Water decontamination

For 1.5 to 2.5 billion people in the world, lack of clean water is a critical issue. It is estimated that by the year 2025 there will be an additional 2.5 billion people who will live in regions already lacking sufficient clean water. In the United States today, it is estimated that 90% of citizens live within 10 mi of a body of contaminated water. Large numbers of point (single, identifiable) and nonpoint sources having low flow volume [50 gal (190 L) per minute or less] contribute significantly to these water contamination problems. These sites pose a major unsolved problem because they also can be intermittent, reducing the cost effectiveness of many current mitigation technologies. The northeastern United States–with its large population, concentrated residential areas, industrial sites, livestock confinement operations, and the like—has many such sites where low-volume-flow water runoff and discharges need to be treated. In addition, it is estimated that there are approximately 500,000 abandoned hard-rock mine sites in the United States, many of them located in or near watersheds where acid mine drainage may release heavy metals into thousands of public drinking-water systems.

Decontamination systems. There are many technologies used today to remove contaminants from water, including reverse osmosis, synthetic resins, activated carbon, sand filtration, and inorganic substrates. Several of these technologies are very effective but can be expensive. Low-cost filtration systems are needed to remove an array of pollutants such as heavy metals, pesticides, herbicides, and other toxic chemicals; bacteria; particulates; nutrients; phosphorus; oil and grease; and nitrogen. Research has shown that lignocellulosic (plant-derived) resources such as wood and agricultural residues (for example, stalks, nut shells, and grasses) have ion-exchange capacity and general sorptive characteristics derived from their constituent polymers and structure. The polymers include extractives (those chemicals removed by solvent extraction), cellulose, hemicelluloses, pectin, lignin, and protein, which are adsorbents for a wide range of solutes, particularly divalent metal cations.

lignocellulosic materials. Lignocellulosic materials are very porous and have a very high free-surface volume that allows accessibility of aqueous solutions to the cell wall components. One cubic inch (16.4 cm^3) of a lignocellulosic material, for example, with a specific gravity of 0.4, has a surface area of 15 ft^2 (1.4 m^2). Even when the lignocellulosic material is ground, the adsorptive surface increases only slightly. Thus, the sorption of heavy-metal ions by lignocellulosic materials does not depend on particle size. Lignocellulosics are both hygroscopic (have the ability to absorb water) and hydrophilic (have an affinity for water). Water is able to permeate the noncrystalline portion of cellulose and all of the hemicellulose and lignin. Thus, through a combination of absorption (sorption into a three-dimensional matrix) and adsorption (sorption onto a two-dimensional surface), aqueous solutions come into contact with a very large surface area of different cell wall components. The cell wall polymers of lignocellulosics contain acid, phenolic hydroxyl, and other hydroxyl groups that can act as ion-exchange sites. Thus, sorption of heavy-metal ions by lignocellulosics can be accomplished by ion exchange, complexation, and precipitation. Removal of heavy metals from solution using lignocellulosic resources is dependent on temperature, pH, sorption time, and metal concentration. Generally, the optimum temperatures are 15 to 30°C (59 to 86°F), pH range is 4 to 6, sorption time is as long is practicable, and metal concentration is low.

Many different types of lignocellulosics have been studied to remove heavy-metal ions from aqueous solution. Several types of sawdust have been used to remove cadmium and nickel, and several types of barks have been used to remove cadmium, copper, lead, zinc, nickel, and cobalt from solution. The fibrous remains of other plant products, such as sugarcane bagasse, corncobs, kenaf, cotton, coconut coir, tea leaves, sugarbeet pulp, and various types of straws and ground nut shells, have also been used to remove heavy metals. One of the best lignocellulosic materials found to date to remove heavy metals from solution is base-extracted fiber from juniper trees, which cover up to 124 million acres in the southwestern United States; the reason this particular fiber seems to work best is presently under investigation. Isolated cellulose as well as kraft and organosolv lignin (by-products from pulp and paper production) has also been used to remove copper and cadmium from aqueous solutions.

Filtration methods. The lignocellulosic fibers can be used as filters in several ways. Filtration containers can be packed with fiber, but this can result in restricted flow due to uneven distribution of the fiber bed. The fibers can be made into webs using several technologies: fibers can be carded into a uniform web, formed into a web using nonwoven needling equipment, or combined with a thermoplastic fiber and bonded thermally. Flow rate through the webs is then a function of web density and thickness.

The exact mechanism of heavy-metal removal using lignocellulosic materials is open to debate. Lignin content, type and amount of extractives, free acid functional groups, and hydroxyl content have been suggested, but no direct correlations have been found. Cell wall structure and surface area may also influence heavy-metal sorption.

Heavy-metal sorption capacity of lignocellulosic materials can be increased in several ways. Solvent extractions, alkali treatment, sulfonation, acetylation, reactions with multifunctional carboxylic acids, and surface functionalization have been used to increase the sorption capacity of heavy metals.

Future research. This technology is presently being tested in two National Forests by the U.S. Forest Service to remove toxic heavy metals from abandoned coal and hard-rock metal mines. These sites, where the heavy-metal ions concentration is high and the water flow is low, are ideal for this technology. Many other locations where acid mine drainage is a problem are presently under consideration for possible sites for this technology.

For background information *see* FILTRATION; ION EXCHANGE; WATER POLLUTION; WATER TREATMENT; WOOD PRODUCTS in the McGraw-Hill Encyclopedia of Science & Technology. Roger Rowell

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McGRAW-HILL YEARBOOK OF Science & Technology 2004

Comprehensive coverage of recent events and research as compiled by the staff of the McGraw-Hill Encyclopedia of Science & Technology

McGraw-Hill
New York Chicago San Francisco Lisbon London Madrid Mexico City Milan
New Delhi San Juan Seoul Singapore Sydney Toronto

The McGraw-Hill Companies

Library of Congress Cataloging in Publication data

McGraw-Hill yearbook of science and technology,
1962- . New York, McGraw-Hill.

v. illus. 26 cm.
Vols. for 1962- compiled by the staff of the McGraw-Hill encyclopedia of science and technology.
1. Science—Yearbooks. 2. Technology—Yearbooks. 1. McGraw-Hill encyclopedia of science and technology.
Q1.M13 505.8 62-12028

ISBN 0-07-142784-8
ISSN 0076-2016

1 2 3 4 5 6 7 8 9 0 DOW/DOW 0 9 8 7 6 5 4 3

This book was printed on acid-free paper

It was set in Garamond Book and Neue Helvetica Black Condensed by TechBooks, Fairfax, Virginia The art was prepared by TechBooks. The book was printed and bound by RR Donnelley, The Lakeside Press,