ject. The physician suddenly moved to another city, leaving his books, and Antheil froze onto them and eventually became something of an authority. Later he went to France and solidified his theoretical knowledge by working with the Paris police, thus winning the honorary life membership. The *Esquire* articles led logically to a column called "Boy Advises Girl," which is syndicated to some thirty papers. This isn't all Antheil does, by any means, but it's enough to give an idea.

Immoderate

IT'S late in the game for anecdotes about salutes, but maybe you'd like just one more, on the house. This one is about a Wac who was celebrating her promotion to a captaincy by entertaining her mother in New York. When they ventured out on a shopping tour the first morning, the daughter was saluted four times within three blocks. After the last salute, the mother said indulgently, "That's enough, now. I see how you do it, and you don't want to make yourself conspicuous."

DDT

AN amateur naturalist we know, who is currently skipper of a landing barge in the South Pacific, wrote us a letter a few weeks ago describing the effect of DDT, the deadly military insecticide sprayed from airplanes before invasions. "It kills every insect," he informed us. "The Lord knows what's going to happen if they start using it promiscuously in the States." Nobody is using the stuff promiscuously at the moment, but a few weeks ago the W.P.B. announced that it was planning to release small quantities of DDT for experimental use by civilians. Just in case you're thinking of doing a job on your plant lice or Japanese beetles with DDT, we've dug up some information on the subject that you'd do well to mull over. In the first place, DDT gets its name from its chemical composition, formally described as "2,2 Bis (P-Chlorophenyl) 1,1,1 Trichlorethane," which is, more familiarly, dichlorodiphenyl-trichlorethane. It was developed in Switzerland by researchers of a dye-manufacturing outfit, which discovered later on that its new insecticide was the same as a dye formula put together by a German scientist seventy years before. It was first used commercially by the Swiss in 1939 to combat the Colorado potato beetle. Presently the Swiss noted that it played hell with lice and used it to delouse refugees when they streamed across the French border. It is so persistent in its effect that it remains lethal to insects for months after an application, and since it won't dissolve in water it has to be removed with alcohol, oil, or other organic solvents. The Navy sprays it over South Pacific atolls to destroy mosquitoes and flies that might introduce malaria and typhus among the troops after they have landed. The Public Health Service has just issued a bulletin revealing that DDT in fairly large quantities has a toxic effect upon rabbits. Nobody knows exactly how much it takes to harm human beings. Unlike most insecticides, it works by both contact and ingestion; whether an insect merely crawls over a leaf sprayed with DDT or nibbles on the edge of it, he's a dead duck. All of which sounds fine. However, Edwin Teale, former president of the New York Entomological Society, who has been making DDT his major work for several years, doesn't sound fine.

"A spray as indiscriminate as DDT," Mr. Teale told us, "can upset the economy of nature as much as a revolution upsets social economy. Ninety per cent of all insects are good, and if they are killed, things go out of kilter right away. Just suppose that DDT is sprayed from airplanes over huge acreages. Your bumblebees will be eliminated. Once they're gone it means the end of your red clover, which they fertilize. Darwin once said that you could tell the number of old maids in a village by the size of the clover fields in its environs. He figured that old maids have cats, cats kill mice, mice destroy bumblebees. So fat fields of red clover mean lots of old maids. Now, suppose they introduce DDT in the South to kill the pink bollworm. Suddenly they're going to have a tremendous cotton crop. Prices will promptly go down, foreclosures will be made, and there'll be more Tobacco Roads than ever before. I remember early in the thirties when an attempt was made to wipe out the gypsy moth. The spray unfortunately also killed the monarch, or milkweed butterfly, which lays its eggs in the milkweed and thus kills it before it can spread all over. On the other hand, if milkweed is needed for kapok, then of course the monarch must be destroyed."

