ser that emits 1.06-micrometer light. It has just been shut down while an even larger laser is built. Peter Hagelstein, a recent MIT graduate whose Ph.D. thesis was to develop x-raser designs while working in Wood's group, notes that no experiment was ever done, although theoretical work was extensive on two neon systems that would lase at 460 and 82 angstroms.

In a second laser-based project, Robert Carman of Los Alamos and Chapline plan to use the eight-beamed Helios laser at Los Alamos. Helios is a carbon dioxide gas laser that emits light at 10.6 micrometers. Chapline reported at New Orleans that there may be experiments with copper targets this year and that additional theoretical work was needed even to predict what the lasing wavelengths would be in the range from 220 to 327 angstroms.

The third x-raser project with Livermore's participation is also based on a high-temperature plasma, but it does not use a laser to produce it. Richard Fortner is working with Glen Dahlbacka and Ray Dukart of Physics International in San Leandro, California. The company has a machine called Pithon, originally built for nuclear weapons effects simulations, that generates extremely high bursts of electric current (up to 3.5 million amperes) into a gas or solid laser medium and thereby creates a plasma. A first round of experiments has been completed, but only one test produced any evidence of x-rays being emitted at the correct wavelength. The plasma was very inhomogeneous in both temperature and density, and the prospects for achieving lasing in future tests with krypton and molybdenum that emit at 149 or 97 angstroms are viewed as uncertain.

Livermore, of course, is not the only laboratory in the world with x-raser projects. But, as with the laboratory's unclassified work, all are far from fruition or else are concentrating on wavelength ranges far from those required for x-ray holography in the soft x-ray region of interest for biological imaging.

How interesting is x-ray holography? John Sedat of the University of California at San Francisco, who has also been contacted by Livermore about collaborating on a holography project, says that the technique would "really change the whole field of structural biology." For example, the importance of the aqueous environment in maintaining structures without distortions is crucial, and x-ray holography would allow this. Sayre at IBM is a bit more cautious in noting that there are two or three other methods that promise three-dimensional imaging capabilities similar to holography. Both researchers enthusiastically hold that x-ray holography should be tried. Now it looks as though it will, although under rather unusual circumstances. Meanwhile, laser scientists hope that the details of the putative x-raser will soon be declassified so that work can begin on the possibility of making a laboratory version of the device that will use a more conventional pumping source.

—ARTHUR L. ROBINSON

Just How Hazardous Are Dumps?

Everyone knows toxic wastes are hazardous, but there is little agreement about how to assess the potential risks to health

In October, the United States Environmental Protection Agency (EPA) finally issued a list of 115 hazardous waste storage sites that represent the most serious potential danger to human health. These sites were among the first candidates to be cleaned up with support from Superfund, a $1.6-billion kitty accumulated primarily from taxes on industrial chemicals. In November, however, the Congressional Office of Technology Assessment (OTA) sharply criticized that list, arguing that EPA had used inappropriate criteria in preparing the rankings. States and environmental groups have had their own thoughts about which dump and storage sites deserve first call on the funds.

These conflicting opinions symbolize the most crucial problem confronting individuals and agencies that must deal with the hazardous waste problem: There is no firm consensus about how to determine the potential hazard of chemicals at a dump site, the risk of exposure, and the potential health effects from such an exposure. The problems are not simply academic. A 1979 survey by EPA of 100 waste disposal sites produced an average estimated cost for cleanup of more than $8 million, with the cost at some sites running as high as $25 million. There are hundreds of such sites—perhaps thousands—and even $1.6 billion will not go very far. Hard choices are going to have to be made—and soon.

Part one of two parts

A good example of the problems involved is the highly publicized Love Canal area in Niagara Falls, New York, where homes were built immediately adjacent to a waste disposal site that was disturbed. Despite the great amount of time and effort that has been devoted to this volatile problem, it has been extremely difficult to document the extent of exposure of area families to the chemicals. There has been no conclusive evidence linking any such exposure to health effects in humans—particularly since some potential effects may not become apparent for at least another 15 years.

