are checked to see if they provide mutations in a specific line of bacteria. If they do, additional bioassay tests with cultured human or animal cells may then be employed. Short-term cell bioassays require only a fraction of the cost (an estimated $35 million is spent annually) and time of comparable screening by animal studies, and therefore many more compounds can be screened than was possible earlier.

Analyzing Complex Mixtures for Toxic Agents Industries and government have responsibilities requiring a range of instruments and techniques to protect human health. Two instruments, in particular, have been useful as scanners and detectors of elements in complex mixtures found in the workplace and in the environment. One of these developments is based upon an instrument in use since the 1930's, the crystal X-ray spectrometer, which identified elements in an irradiated sample by the characteristics of the reflected X radiation. In today's instrument, the crystal has been replaced by a semiconductor detector that can distinguish among many elements by producing currents which are unique to each irradiated element and which can be processed and identified automatically. Approximately 8300 semiconductor X-ray spectrometers are now in use. The average annual savings to users of these spectrometers, in terms of reduced analytical costs as compared with other techniques of elemental analysis, is estimated to be at least $43 million. This figure is conservative since it is based on savings to only 1300 commercial users, who are in a better position than other users to estimate tangible benefits.

The other highly significant development in instrumentation, also a spectrometer, was designed specifically to identify radioactive materials. The scintillation spectrometer, commonly used for this purpose until 1965, could not distinguish well enough between radioactive elements with emissions of similar energies. Once again, the development of new crystal detectors led to a more capable instrument, now called the *high-resolution gamma-ray spectrometer.* Today it is used widely in nuclear power plants and laboratories and by state and local agencies to monitor the environment as well as in many research applications. Based on the value of rapid analysis as compared with slower alternatives, the benefit to nuclear plant operation alone is estimated to be $20 million annually.

Industrial Hygiene Monitoring The research program has also supported the development of instruments to detect and monitor toxic chemical substances. Specifically, it has supported the compilation of information relevant to instrumentation for all environmental monitoring applications. This survey has been in use as a standard for several years and will soon be issued by a private publisher. In addition, the program has supported the development of monitoring instruments specific to three important toxic chemicals which were formerly unavailable.

Predicting Pollution Pathways in the Atmosphere Finally, the means by which pollutants are carried and dispersed in the atmosphere have been traditionally the subject of intense study in the research program. Understanding and predicting pollutant transport are important because transport is a principal means by which health effects might be produced in the public by an emerging technology. The research program pioneered the mathematical modeling, or prediction, of pollutant behavior in the atmosphere because of the early responsibility for understanding the possible effects of radioactive contamination. But the validity of models and predictions must be tested, and in this area also the program has supported the development of the necessary tools for verification. One of these developments has been the use of nonradioactive, nontoxic, inexpensive tracers (related to the refrigerant used in home air conditioning). These tracers are injected into the air at designated locations at known release rates, and their concentrations are later measured at other locations to determine the dispersive effects of meteorological factors, terrain, conditions of release, etc. Although gas tracers have provided valuable information of this kind, it is also known that pollutant gases often interact with minute particle clouds (aerosols) from which they may be deposited on the ground or become resuspended in air. Pollutants themselves may even originate as aerosols. Thus the program has also supported instruments to monitor aerosol behavior. The major benefit of this research has been a sounder understanding of the relationships between pollutant releases and pollutant concentrations in the human environment, information that is essential to regulation of pollutants in the general interest and for sound industrial planning.

Identification and Evaluation of Environmental Effects

Effects of emerging technologies on the environment, as well as on human health, are a prime concern of the research program. Among the major environmental issues today are the responsible uses of land and water resources. Pertinent to land use, fundamental research in soil science and plant ecology is aimed at developing an understanding of the processes that lead to changes in soils and plants.

Riverine Ecology In the area of water resources, fundamental research has been of value to regulatory bodies in determining to what extent rivers and other inland waters can be used for industrial cooling. In one instance, the issue was whether the impact of several operating power plants on the Hudson River would seriously damage important East Coast fish populations that inhabit the lower part of the river. The research program on riverine ecology