Slightly confused, we said goodbye to Mr. Teale and headed up to the Audubon Society to supplement our information with a few words from Richard Pough, the Society's ecologist. "We are," said Mr. Pough, "definitely alarmed over the possibilities of DDT. It might conceivably eliminate all insect-eating birds as well as shrews, moles, bats, and skunks. The insect eaters make up one-half the base that supports the whole natural economy. You may remember when they experimented with an arsenic spray not nearly as lethal as DDT at the Jockey Hollow National Monument at Morristown. They went over the acreage afterward and found no dead birds, but they didn't find many live birds either. They had moved out, to find insects. A spray like DDT makes people think of a continent arranged like a manicured garden, but you can't kick nature around that way. If DDT should ever be used widely and without care, we would have a country without fresh-water fish, serpents, frogs, and most of the birds we have now. Mind you, we don't object to its use to save lives now. What we're afraid of is what might happen when peace comes."

O.K. It's up to the gardeners.

Credential

BEATING the gun on the W.M.C.'s unfreezing of manpower, we made V-E Day confetti out of all but one of the maid-shortage anecdotes we had on hand. This is the one we saved out, and we will never again print another. A lady who had had a very satisfactory interview with a colored cook named Celia concluded with a mention of references. "References?" said Celia. "Yes'm." She thereupon rolled up her sleeve. Her name was tattooed on her forearm.

Flexible

FERDINAND CARL AUGUST FREDERICK KRAMER is the architect of the week, by reason of the news that the British, Norwegian, and Russian governments are all interested in a product of his which is not strictly architectural at all; briefly, it is low-cost knocked-down furniture which saves seventy-five per cent in shipping space and can be assembled by the householders themselves. Kramer's beds, tables,

Assessing chemical hazards

Evaluation of hazards requires an interdisciplinary approach

By Eugene E. Kenaga

For a long time toxicologists have told us that all chemicals are toxic to organisms at some concentration if exposure lasts long enough. We all know that common things encountered in our daily lives illustrate this principle: water, oxygen, carbon dioxide, cigarette smoke, alcohol, aspirin, coffee, vitamins. But think of this:

- Why does it take so long for scientists to convey the reasons a given chemical may or may not be toxic to a given organism?
- Why does it sound so complicated?
- Why do the public and the media come away from nearly any short meeting that gives explanations of scientific problems with more questions, fears, and doubts than they had when they were in ignorance of the problem?

The simple solution for those not involved financially in the cause of the problem is to get rid of the source of the problem. Many items that cause problems, such as automobiles, pesticides, plastics, aspirin, alcohol, and tobacco, are difficult to remove from public use because of the desire for the products, economic factors related to business, and tolerance by a public familiar with the desirable uses of such products. Many one-sided arguments by experts either for or against their use are heard by the public concerning the benefits or risks of these products.

How does one choose the right side? The answer is rarely clear-cut. The benefits to some people may or may not outweigh the risks to others. Obviously, most people cannot take time to be experts on every risk–benefit problem.

Whom can they trust? We often hear neophyte activists saying, "We just don't know anything about the toxicity of [the scare chemical of the week]." They intimate, with this statement, that the information they need does not exist, that it is inaccessible to them, or that someone must be criminally negligent—regardless of whether or not they have taken the time to learn the facts. The solutions to these communication problems are not easy.

Hazard assessment involves comparisons of the magnitude and duration of chemical concentrations in various segments of the environment—which result from the manufacture, transportation, use, and disposal of a compound—with concentrations in food, water, air, and soil at levels that are toxic to the environment.

Eugene E. Kenaga

At the spring meeting of the American Chemical Society in April 1986 in New York, Eugene E. Kenaga received the ACS Award for Creative Advances in Environmental Science and Technology. In his lecture at a symposium on risk assessment and risk management of chemicals he reviewed some of the important events leading up to current techniques for evaluating hazardous chemicals. Kenaga led the way in developing methods and protocols for predictive testing, for evaluating toxicity to wildlife and aquatic organisms, and for monitoring the environmental fate of chemicals. He has contributed extensively to the evaluation of environmental properties and hazards of chemicals.

Kenaga works as a consultant in Midland, Mich. He started his career in 1940 at Dow, and in 1966 he became Dow's first full-time ecologist. In 1979 he was promoted to research scientist, Dow's highest level of professional recognition. He left the company in 1982 to become a part-time consultant for industry and government agencies.

Some understanding of the extent of the effort put into hazard evaluation can be had by looking at the number and variety of tests that EPA requires of chemical companies that want to register and use pesticides and other chemical products. These tests can cost millions of dollars because they require a broad range of information on manufacturing, chemistry, and toxicology. The test results are supplemented specifically or generally by the work of many university research laboratories, private consultants, and a host of government agencies.