Investigators have even had problems defining precisely which questions should be asked about hazardous waste sites. There is consensus about only a few of the most general:

▶ What do we know about how chemical waste disposed onto and into the land contributes to pollution of air and ground water?

▶ In sampling and analyzing air, water, and other media, what strategies are most promising?

▶ How can human exposure best be estimated?

▶ What is the extent of normal human exposure to the chemicals in dumps?

▶ How can exposure to chemicals be related to human health problems?

▶ What are the health effects of mixtures of chemicals? Are they additive or synergistic?

▶ Are there existing technologies that have not been applied to the problem? What new technologies need to be developed?

These questions and others have been addressed at three major meetings during the past year. Proceedings of two of the meetings are now available in book form

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and those of the third should be available sometime this spring.* Unfortunately, none of the meetings appears to have produced conclusive answers to any of the questions.

One of the biggest problems in approaching this task is the fact that, in the words of Clark Heath of the Centers for Disease Control (CDC), "Every dump is different. There are the classic dumps, with piles of unrecorded, corroding drums, and then there are the roads around Raleigh [whose shoulders have been contaminated with polychlorinated biphenyls]. There are carefully constructed, lined, covered, fenced in, and monitored basins, and then there are country ponds contaminated with industrial wastes, such as a DDT-contaminated pond near Triana, Alabama." A dump may contain one chemical predominantly, or it may contain tens or hundreds of major chemicals and literally countless minor ones.

It may be possible to draw analogies among dump sites, says William W. Lowrance of Rockefeller University, but "chemical, geological, or medical generalizations not based on site-specific analyses should always be considered unreliable." A corollary to this axiom is that it is virtually useless to combine statistical health data from groups of individuals exposed at different sites.

The primary route of human exposure to waste chemicals is usually assumed to be through ground water. Ground water furnishes about half of all U.S. drinking water, according to David W. Miller of Geraghty & Miller, Inc., of Syosset, New York, who spoke at the Rockefeller symposium. More than 40 million people depend on untreated domestic well water, many of them in urban areas. Impingement of hazardous chemicals on these water supplies is thus of great concern. Proximity to water supplies serving large numbers of people is, in fact, one of the primary criteria by which the Mitre Corporation, of McLean, Virginia, compiled the list of 115 most hazardous dump sites for EPA. Sixteen of the sites on the EPA list, for example, are in Florida, reflecting that state's great dependence on ground water.

Not all of the contaminants in water supplies come from dumped or improperly stored industrial wastes. Many household products contain organic chemicals that eventually find their way into the water supply. Pesticides are also a frequent contaminant, as are fertilizers and solvents used in garages, print shops, and dry-cleaning facilities. These chemicals can mask the presence of chemicals that escape from a dump or distort their apparent concentrations.

"Chemical, geological, or medical generalizations not based on site-specific analyses should always be considered unreliable."

Cleanup of an aquifer that has been contaminated by organic chemicals, says Miller, is almost never physically or economically feasible. Strong consideration might thus be given to dedicating badly contaminated aquifers as waste disposal sites; such a scheme has already been adopted in one region in West Germany. Conversely, greater emphasis should also be placed on protecting aquifers that have not yet been polluted.

Fortunately, Miller says, most groundwater contamination incidents are local phenomena affecting only the uppermost aquifers. The typical contaminated area is less than a mile long and half a mile wide. Despite the fact that many chemicals in water are extremely mobile, the average rate of movement of the pollutants is about 1 foot per day. Depending on the hydrogeological characteristic of the area, adds Philip J. Landrigan of the National Institute for Occupational Safety and Health, the pollutants can often follow a rather tortuous path. Epidemiologists, he said at the Research Triangle Park meeting, must thus recognize that individuals who live closest to the dump or spill site are not necessarily those who receive the greatest exposure, and there must be extensive monitoring of the path of the pollutants.

