Chapter VII

Environmental hazards

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HUMAN HEALTH has always been dependent on the relationship of man to his environment. The human being, like other animals, is constantly being transformed by natural forces in the environment that act on him, and he is continuously transforming his environment. Human beings, other animals of all sizes and shapes from the sizable whale to the microscopic amoeba, bacteria that are smaller than the smallest animal, viruses tinier even than bacteria, and all plants of different sizes and shapes—all these living organisms are part of a dynamic system in which they continuously interchange matter and energy with the world about them (their environments). The human being, for example, takes into his body solid and liquid matter from his environment and puts solid, liquid, and gaseous waste into his environment; he exchanges gases with his environment and he even contrives machines and gadgets that also exchange matter and energy with their environments. Other living organisms may get into man's body. Some act for his physiological benefit while others cause trouble. In addition, man both benefits from and becomes afflicted by the nonliving forces of his world. *All* of these interactions with the environment, including the great changes in the past 30 years, are involved in the relationship of man's environment to man.

Man's relationship to his environment necessarily must be regarded in two contexts: *1*) the elements of the natural environment that are hazardous to his health and

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safety, and *2*) man's actions within his environment that themselves threaten his health. Within the first context are biological agents of disease or injury, including microorganisms, noxious plants, and toxic or physically harmful animals; weather, including violent storms, cold, and thermal stress; natural radiation from the soil or from the atmosphere; geological perturbations such as earthquakes, volcanic eruptions, and floods; and certain naturally occurring chemical substances. The second context consists of hazards to man's health which result from his own actions and maladaptations of the natural environment. This second context of human hazards brings the biological scientists into a confrontation with conditions even more complex than those that comprise health threats of "natural" origins.

Man-made hazards include such things as accidental injury, suicide, and homicide; injury and genetic damage from ionizing and nonionizing radiation; poisoning from industrial, agricultural, and therapeutic chemicals; noise-induced hearing loss; and health threats from polluted air, land, and water. These health problems are direct though unintended results of social and technological advancement or aberrant human behavior or both.

The automobile is an outstanding example of a social and technological advancement that has brought with it a staggering toll in accidental death and injury, pollution of air, water, and land, and unmeasured hearing loss from noise as well as some of the most hazardous occupational environments such as oil drilling and highway construction. Elimination of the automobile as a threat to health and life cannot be achieved either by its removal from society or by "immunizing" mankind against its effects. Inevitably, a trade-off must be reached where our chosen systems of transportation provide sufficient benefits to justify whatever toll results in terms of health effects. Similar acceptable cost–benefit decisions will have to be made with respect to radiation, pesticides, drugs, industrial chemicals, and most other hazards in this category.

Aberrant human behavior underlies many health hazards. Obvious examples are the steadily rising incidence of death from suicide and homicide. More subtle but significant is the inexplicable risk-taking associated with misuse of narcotics and alcohol, exposure to venereal diseases, and many sources of accidental injuries. An ever-increasing number of people in our society seem willing—even eager—to risk the almost certain health threat of addiction or accidental death or injury so as to achieve whatever the benefit that risk offers them. There is much fancy and little fact to aid the life scientists in reducing health threats related to such behavior.

The unique nature of human and environmental hazards, especially those generated by man, is such that many complex social, economic, and political factors bear heavily on them, their genesis, their study, and their solution. Although the net result of such hazards is an unwanted effect on man's health and well-being, the traditional training and experience of the life scientist is insufficient to cope with these problems single-handedly. By introducing the element of human action—either purposeful or by indirection—the health scientist finds it necessary to form an alliance with engineers, physical scientists, behavioral scientists, economists, educators, and political scientists if prevention or control of these human hazards is to be achieved.

The successful development of the antipoliomyelitis vaccine against a biological hazard was an excellent example. Health scientists recognized the health hazard and the need to eliminate it. They conceived of and successfully pursued the biological means of accomplishing this. But the actual fulfillment necessitated working with physical scientists to develop the production equipment; with engineers and industrial designers to develop a high-speed hypospray for safe, sterile, rapid, mass application of the vaccine; with behavioral scientists and educators to motivate individuals and groups and to understand and overcome the objections and misunderstandings of some; with economists to obtain the significant amounts of funds required for polio research and application of its results; with lawyers to provide legal protection; and with various elected and employed practical political scientists and public administrators to secure the necessary social and community sanctions. Throughout, from conception to successful application, the biological or health scientist was fundamental, but assistance was needed from the others. The total cost was great, but the benefit in lives and dollars was tremendous.