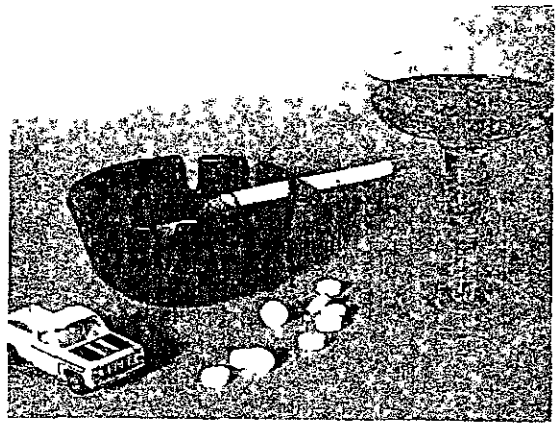
Congress has passed many laws that protect wildlife by regulating the distribution of chemicals from manufacture to disposal. There are at least five laws related to manufacture, three related to transportation, ten related to disposal, and four related to use. There are laws that protect humans in the work place and those that protect food and water. These necessarily spawn many regulations, which require development of tests to satisfy the intent of the laws.

The results of scientific tests are made public in federal agency reports, university reports, and journals and at meetings of professional societies of the many disciplines of science involved in environmental study.

Scope of the approach

This information indicates the depth and breadth of sources of environmental information. The need for summarizing such information becomes obvious and requires an interdisciplinary approach to hazard evaluation. A special breed of scientist is needed for the overall integration of these data. Hazard evaluation requires the combined use of toxicology, meteorology, geology, geography, and chemistry.

To perform meaningful toxicity tests on wild animal and plant nontarget organisms, scientists must know the range of concentrations, particularly the maximum that can occur in soil, water, air, and biota from the uses, distribution, and fate of the chemical as it is in the environment.



It is also necessary to know whether concentrations of the test chemical are uniform or fluctuating; short-term or long-lasting; occurring during the critical, sensitive stages of the organisms' life cycles; occurring by means of vapor, water, food, or cuticular contact routes; and whether they affect individuals, species, populations, food, or ecosystems of the organisms. Toxicity test methods and results must reflect the realities of these variables. The question here is how well these problems are addressed.

Knowledge of the natural history of organisms is a necessary prerequisite for those who study the effects of chemicals on a given species or ecosystem. We need to know about the life cycles of organisms, desirable or necessary environmental conditions, food requirements, growth, reproduction, and other ecological relationships before we can determine the difference between man-made chemically induced effects on the population and those that follow natural ecological successions. Because it is impossible to test all species or ecosystems for even one chemical, selection of surrogate species that are representative of various phyla, classes, orders, or families of related species is necessary for conducting toxicological or chemical tests.

Considering the number of chemical compounds that need quick environmental evaluation, the costs involved, and the shortage of toxicity testing facilities, we see that the important question is "What is the best and minimum number of indicator toxicity test methods and species for range-finding toxicity to a broad spectrum of organisms (vertebrate and invertebrate, terrestrial and aquatic)?"

Many species could be selected for screening, but certain organisms are more suitable representatives than others. Data on acute toxicity to 75 insecticides and herbicides were collected and tabulated for eight species (rat, mallard, bobwhite, rainbow trout, saltwater fish, *Daphnia*, shrimp, and honeybee) commonly used for evaluation of environmental hazards of chemicals.

Correlation coefficients and regression equations for each species were developed to determine the most selective and sensitive indicator species for a wide spectrum of species. This correlation provides a basis to test methods for screening the toxicity of thousands of industrial chemicals. Rats, one species of fish, and *Daphnia* were found to be the best indicators of acute toxicity to a wide range of chemicals.

Amount makes a difference

Toxicity values given in terms of concentration or dosage can be confusing. However, the difference between the two terms should be understood. Dosage is the amount of chemical applied directly to an organism. The LD_{50} is the dosage of a chemical that will cause 50% of a given test species of organism to die. A concentration applied to a given medium, such as water, soil, or food, results in uptake of a certain amount by an organism. The LC_{50} is the concentration in the medium that results in 50% mortality of a given species of test organism. Toxicity values are commonly expressed in terms of milligrams of chemical per kilogram of body weight of the organism tested. To arrive at this toxicity value, LD values need no conversion. LC values, however, must be converted by such values as the bioconcentration factor (BCF) or dietary intake rate to calculate milligrams of toxicant per kilograms of body weight.

