Nanomaterials for Water and Environmental Remediation

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Abstract

The objective of this paper is to screen naturally occurring and synthesized nanoporous materials as adsorbents for the removal of different contaminates such as lead, arsenic and organics from water. The nanoporous materials used are very promising as protective barriers to ground water from potential contaminates and as point-of-use water purification systems..

Introduction

Nanoscience and nanotechnology are emerging fields of research. Nanomaterials are those measured in the scale of one billionth of a meter; for example, a human hair measures a width of 50,000 nanometers (nm). We have used nanomaterials as nanoreactors for large scale and low cost production of carbon nanotubes for airspace applications in the National Aeronautics Space Agency (NASA) [1-2]. We will discuss several projects based on synthesis, modification, and use of nanomaterials as nanosponges for environmental remediation and water purification [3-7].

Nanoporous materials are characterized by well-defined pores and/or cavities and are measured in a nanometer scale. They have unique molecular sieving capabilities and ultrahigh surface area, and are suitable as hosts for environmental remediation and water purification. We will focus on the fundamental principle of designing syntheses, characterizations, and applications of nanoporous materials as adsorbents for environmental remediation and water purification [3-7].

Results and Discussion

In collaboration with Langley US Air Force Base, we designed processes and materials for immobilizing lead in the soil of Small Arms Firing Ranges (SAFR). The US Environmental Protection Agency (EPA) has estimated that 4%, or 72,575 metric tons per year, of all lead made in the United States is made into bullets. There are 2,600 military SAFR and 9,000 non-military outdoor shooting ranges in the United States. The state of Virginia has at least 35 outdoor shooting ranges in addition to military ranges. Therefore, immobilizing lead (Pb) contaminants in soil and storm water at SAFR is needed to comply with environmental regulations and to protect the environment. Various adsorption technologies have been studied to solve the problem of lead species releases to the environment. First, we screened low-cost adsorbents, such as naturally occurring clinoptilolite and chabazite, which are mined in large quantities in southwest United States and are relatively inexpensive [3-4]. Figure 1, shows the percent removal of lead ions from aqueous media, which is more than 90 percent of all nanoporous materials (in the range of 0.5-0.75 nm pore size; micro-range) except activated carbon removes only 63 percent. The maximum adsorption needs over 12 hours to be reached using nanomaterials in the micro-pore range, as in Figure 2. Second, we synthesized novel nanopororus materials (pore size in the range of 3.5 nm; meso-range) for lead ions remediation. The maximum adsorption needs only few minutes for the synthesized nanoporous materials in the meso-pore range. The potential application of these novel adsorbent materials is as large filters (barriers) to prevent ground water contamination and as point-of-use water purification systems [3]. Batch adsorption kinetic and isotherm studies were conducted to compare and evaluate different types of adsorbents for lead ion removal from aqueous media. The effects on lead ion absorption from pH changes, competing ions, and temperature increases were also investigated [3-5].

In another study, we synthesized and used organosilicates nanocomposite materials for the elimination of 2,4-dichlophenol (DCP) from aqueous media [6]. Dichlorophenols (DCP) are aromatic compounds used as antiseptics, herbicides, wood preservatives, in paper and pulp industry. Additionally, they are intermediates in the synthesis of other chlorinated phenols. At significant levels, exposure to DCP can cause death. Chronic exposure can result in kidney and liver damage. The U.S. Environmental Protection Agency has placed 2,4-dichlorophenol on the Water Contaminant Candidate List. In addition, 2,4-DCP is toxic to aquatic organisms. The rates, affinity, and stability of these synthetic nanocomposite materials to remove and retain chlorinated phenols from aqueous solution were investigated and compared with activated carbon. All nanocomposite materials have the ability for sorption and retention of 2,4-dichlophenol (2,4-DCP) with very fast kinetics, 10 time faster than activated carbon. Activated carbon is the current base technology to remove DCP from water.

In addition, we will present a study to support worldwide research efforts to obtain drinking water with arsenic levels below the 10 part per billion (ppb) limit that is recommended by the World Health Organization (WHO). Batch adsorption kinetic and isotherm studies were conducted to compare and evaluate iron treated adsorbents for arsenate and arsenite removal from aqueous media. Two iron treatments were investigated as well as the effects of varied pH, temperature, and ionic strength increases on adsorption effectiveness [7]. This will be helpful in saving millions of people who suffer from elevated arsenic levels in drinking water.

In summary, the potential uses of the different nanoporous adsorbents investigated in our projects are as protective barriers to ground water from potential contaminates and as point-of-use water purification systems. Point-of-use water purification systems are small-scaled water purification systems, for small communities, which can be suitable for many communities in the Arab world. Furthermore, nanoporous materials may be used for desalination systems.

Conclusions

In conclusion, the synthesis and modification of nanomaterials used in all of these projects are very promising and rewarding areas of research because they will have a high impact on improving the lives of millions of people around the world in the near future, due to the shortage of clean drinking water.

Pb removal using different adsorbents at 144h exposure. Each bar is an average of duplicates with standard deviations shown by whiskers. Each symbol is an average of duplicates. C_a = initial solution Pb concentrations (50 mg l^{-1}). C_t = solution Pb concentration at time t.