Typical costs for determining groundwater quality at an industrial waste disposal site can range from \$50,000 to \$250,000. These efforts, however, give only an estimation of the extent of contamination and the rate of its movement. Plume shapes, lengths, rates of movement, and concentrations over time cannot always be predicted accurately, even with extensive study. In general, concludes Miller, the monitoring industry is in its infancy. There is no consensus on drilling methods, sampling frequency or protocol, standard quality assurance procedures, or the number of wells needed to define problems. Many drillers are also unfamiliar with the specific techniques required for working with hazardous wastes, and they run the risk of contaminating clean aquifers while drilling into polluted ones. And finally, there is no legal framework for facilitating access to areas where wells must be drilled and for protecting investigators from liabilities associated with the assessment.

Contaminated water is not the only problem, of course. At Love Canal, for instance, the principal sources of exposure were volatile chemicals in the air and physical contact with contaminated soil. Technology for analyzing chemicals in such samples is adequate, but there is still the problem of deciding where to monitor. An even bigger problem is deciding what to look for when the contents of the dump are not known. The need to analyze multiple samples of air, soil, and water for a multitude of chemicals can overwhelm laboratory facilities, says Robert D. Stephens of the California Department of Health Services. In general, he contends, the private testing industry in this country is simply too small to deal with the uncontrolled waste site problem. There must thus be a strong effort to develop priorities both to limit the number of chemicals to be studied and to minimize the number of samples required.

Those analyses that are performed may be misleading. Quality control at many private and governmental laboratories is poor, says John A. Liddle of CDC, and reported results may be inaccurate. CDC has, for example, been monitoring interlaboratory comparability among some 100 laboratories that have been participating in a nationwide screening program for lead poisoning. Each month, CDC sends each laboratory three samples of blood from cows fed varying amounts of lead nitrate. When CDC started the program in 1974, Liddle says, only 35 percent of the laboratories

* A. D. Bloom, Ed., *Guidelines for Studies of Human Populations Exposed to Mutagenic and Reproductive Hazards* (March of Dimes Birth Defects Foundation, White Plains, N.Y., 1981); W. W. Lowrance, Ed., *Assessment of Health Effects at Chemical Disposal Sites* (The Rockefeller University, New York, N.Y., 1981); "Research Needs for Evaluation of Health Effects of Toxic Chemical Waste Dumps," symposium sponsored by the National Institute of Environmental Health Sciences, held at Research Triangle Park, North Carolina, 27–28 October 1981.

got correct values (within 15 percent) for more than 70 percent of the samples. After an intensive training program at CDC and much work, about 65 percent of the laboratories now get more than 70 percent of the determinations correct. It is clear, however, that the laboratories are putting special emphasis on the CDC samples. When identical samples are sent to the laboratories from a disguised source, the number getting more than 70 percent of the answers correct drops by half.

> "The private testing industry is simply too small to deal with the uncontrolled waste site problem."

CDC recently began a similar study with polychlorinated biphenyls (PCB's) in cow's blood, but only about half of the state laboratories and only five of the 114 largest private laboratories invited to participate did so—"They can't be convinced that we are nonregulatory," says Liddle. The samples were spiked with other halogenated hydrocarbons commonly found in humans so that they represented "the worst case" that the laboratories might encounter. Only three of the 29 participating laboratories produced values of PCB concentrations that were within 2 standard deviations of the correct value. Both lead and PCB's are compounds that have been studied for a long time and should be readily measurable, Liddle says; the implication is that results may be much worse for other chemicals with which there is less experience. There is a "desperate need" for more work on interlaboratory comparability, he concludes, so that it will be possible to believe published results and accurately relate them to health effects.

Even when the concentration of contaminants in air, water, and soil is known, it is still difficult to determine whether humans have been exposed to them and, if so, at what concentrations and for how long. "The only objective measures of this so far," says Heath, are for chemicals that collect and persist in the body, particularly chlorinated aromatics such as PCB's and pesticides. Even for these, it is necessary to know baseline levels in the population at large before the extent of exposure can be determined. In some cases, those baseline concentrations are quite high.

One of the few sources of such information is the Health and Nutrition Examination Survey (HANES) conducted by the National Center for Health Statistics. For HANES, physical examinations were conducted on more than 15,000 people, ages 12 to 74, at 64 locations throughout the country. As part of the survey, says study director Robert S. Murphy, blood and urine samples from many of the participants were examined for pesticides and related chemicals.