The relationship of the acute LC_{50} of chemicals to the chronic toxicity no-effect concentration (NOEC) for aquatic animals can be expressed as the acute–chronic toxicity ratio (ACR). Calculation of the predictability of chronic toxicity from acute toxicity of chemicals in fish and aquatic invertebrates is based on 125 ACRs available for 84 chemicals using nine species of fish and two species of aquatic invertebrates.

Eighty-six percent of the LC_{50} acute toxicity data were less than two orders of magnitude greater than the NOEC when the same chemicals and species were compared. The lowest ACR was 1, and the highest was 18,000. Distribution by size of the ratios for all chemicals shows that 31% are under 5, 43% are under 10, 66% are under 25, 87% are under 100, and 90% are under 125. Among the industrial organic chemicals, excluding pesticides and metals, the average of the ratios for four species of organisms was 12. Ninety-three percent of these ratios were 25 or below.

From these data on the use of an assumed ACR, such as 25, a simple equation allows the prediction of NOEC in water for chronic toxicity of most chemicals from the known concentration causing acute toxicity:

$$ACR = \frac{LC_{50}}{NOEC} \text{ or } NOEC = \frac{LC_{50}}{ACR}$$

Chemicals with large ACRs *cannot* be correlated with any *one* of the following factors: general commercial use, broadly related classes of chemical structures, invertebrate aquatic species sensitivity, size of the LC_{50} value for a species, size of the acute NOEC, size of the BCF, persistence in the environment, or size of the octanol–water partition coefficient. There does not appear to be any single property associated with large ACRs.

Many chemicals are chronically present and chronically toxic either in the applied form or as metabolites. Chronic exposure can come from the chemical reservoir in the environment (maintained by a chemical's stability or by constant renewal of less stable chemicals) or from tissue accumulation that creates a reservoir in the organism, the BCF.

It should be noted in calculation of ACRs that chronic no-effect levels of a chemical are compared with LC_{50} (mortality) levels, which are not truly comparable toxicity values. This is done because statisticians do not recognize the validity of an absolute no-effect concentration (LC_0) level. However, it is as justifiable to use an *acute* no-effect level as it is to use a *chronic* no-effect

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level, as it is usually practiced. It has been shown that concentrations of few chemicals are more than six times higher at the LC_{50} level than they are at the no-effect level for acute toxicity. Thus, the acute no-effect level divided by the chronic no-effect level would be only about one-sixth of the ACR given here and should represent a more accurate ACR.

Predictive methods

It is important to estimate or know which environmental problems will most likely occur from the use of a compound at an early stage in its development and the concentrations that are most likely to cause problems. Predictive methods for these problems are very useful at this stage.

Under equilibrium conditions, a chemical will reach a typical concentration distribution pattern in specific environments, depending on the relative proportions of soil, water, air, and biota. Based on certain physical and chemical properties (and natural laws related to them), a number of distribution ratios between media can be estimated. Assuming no degradation, these ratios indicate the medium where the chemical is most likely to accumulate.

The basic physical data needed to calculate a partition coefficient for a given chemical in various media are its molecular weight, water solubility, and vapor pressure. Partition coefficients are needed between water and soil organic carbon (K_{oc}), water and biota (BCF), water and *n*-octanol (K_{ow}), and water and air (K_w). Rapid methods for estimating these coefficients have been developed.

Partition coefficients and physical data can be used to predict the equilibrium distribution of the chemical in an environment consisting of air, water, and soil. Realistic models composed of certain proportions of these media are the basis for calculating chemical distribution. When different model ecosystems containing various proportions of different media are used as the basis of calculation, along with the physical properties and partition coefficient of the chemical, the equilibrium distribution of each chemical can be determined for each medium by computer. These values can be modified by inclusion of degradation rates in air, soil, and water.

Now that an increasing data base on sorption, volatility, and bioconcentration properties has been determined for a number of benchmark chemicals, the use of regression equations creates a number of surrogate methods for determining a given partition coefficient or physical property with sufficient accuracy for hazard evaluation purposes.