If one accepts the conditions of trade-off improvements as opposed to absolute prevention and need for multidisciplinary involvement, it is necessary to reexamine the criteria by which program priorities are established. Eight such criteria may be listed: *1*) mortality rates, *2*) morbidity rates, *3*) financial impact on national economy, *4*) utilization of hospital space, *5*) numbers and availability of health personnel, *6*) types of control measures available for attacking the problem, or the ease with which they can be attained, *7*) available or obtainable human and financial resources, and *8*) public receptivity to the idea and method of controlling the hazard.

None of the hazards to health considered here meets all of these criteria. Thus accidents and occupational injury and illness should receive high priorities in terms of the first four and possibly the fifth criteria but should probably be rated low on the last three.

With respect to scientific breakthroughs, the widest possible variance exists among the hazards considered. They range from vast strides and control over many communicable diseases to meager beginnings on the subject of noise. In a very real sense accomplishments serve as a measurement of both society's concern for the problem and its willingness to invest in its solution. Even more specifically, progress in controlling human and environmental hazards reflects the extent to which political leaders are motivated by physicians, scientists, and the general public who may believe that a particular hazard can and must be controlled and eliminated.

History describes the sequence: the first step is taken by a scientist who believes that a hazard might be understood and controlled. Then, after successful research has shown what can be done, concerned citizens and their political leaders are prompted to apply the results.

The past 3 decades have witnessed tremendous advances in medicine, science, engineering, and technology. In the United States varying degrees of affluence and high standards of living have been achieved for a large proportion of the population. The chief health problems of the past—yellow fever, plague, malaria, cholera, typhoid, dysenteries, and many others—have all succumbed to the application of research. Unfortunately, we now find that many of the recent technological advances have given rise to new and unfamiliar limitations to human life and happiness. Population increase, road construction, and transportation improvement have led to grotesquely increased crowding and its accompanying stresses.

An ever increasing barrage of new chemicals reaches man's body through food and water consumed, air breathed, and drugs taken therapeutically or otherwise. Streams and lakes have become contaminated with biological, agricultural, industrial, and mining wastes. Rapidly increasing amounts of garbage, solid wastes, and discarded vehicles multiply the opportunities for insect and rodent breeding. A crescendoing cacophony is affecting the auditory perception of an increasing number of persons. Ionizing and nonionizing radiation are a growing part of man's environment. It is used not only in nuclear testing but also in industry, laser and microwave technology, and in electronic products in the home as well as in devices for medical diagnosis and treatment. Each of the various environmental hazards is becoming increasingly significant in its own right, but the implications in terms of total "body burden" is yet to be comprehended.

Thus, the modern environment is dangerous on two accounts: it contains elements that are clearly noxious and stressful, and it has been changing so rapidly that man appears unable to make proper adaptive responses to it. The rate of technological change is accelerating every year; most changes demand a human adaptation. A complex of physical, mental, and emotional stresses of human life are resulting from increasing urbanization. Small but long-term exposures to many environmental stresses, hazards, and contaminants cause many previously little understood chronic ailments, disabilities, and even death. There is only now a beginning realization of the complexity of the environment and of the various factors within it that may act together to reinforce each other (synergism) or to oppose each other (antagonism). Those who are today concerned about human health and welfare must learn more and more to assess the problems of their own special areas of interest from an overall, a total, a holistic viewpoint. It will no longer do for the problems of one area to be considered in isolation or separately from the problems of related areas.

Very little has been learned about the interactions within the human body and human mind of the various environmental stresses, although it is known, for example, that the intended effects of certain medications may be initiated, intensified, or otherwise transformed by certain other factors in the environment. Similarly, it is known that radiation, cigarette smoking, certain air pollutants, and various chemicals encountered in the occupational setting can have a multiplying effect in the development of pulmonary cancer. The little that is known about multiple hazardous impacts merely highlights the vast amount still to be learned about human response to the environment. Most of the vast and ever-increasing array of physical, chemical, biological, and psychological stresses to which the modern urbanized American is now being subjected did not even exist in his grandfather's time.

In 19th century America the sociological and hygienic leaders were primarily concerned with malnutrition, overwork, filth, and microbial contamination. Today's characteristic diseases result from economic affluence, chemical pollution, and high population densities. The increase in chronic and degenerative diseases is due in part to these environmental and behavioral changes and not, as often mistakenly supposed, due to an increase in human life expectancy. Most people do not realize that life expectancy after the age of 45 years has not increased significantly. A person 45 years or older is little better off than he would have been in 1900 or before, even if he can afford good medical care. It can be assumed that medical science will continue to develop useful techniques for ameliorating cancers, vascular disease, and certain other degenerative disorders. Undoubtedly, it will refine methods for organ transplantation and for artificial prostheses. But most of the conditions to be treated need not have occurred in the first place. Greater knowledge of environmental determinants, provided by more biomedical research, is the path to prevention and control—a better and less expensive way.