Among some 6000 subjects whose blood was examined, more than 99 percent had significant quantities of DDT. The proportion with other halogenated pesticides in their blood ranged from 4 to 14 percent. Among some 4000 individuals whose urine was examined, 79 percent had significant quantities of the pesticide-related compound pentachlorophenol. Other halogenated intermediates were present in 4 to 7 percent of the samples, carbamate pesticides were present in 2 to 4 percent of samples, and organophosphate pesticides were present in 6 to 12 percent.

The center has also conducted a Human Adipose Tissue Survey, says Murphy, in which samples of fat were obtained from cooperating pathologists. Some 93 percent of 785 samples contained significant quantities of the pesticides DDT, chlordane, and dieldrin, as well as hexachlorobenzene. A third of the samples also contained PCB's.

Other studies have shown significant regional variations. A survey in the Southeastern United States showed that 23 percent of the individuals studied had trace levels of the potent carcinogen aflatoxin in their blood, according to Renate Kimbrough of CDC; aflatoxin is produced by a microorganism that grows on peanuts. Studies in Michigan show that 99 percent of individuals in the lower peninsula and 85 percent in the upper peninsula show significant quantities of polybrominated biphenyls in their adi-

Battelle's Columbus Laboratories

Some dump sites are obvious . . .

Piles of corroding barrels may or may not represent a hazard, depending on their contents and location.

pose tissue, according to Mary Wolff of the Mt. Sinai School of Medicine in New York City. Polybrominated biphenyls were inadvertently mixed with animal food in the state in the early 1970's. Interestingly, the chemicals were found in blood serum in 78 percent of individuals from the lower peninsula, but in only 19 percent of those from the upper peninsula.

No one knows what other chemicals might be found in human fat, largely because there has been no organized program to search for them and no consensus on what to look for. And, says Wolff, there is no consensus on whether adipose tissue is the best place to look for organic chemicals. The most severe limitation, obviously, is that collection of adipose tissue samples requires minor surgery. Some chemicals such as Kepone and tetrabromobenzene, furthermore, do not partition to a great extent into fat, Wolff says. Also, levels of chemicals in adipose tissue are lower in women than in men, presumably reflecting a dilution resulting from women's higher fat content.

A potentially better monitoring tool is human milk, which contains about 3 percent fat, and thus should have higher levels of fat-soluble chemicals than blood or urine. Samples of human milk throughout the United States generally contain DDT, DDE, PCB's, dieldrin, and heptachlor epoxide, says Walter J. Rogan of the National Institute of Environmental Health Sciences, and there is a wide geographic variation in observed concentrations. Any monitoring use will thus require extensive baseline studies with controls.