For example, soil sorption K_{oc} values are significantly correlated by equations with water solubility, BCF, and K_{ow} values. High K_{oc} values also have been correlated with reversed-phase high-performance liquid chromatography (HPLC) data and short leaching distances in soil columns. HPLC values have been correlated with BCF values. Thus, five methods of estimating K_{oc} values are available as surrogates for experimental K_{oc}s. BCFs and soil adsorption coefficients are important indicators for the movement of chemicals in the environment.

The residence time of relatively stable compounds in soil appears to affect desorption properties. Over time stable chemicals become more highly sorbed and less susceptible to leaching because of increased internal concentrations compared with external soil particle concentrations.

The fate of chemicals in the troposphere and stratosphere has been studied for chemical removal processes by use of photolysis transformations and reactions with hydroxyl radicals, ozone, and other tropospheric chemicals. Reaction rates and products of many chemicals transformed by the natural elements of weather can be predicted. Physical processes, such as rainfall, dry deposition, and adsorption on aerosol particles, are generally not as efficient for removing hazardous compounds as chemical means are.

What have we learned about bioconcentration of chemicals in various media? Chemicals like DDT that are highly soluble in fat, nearly soluble in water (less than 1 ppm), low in vapor pressure, and relatively stable in the environment are widely distributed. These properties result in bioconcentration in the fat tissues of animals; in strong sorption to soil, especially that which contains organic matter; and in relatively low levels in plants, air, and water.

Bioconcentration can be defined as the ratio of a chemical in or on an animal organism to that in the surrounding media. The highest BCF, which may be over a million with DDT in animals, occurs when the medium is water. When the medium is soil, soil competes with organisms for sorption of the chemical. The BCFs from comparison of treated dietary food to residues in fat tissues of mammals for many chemicals are less than 1. The BCFs for chemicals in aquatic organisms are directly correlated with the much lower BCFs in fat tissues of large mammals in dietary feeding tests, as shown by binary regression equations. The BCFs for fish and *Daphnia* from water are essentially the same for comparative chemicals. The following formula can be used to predict the NOEC for a given medium only if we know the NOEC for another medium:

$$BCF = \frac{\text{NOEC (fish)}}{\text{NOEC (water)}}$$

There are many other facets of environmental hazard assessment, which include

- the statistical use of climatic data;
- monitoring of residues in rivers, soil, and foliage;
- effects of test method variation on results;
- analytical techniques;
- structure–activity relationships;
- interpretation of data from various toxicity tests;
- statistical techniques; and
- computer modeling of environmental fate of chemicals in various segments of the environment, which allows quick preliminary estimation of concentrations likely to occur from a given chemical.

Because of the great progress in all areas of hazard assessment, the accuracy possible in predicting environmental fate and toxicity is improved and is now much more a science than an art. The combination of many scientific disciplines is necessary before risk assessment and risk management decisions can be made; decision-making groups must make use of all disciplines. This is an area that needs much improvement. The methods of risk assessment must be communicated among scientists and then explained to the general public.

