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ENVIRONMENTAL GEOLOGY NOTES

APRIL 1977 • NUMBER 79

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PART 2 – HEAVY-METAL ADSORPTION

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Part 2—Heavy-Metal Adsorption

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ABSTRACT

The potential usefulness of clay materials as liners for waste disposal sites depends to a large extent on the pH of the leachate solutions that pass through the landfill and on ionic competition during the ion adsorption process. Adsorption of the cationic heavy metals—lead, cadmium, zinc, copper, mercury, and chromium (III)—was found to increase as the pH increased, while adsorption of the anionic heavy metals—chromium (VI), arsenic, and selenium—decreased as the pH increased. The presence of leachate reduced by as much as 85 percent the amounts of the cationic heavy metals removed from solution, whereas leachate had relatively little effect on the amounts of the anionic heavy metals removed by the clays. Removal of the heavy-metal cations from solution was concluded to be primarily a cation exchange-adsorption reaction affected by pH and ionic competition, whereas removal of the heavy-metal anions is primarily an anion-adsorption reaction in which the monovalent ion is the predominant one being adsorbed.

Precipitation of the heavy-metal cations in leachate was an important attenuation mechanism at pH values of 5 and above. No precipitation of the heavy-metal anions was detected in the pH range 1.0 to 9.0.

Adsorption isotherms determined at various pH values were used to compute how thick a clay liner must be to remove lead from solutions of $Pb(NO_3)_2$, from 0.1 M NaCl, and from two landfill leachates at lead concentrations ranging between 10 and 1000 ppm and at pH values from 3 to 8. Where pH and ionic competition are unfavorable for the interaction of heavy metals and earth materials, some undesirable environmental consequences can occur.

INTRODUCTION

As industry in the United States complies with the Clean Air Act and the Federal Water Pollution Control Act, it finds itself in the position of having to handle and dispose of huge volumes of solid wastes, sludges, and liquid concentrates of pollutants. The quantity of industrial wastes that must be placed in landfills is expected to double in the next 10 years, reaching 260 million dry tons per year (Gordon, 1975). The U.S. Environmental Protection Agency (EPA) estimates that about 10 percent of the nonradioactive industrial wastes will be classified as hazardous, although the definition of "hazardous" is still being clarified (U.S. EPA, 1973a). From 1948 to 1968, United States consumption of certain toxic metals increased 43 percent, and the EPA concluded that generation of hazardous wastes will, in general, continue to parallel industrial production rates in the future.

While the volumes of industrial wastes are doubling in the next 10 years, the available capacity of landfills for solid waste is declining throughout the nation. A recent survey of cities with populations over 10,000 revealed that 46.5 percent of the respondents stated that their present landfill sites would be filled to capacity in from 1 to 5 years (Early, 1974). Not only will acceptable disposal sites be difficult to find in the future, but their location will be approved only after certain geologic and hydrologic criteria are met. In addition, their operation will have to be conducted in an environmentally acceptable manner.

Before about 1965, few people were aware of the environmental degradation that could occur from the leachate generated in landfills. Walker (1969) and Hughes, Landon, and Farvolden (1971) described how leachate from solid-waste disposal sites has polluted some Illinois aquifers. Since officials have become aware of these problems, landfill disposal sites are not uncommonly approved for use with the provision that any leachate generated must be collected and disposed of in some harmless manner. This provision implies that adequate technology is available for the environmentally acceptable disposal of the leachate, but that is not entirely true. Davies (1973) reported that at one disposal site installation of a small lagoon to treat the collected leachate proved ineffective and created a surface-water problem that would otherwise not have existed. Such failures have caused considerable interest in land treatment of leachate. Spray irrigation has been discussed (Garland and Mosher, 1975) as a method of leachate disposal, and the effect of municipal wastes on crop yields has been studied by Giordano, Mortvedt, and Mays (1975).

The results of chemical analyses of 20 municipal leachates, reported by the U.S. Environmental Protection Agency (1974), showed that leachate was