The protection of the public from hazards involves skills and knowledge far more extensive and varied than seemed sufficient even in the recent past. To accomplish this requires sound scientific understanding resting on intensive and extensive biological and biochemical research. Fortunately there is a growing public awareness of the need for improved environmental quality. Increasingly, as environmental deterioration has affected more and more citizens, their uneasiness has produced demands for safer and more sensible use of the environment, and an increasing willingness to provide whatever support is necessary for the restoration and preservation of the environment. This implies involvement which, in terms of universities and similar concentrations of expertise, brings one back to the subject of research. In the absence of increased attention to the study of the effects of environmental hazards on man, increases in disease rates and greater expenditures for avoidable therapy are inevitable.

The population of the nation is projected to increase to 250 million people by 1980 and over 300 million by 2000 A.D. Metropolitan areas probably will absorb nearly all the increase, and environmental problems will be intensified geometrically. Moreover, new and presently unsuspected environmental hazards will be identified. Without corresponding growth in environmental health protective activity, the future can only bring mankind increased physiological and psychological suffering.

An overview of where we stand and how we must proceed is pertinent. Guidance is provided by the successes in the combined areas of environmental biology and aerospace physiology. Man's space travel provided the impetus to bring together the knowledge of several disciplines in a new more positive approach to human health. Thus research on space vehicles has provided facts that are useful in occupational health programs and radiation protection procedures. Already these breakthroughs have begun to result in improved health through the establishment of realistic criteria for technological assessment. They have increased substantially the awareness of the holistic approach to the solution of environmental problems at every segment of society encompassing both professional and general citizenry. Among the "spin-offs," the many specialists in environmental health have necessarily become broader professionally and are now more effectively bringing together the health scientist and the urban planner, and the lawmaker and the toxicologist, to mention only two of innumerable examples. Other spin-offs worthy of mention are in the area of therapeutic medicine. Better health care delivery systems have evolved and the need for comprehensive health programs has been more clearly defined.

Against this background, two major breakthroughs during recent decades are worth special note. The first was the appreciation that small amounts of chemicals may become toxic after periods of accumulation or latency. The kind of biological and toxicological research that was carried out on beryllium, asbestos, benzene, and mercury exemplify this. It demonstrated some of the fundamental enzyme systems involved and showed that the rate at which the body acted on a chemical affected its toxicity. As a result, the basic mechanisms of toxicity became better understood as these biological and chemical processes were probed in depth. Safety evaluation techniques were improved and methods for studying the potential of chemical carcinogenesis, teratogenesis, and mutagenesis, were and are still being developed as a result of these research efforts.

The second major and concurrent breakthrough was that the scientific community became aware that there was inadequate information on the effects of these widespread chemicals (air pollutants, metals, persistent pesticides, additives, pharmaceuticals, and the like) in the biosphere. As a result, the research community is now expressing its concern that the total ecological threat may in some instances be more important than any direct toxic effect on humans. In sum, the major breakthrough was to appreciate the latent, insidious, and chronic effects of small amounts of chemicals in the environment, often over prolonged time periods, and their potential threat to future generations through their effects on the biosphere. Even this breakthrough is inadequate unless consideration goes beyond acute, easily recognized, clinical responses to chemical toxins, to consideration of genetic potentials.

The number of factors in the environment that may affect man are presented in Table 1. Some of these factors in proper form or amount are helpful or even necessary to life, others are hazardous. Consideration of a number of them, with some consideration of significant breakthroughs and further needs, follow under three categories of hazards—biological, chemical, and physical.

BIOLOGICAL HAZARDS TO MAN

The biological hazards to human health are mostly those posed by bacteria, viruses, and other microorganisms and parasites. Since the advances against them have been discussed in other chapters, they will be considered here in a general way. Those microbiological accomplishments directly related to human health include modifications of man's susceptibility to disease or of his recuperative ability (better diagnostic and immunizing methods and better antimicrobial drugs); modification of his environment or of his relationship to his environment (more knowledge of the agents that cause or induce infectious disease and how to control them; better methods of insuring that food, milk, and water are free of disease-producing microorganisms; more aseptic homes, public institutions, and food distribution industries; better understanding of community health