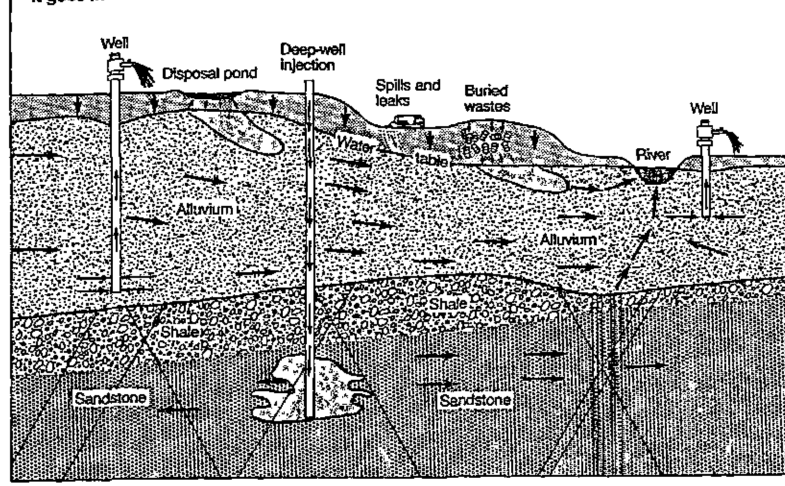
Additional reading

(1) Cupitt, L. T. "Fate of Toxic and Hazardous Materials in the Air Environment," EPA-600/53-80-084, Environmental Science Research Laboratory: Research Triangle Park, N.C., 1980; pp. 1–7.
(2) Kenaga, E. E. *Environ. Sci. Technol.* **1978**, *12*, 1322–29.
(3) Kenaga, E. E. In *Analyzing the Hazard Evaluation Process;* Dickson, K. L.; Maki, A. W.; Cairns, J., Jr., Eds.; American Fish Society: Washington, D.C., 1979; pp. 101–11.
(4) Kenaga, E. E. *Regul. Toxicol. Pharmacol.* **1981**, *1*, 293–315.
(5) Kenaga, E. E. *Environ. Toxicol. Chem.* **1982**, *1*, 347–58.
(6) Kenaga, E. E.; Goring, C.A.I. "Relationship between Water Solubility, Soil Sorption, Octanol–Water Partitioning and Concentration of Chemicals in Biota," STP 707; American Society for Testing and Materials: Philadelphia, 1980; pp. 78–119.
(7) Laskowski, D. A. et al. *Residue Rev.* **1983**, *85*, 139–47.
(8) McCall, P. J. et al. *Residue Rev.* **1983**, *85*, 231–44.
(9) McCall, P. J.; Agin, G. L. *Environ. Toxicol. Chem.* **1985**, *4*, 37–44.
(10) Swann, R. L. et al. *Residue Rev.* **1983**, *85*, 18–28.
(11) Tucker, R. K.; Leitzke, J. S. *Pharmac. Ther.* **1979**, *6*, 167–220.
(12) Veith, G. D.; Defoe, D. L.; Bergstedt, B. V. *J. Fish Res. Board Can.* **1979**, *31*, 1040–48.

Cleaner water and safe disposal of wastes

Continuation of the Pimentel report

It goes in here—but it comes out there



Our surface and subsurface waters are precious resources. Most of us take it for granted that when we want a drink of water or to go swimming or fishing, our streams, lakes, and aquifers will be safe to use. Our progress in protecting water bodies from contamination has not generally been as successful as our efforts in cleaning up pollution in the air. Nonetheless, some important progress has been made. Lake Erie, once thought doomed to die biologically from eutrophication induced by phosphates and other nutrients, is making a comeback. Improved water treatment, coupled with more rigorous attention to hazardous waste treatment and disposal, holds the key to future advances. To recognize and control the sources of pollution, we must understand the intricacies of pollutant movement and conversion.

Nearly half of the citizens of the United States depend upon wells for their drinking water. A recent National Academy of Sciences assessment of groundwater contamination estimated that about 1% of the aquifers in the continental United States may be contaminated. Evidence of subsurface migration of pollutants makes it increasingly important to protect, with the best science and technology available, the aquifers feeding those wells.

A number of disposal practices and waste repositories involving burial in the ground have been used for many years with only minimal groundwater contamination. Procedures have been predicated on the assumptions that the waste material was unlikely to migrate and that, over time, the compounds would be oxidized, hydrolyzed, or microbially decomposed to harmless products. Now, however, some instances of serious groundwater contamination have appeared. Some compounds have proven to be more stable and mobile than expected, while some of them are bacterially converted into more toxic and mobile forms. In retrospect, it is clear that the scientific knowledge base for the earlier decisions was inadequate.

Proposals currently under consideration for recovering seriously contaminated aquifers are soberingly expensive. For example, estimated costs for "containment" efforts at the Rocky Mountain Arsenal near Denver are about $100 million and for "total decontamination," up to $1 billion. Such enormous prospective cleanup costs require thoughtful weighing of the cost–benefit trade-offs to society in deciding what to do. More relevant than these cleanup costs is the inescapable conclusion that it is only prudent to invest the much smaller amounts of public funds in research that will better define cleanup options and lessen the chances of recurrence.

If the subsurface is to be used as a repository for our wastes, we must have a much more thorough under-