and it can be added to membranes to improve their performance.

BIBLIOGRAPHY

[1] He, Ming, et al. "Facile Synthesis of Zeolitic Imidazolate Framework-8 from a Concentrated Aqueous Solution." *Microporous and Mesoporous Materials*, vol. 184, Jan. 2014, pp. 55–60. *DOI.org (Crossref)*, doi:10.1016/j.micromeso.2013.10.003.

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