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COVER The crystal structure of *Escherichia coli* glutamyl-tRNA synthetase (in blue) complexed with tRNA^{Gln} (in red and yellow) and adenosine triphosphate (ATP, in green). The structure shows that this enzyme recognizes this specific tRNA and discriminates against the other sixty through extensive interactions with the acceptor stem and anticodon of the tRNA. See pages 1135 and 1152. [Graphics by M. A. Rould, J. J. Perona, P. Vogt, and T. A. Steitz, Yale University, New Haven, Connecticut]

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Cleaning Hazardous Waste Sites

Since the inception of the Superfund program, there has been a paucity of completed clean-ups. But the pace of action is likely to accelerate, leading to requirements for training and employment of scientists and engineers. Remediation activities could last 30 years or more and cost as much as \$500 billion. About half of this would be furnished by the government and the remainder by private parties who had disposed of their wastes in common dumps.

The major cost will be incurred in treating abandoned or inactive sites (Superfund program). Another substantial sum will be spent at government-owned facilities. (Costs of remediation for the Department of Energy alone have been estimated at \$130 billion.) In the private sector, as many as 375,000 leaking underground tanks have contaminated, or will contaminate, ground water. Remediation will be difficult and costly.

The Environmental Protection Agency has been ineffective in fulfilling its role as the key government agency in clean-up matters. Since 1980 more than 31,000 abandoned or inactive waste sites have been identified. Of these, 1224 have been placed on a National Priority List. As of early 1989, EPA had initiated studies of approximately 70% of the NPL sites. Actual remedial action had been begun on only 20% (about 250) of the NPL sites, and clean-ups had been completed on only 43 of them. The time from site identification to start of clean-up has averaged 7 to 9 years. Actual clean-ups have required an additional 2 to 3 years. At sites with contaminated ground water, 20 to 40 years more may be spent in treatment of ground water.

The poor performance of EPA has been due to lack of money and technical expertise plus an excess of willingness to respond to the headlines of the day. Costs of clean-ups range up to \$1 million an acre, and some sites contain more than a hundred acres. No sites are identical, and within a given site variable conditions prevail. To conduct cost-effective remediation requires a highly expert interdisciplinary team, including earth scientists, chemical engineers, and bioscientists. During the current 5-year Superfund program, EPA has about \$2 billion per year to spend. Responding to criticism, the new EPA administrator has spurred the formulation of a plan that will provide more money from private parties and an increase in EPA personnel.

The best hope for a vigorous, innovative program lies in the Department of Energy. Secretary James D. Watkins, a retired admiral, has the technical and managerial expertise to make things happen. His organization contains the necessary scientific and engineering expertise to devise or choose cost-effective means of remediation. Their tasks are demanding. The DOE is responsible for a total of 3700 sites of which many are no longer active. The problems at the sites include leaking storage tanks at Hanford that contain high-level radioactive waste. They also include soil and ground water contaminated by mixtures of heavy metals, radioactive substances, and hazardous organic liquids. Some of the sites have been active for more than 40 years, during which the various contaminants were dumped locally. The pollutants have migrated deep into the soil. Cubic miles of earth have been contaminated. A recent draft of a DOE report is impressive in its outline of problems and its mode of organizing to deal with them.*

Contamination of ground water is common to the majority of all waste sites. Insofar as there have been or will be health effects related to waste sites or leaky tanks, the largest fraction of them will be due to ingestion of polluted waters. The principal organic compounds found in leachates are small chlorinated hydrocarbons, benzene, toluene, and xylenes. Since World War II, more than 40 billion pounds of small chlorinated hydrocarbons have been distributed, of which 4 billion pounds or more have been incorporated into waste sites. Much of that has already been leached. Vast sums of money will be spent in removing contaminants from ground water. The costs will be determined by the effectiveness of the technologies employed. Particularly promising is bio-remediation. The costs will also be determined by answers to the questions, "At what level of contamination is toxicity negligible? How clean is clean?" —PHILIP H. ABELSON

*"Applied research, development, demonstration, testing, and evaluation plan for environmental restoration and waste management" (Department of Energy, Washington, DC, 1989).