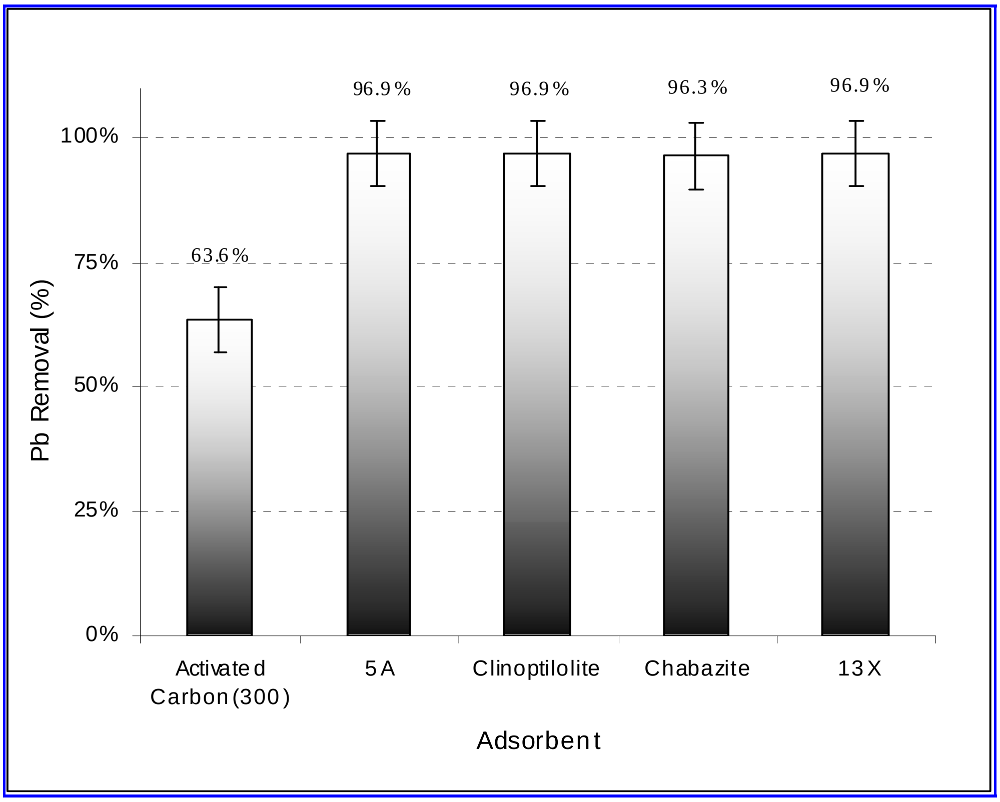

Figure 1 - Percent Pb Removal by Different Adsorbents [3]

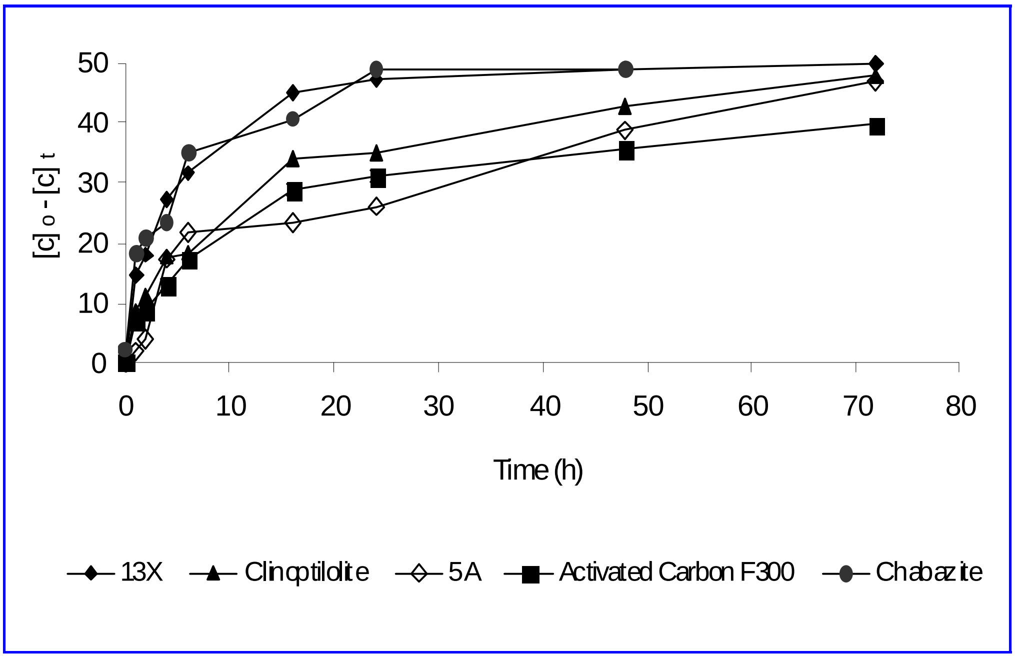

Figure 2 - Lead Removal vs. Time for each Adsorbent [3]

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