electric power plants. Moreover, what began as developing methods for estimating the health effects of particles and sulfates found application in a wide range of analyses of the risks of other pollutants.

Evaluation of Health Risks from Atmospheric Particles A comprehensive body of information is being developed to evaluate the health risks associated with the inhalation of atmospheric particles released from energy-related industries.

The human health risks associated with exposure to atmospheric pollution depend on many factors, including the physical and chemical composition of the pollutants, their transport and transformation in the environment, the amounts that may be inhaled or ingested by humans, and their toxicity. DOE-supported research is playing an important role in identifying the pollutants of greatest concern, the manner in which they can enter the body, and their potential for causing adverse health effects. The research provided methods for characterizing and evaluating emissions from different types of coal combustion plants, coal conversion processes, oil shale recovery, and the use of petroleum fuels in diesel and gasoline engines. In some cases, new instruments were invented, for example, a family of particle samplers for use under normal atmospheric conditions and at high temperatures and pressures. New techniques were also developed for chemical fractionation and identification of pollutants and for characterization of their toxicities.

History Work dealing mainly with radioactive aerosols began in the late 1950's at the University of Rochester, PNL, and the Lovelace Fission Product Inhalation Laboratory (now the Inhalation Toxicology Research Institute). This research was expanded after 1970 to include studies of aerosol particles originating from many different energy-producing, consuming, and conservation activities. These studies have examined the ranges of particle sizes that can be inhaled by humans and test animals, to ascertain the fractions that deposit in the respiratory tract, and the potential mechanisms of their toxicity. Several such studies are now under way but will require several years to complete because lifetime observations of large groups of laboratory animals exposed to the toxic substances are necessary.

Each research project evaluates a single energy technology and estimates the risks resulting from human exposures to its products, by-products, and waste products. This research integrates diverse types of information, most of which has been developed in DOE-supported health and environmental research programs, on pollutant sources, characteristics, movement through the environment, human exposures, and health effects. These analyses are expected to provide the information necessary for cost-effective regulation of future energy industries, including models of exposure and risk from atmospheric particulates.

At present, the estimation of health risks from particles emitted by energy technologies is a complicated and uncertain process because of incomplete information regarding which components of atmospheric articulate matter are toxic and may cause illness or death in humans. As the toxicity of atmospheric particles becomes better understood, this information can be combined with knowledge of the atmospheric dispersion of particles to decrease the uncertainty involved in projecting the health risks that energy technologies might pose to the general population.

Benefits Two major benefits of research to evaluate the health risks associated with exposure to atmospheric particles follow.

1. *Development of the scientific information base.* The fossil fuels research program has focused mainly on characterizing emissions from electricity-generating power plants and light-duty vehicles used in road transportation. These two categories of energy use account for nearly 50 percent of the emissions of regulated pollutants in the United States. The physical and chemical characteristics of these emissions are now well known.

   The research program has also contributed greatly to an understanding of the deposition, retention, and health effects of atmospheric pollutants in general. It is now known that future regulations should be aimed at controlling respirable-size particles, that is, those with aerodynamic diameters below 10 microns. It is also known that sulfur dioxide emissions contribute greatly to the formation of sulfate particles, which are mostly in the small respirable particle-size range. Automobile emissions have also been shown to be respirable. This knowledge, along with the ranking of the toxicity of various respirable particles, is crucial to the development of cost-effective pollution control guidelines.

2. *Development of atmospheric dispersion models.* An important aspect of evaluating the health and environmental impacts of new pollution sources is projecting the atmospheric concentrations of pollutants in nearby populated areas. This must be accomplished before new industrial sources are permitted. Mathematical models have been developed for projecting the atmospheric dispersion of pollutants; an example of these efforts is the *Handbook on Atmospheric Diffusion* published in 1982 (Steven R. Hanna et al., DOE/Technical Information Center, DOE/TIC-11223). Although the value of these research programs lies in the development of new knowledge, it appears reasonable to assume that the enforcement of air quality standards would be on a "trial-and-error basis" if acceptable means of projecting environmental dispersion of pollutants were not available.