AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SCIENCE

ISSN 0036-8075
12 JANUARY 1990
VOLUME 247
NUMBER 4939

■ **SCIENCE is published weekly on Friday, except the last week in December, and with an extra issue in March by the American Association for the Advancement of Science, 1333 H Street, NW, Washington, DC 20005.** Second-class Non-profit postage (publication No. 484460) paid at Washington, DC, and at an additional entry. Domestic individual membership and subscription (51 issues): $75. Domestic institutional subscription (51 issues): $120. Foreign postage extra: Canada $46, other (surface mail) $46, air mail via Amsterdam $85. First class, airmail, school-year, and student rates on request. **Single copy sales**: Current issue, $3.50; back issues, $5.00; Biotechnology issue, $6.00 (for postage and handling, add per copy $0.50 U.S., $1.00 all foreign); Guide to Biotechnology Products and Instruments, $18 (for postage and handling add per copy $1.00 U.S., $1.50 Canada, $2.00 other foreign). Bulk rates on request. **Change of address:** allow 6 weeks, giving old and new addresses and 11-digit account number. **Postmaster:** Send Form 3579 to *Science*, P.O. Box 1722, Riverton, NJ 08077. *Science* is indexed in the *Reader's Guide to Periodical Literature* and in several specialized indexes.

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COVER Experimental angular distribution of 65–electron volts Auger electrons emitted from an atomically clean platinum[111] single-crystal surface. Lighter colors represent larger signal. Contours (green) depict the theoretical distribution from a pair of adjacent atomic layers. These results reveal that Auger electron angular distributions consist of the "silhouettes" of near-surface atoms "backlit" by Auger emission originating from atoms located deeper in the sample. See page 182. [Data acquisition and graphics by D. G. Frank, N. Batina, and A. T. Hubbard; photography by R. Shaw, University of Cincinnati, Cincinnati, OH]

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Volatile Contaminants of Drinking Water

Public concern about possible contamination of water supplies is a fact of life. It is a fear of the unknown that may be overdrawn, but a fear that could lead to a waste of hundreds of billions of dollars. Development of effective means of reducing water contamination would ease concerns while minimizing costs of remediation. This country is only in the beginning stages of conducting the necessary research and development, but progress is being made, particularly in delineating the problems and in conducting research.

The volatile contaminants in a large number of water supplies have been analyzed and means of destroying them are being discovered. The most ubiquitous class of pollutants is chlorinated hydrocarbons, notably TCE (trichlorethylene, $CHCl{=}CCl_2$) and its degradation products. TCE is one of the leading contaminants found in ground water and is the chemical most often detected at Superfund sites. Large quantities of it were widely used for decades in degreasing, and wastes were carelessly disposed of.

The physical properties of TCE have contributed to its widespread occurrence. It has a boiling point of 88°C and a density of about 1.46. Its solubility in water is about 1000 parts per million (ppm). Thus when dirty fluids were conveyed to waste dumps, part of the TCE evaporated, but much of it moved downward; some ultimately encountered ground water. Ground water in aquifers travels at rates as low as a meter per year and as high as meters per day. Plumes of contaminated water that extend 10 km from sources have been noted.

In pure water at *p*H 7 and ambient temperatures, highly chlorinated hydrocarbons are remarkably stable, with half-lives as long as a million years or more. However, under strongly reducing circumstances, some of the chlorine is removed and the resultant products are more subject to hydrolysis and later to aerobic metabolism.

Because of its widespread occurrence, TCE has been and is the object of considerable research activity. Work by Perry L. McCarty and colleagues at Stanford several years ago showed that under methanogenic (reducing) conditions TCE was almost completely destroyed in a few days. At ambient temperatures in the dark TCE reacts only slowly with oxygen and is ordinarily not subject to attacks by microorganisms. However, some organisms that can employ methane, propane, or toluene with oxygen as sole energy and carbon sources can co-metabolize TCE. This discovery has led to research designed to form the basis for patents on microorganisms to be used in TCE bioremediation. However, many knowledgeable microbiologists suggest that mixed cultures already adapted to the local circumstances will be quite effective. Organisms that can co-metabolize TCE have been found in many places. In one instance a large and active community of microorganisms was found in an aquifer 50 to 65 m beneath the soil surface.

In situ bioremediation of TCE-containing water is apparently limited to fluids containing less than about 100 ppm of TCE. Higher concentrations seem to be toxic. Nevertheless, this leaves enormous volumes of water to which biotreatment might be applicable.

Some fraction of the TCE that has been placed at waste sites remains there in rusting drums that should be removed at once. An additional approach is to transfer contents of the waste site to an incinerator and subject it to high temperatures. This is probably the procedure of choice when concentrations of contaminating waste are high. However, it is expensive, and the cost per unit of waste destroyed can be excessive if the wastes are dilute. Another technique is to bring contaminated water to the surface and to treat it, usually by air stripping. This transfers the contaminant into the atmosphere. One possibility that has not received much attention is a combination of moderate heat, moisture, and oxygen applied to the waste site. One report* states that when a solution of TCE (1 ppm) was enclosed in the dark in a vessel containing air at a temperature of 25°C, the half-life of the TCE was less than a year. At temperatures near 100°C the reaction should proceed in about a day.

Each waste site is different, and each aquifer is different. No single cure-all exists. But a continued systematic approach involving earth scientists, chemical engineers, and microbiologists will surely lead to more effective remediation than has hitherto been achieved.

—PHILIP H. ABELSON

*W. L. Dilling, N. B. Tefertiller, G. J. Kallos, *Environ. Sci. Technol.* 9, 833 (1975).