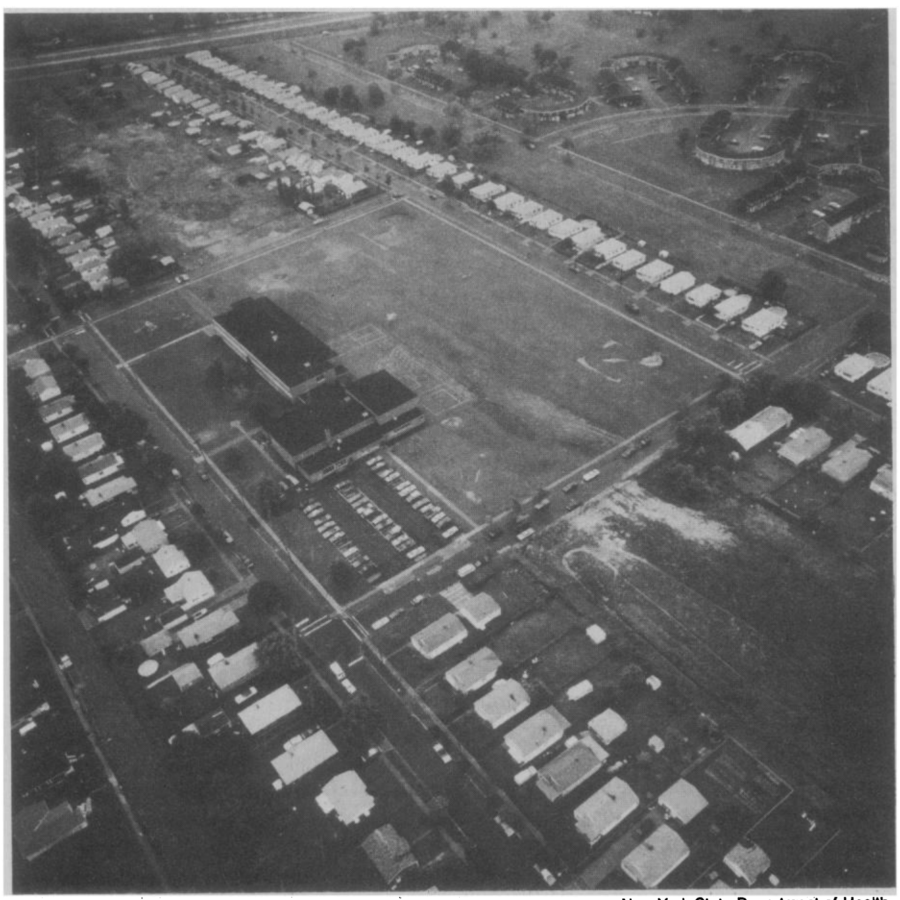
The presence of chemicals in milk is not restricted to the United States, he adds. "It is unusual to find uncontaminated milk anywhere in the world." Collection of milk samples also presents problems. Lactating women are a very small subgroup with a narrow range of ages and may not be representative of exposure among the population at large. Many women who are asked also refuse to participate, says Rogan. And finally, contamination occurs very easily during collection of the samples.

One potential new way to study exposure to the same types of chemicals, says Wolff, is to measure their concentration in skin oils. Limited studies have shown that their concentration in skin oils is proportional to the concentrations in serum and adipose tissue—with the notable exception of individuals who work with PCB's and have very high concentrations of these chemicals in their skin oil. This approach is particularly susceptible to contamination of samples during collection, however, and a great deal more work will be required to establish its validity.

Another potentially useful monitoring technique is the study of hair, says Thomas Clarkson of the University of Rochester. Metals, especially, collect in hair and analysis can provide a good indicator of recent exposures (*Science*, 22 December 1978, p. 1271). Unfortunately, most suspected exposures do not involve metals. There is some evidence that organic chemicals also accumulate in hair, but this aspect requires much further work for verification.

Other ways to monitor exposure to toxic chemicals involve a direct assessment of health effects, including reproductive effects and chromosomal abnormalities. (These will be the subject of a second article.) Estimating the toxicity of the chemicals present at a dump site is another important problem in this area (*Science*, 29 September 1978, p. 1200; 6 October 1978, p. 37). That this problem has not yet been adequately resolved is illustrated by the dispute between OTA and EPA.

The main problem with the EPA listing of hazardous waste sites, says Joel Hirschhorn of OTA, is that it does not give sufficient weight to the degree of toxicity of chemicals in a dump or waste disposal site. Instead, the model used for the ranking gives greatest weight to the number of people close to the site who are at risk of exposure. OTA argues that a dump which exposes a small number of people to an exceptionally hazardous compound is more dangerous than one that exposes larger numbers to more innocuous chemicals. The agency argues in favor of "a well-designed degree-of-hazard classification system" which would provide a more cost-effective way to manage industrial wastes. EPA, in turn, argues that the data simply do not now exist to establish degrees of hazard, particularly when trace quantities are involved. Until better data are provided, presumably by epidemiologists studying exposures, the agency will continue to assume that most hazardous wastes are created equal.—THOMAS H. MAUGH II



New York State Department of Health

. . . and some are not

This infrared photograph of the Love Canal area, taken before any residents were moved from the area, shows vegetation killed by escaping chemicals as white areas across the road from the school.