TABLE 1. *Classification of environmental factors that may affect man*

- *Life Support*
  - Food
  - Water
  - Oxygen
- *Physical*
  - Mechanical
  - Acoustic
  - Electrical
  - Magnetic
  - Thermal
  - Particulate
  - Ionizing Radiation
- *Biological*
  - Microorganisms
  - Toxins
  - Biological Wastes
  - Biological Antagonists
    - Animal
    - Plant
  - Allergens
- *Psychosocial*
  - Crowding
  - Demands
  - Physical time
  - Biological time
  - Cultural time
- *Chemical*
  - Inorganic
    - light metals and their compounds
    - transitional and rare earth metals and their compounds
    - heavy metals and their compounds
    - nonmetallic elements and their compounds
  - Organic
    - acyclic hydrocarbons including alkyl compounds
    - carbocyclic compounds
    - halogenated acyclic hydrocarbons
    - heterocyclic compounds
    - organic phosphorus compounds
    - organic sulfur compounds
  - Product Complexes
    - combustion products
    - macromolecular products
    - industrial wastes
    - agricultural wastes (including fertilizers, pesticides and herbicides)

problems; and better control of disease in domestic and wild animals). Those accomplishments that have an indirect relation to human health include, for example, improvement in worker productivity with consequent increase in plant and animal food production. During the past 30 years microbiological research could have been even more effective had there been more complete communication between scientists, administrators, and agency representatives and less unnecessary duplication of research activities, whether funded by federal, local, or private sources.

Information exchange is vital to success and economy of applied research in the field of microbiology as related to health and disease. There has been little planned exchange of information other than through publication of scientific papers and presentations at scientific meetings. One notable exception is the Arbovirus Information Exchange, which is issued three or four times a year to scientists in 235 institutions. This, plus an annual meeting in conjunction with the Society of Tropical Medicine and Hygiene, minimizes unnecessary duplication and directs attention toward critical problems.

Microbiological research in the past might have been more effective if there had been a federally sponsored Expert Committee for each of the major diseases such as malaria and tuberculosis. The Armed Forces Epidemiological Board has had outstanding success with this kind of system, providing an example that should be followed by others, including the Public Health Service. Another deficient area of communication lies between the researcher and the tax-paying citizen, whose support for research could be retained if he had understandable information on research activities and accomplishments.

The following achievements may be anticipated during the next decade in this fight against microbiological hazards: *1*) more effective and less expensive methods for disposing of human wastes thereby reducing water pollution from this source and reducing the biological usage of oxygen in rivers; *2*) better methods of controlling disease caused by microbes in agricultural products (plants and livestock) leading to an increase in quality and quantity of food; *3*) more specific drugs for use against microbes, fungi, and certain viruses that cause human disease and disorders; *4*) more effective immunizing agents for human and animal use, including attenuated live virus vaccines administered orally or into the nose–throat region; *5*) determination of the causative agents of various types of cancer and their role in the pathological origin of cancer; *6*) improvements in the control of those diseases transmitted from animals to man, diseases such as Rocky Mountain spotted fever, plague, brucellosis, hemorrhagic fevers, encephalitis, rabies, and the like; *7*) more accurate and less expensive diagnostic microbiology due to automating and reducing the size of clinical diagnostic procedures; *8*) better understanding of immune mechanisms leading to significant improvement in the prevention and management of disease problems of the very young and the very old, particularly problems such as multiple sclerosis, rheumatoid arthritis, and disease states of the blood (blood dyscrasias).

While improvements in man's control of the biological hazards of his environment can be expected to continue, these advancements should be accelerated and made more effective by similar improvements in the kinds of communications needed for planning and coordination of research and development activites.

CHEMICAL HAZARDS TO MAN

The chemical hazards to which man is exposed exist in all three aspects of the environment—air, water, and soil. Although a particular chemical hazard initially may be limited to one of these, dispersion to one or both of the others may occur. This is especially apt to be the case for persistent pollutants. Agricultural chemicals present a classic example. As a result, a fourth source of environmental chemical hazard should be considered in the form of food, in the sense that it may reflect possible concentrations from air, water, or soil.

With reference to chemical hazards in terms of implications to human disease, perhaps the major advance of the last 3 decades has been the realization that spontaneous diseases, for which no cause can be found, are in fact induced by environmental pollutants. Thus, certain cancers and deformities may be largely explicable in terms of exposure to certain specific environmental pollutants. More recently, there has been growing realization of the importance of chemical induction of genetic changes. Apart from preformed agents that may cause cancer (carcinogens), induce morphological abnormalities (teratogens), or bring about genetic changes (mutagens), there is a growing interest in the possibility of their synthesis in the body from simpler chemical compounds normally present in the environment.

Although the word pollutant is often restricted to synthetic industrial chemicals, there are four broad categories of other important chemical pollutants: the first group consists of natural chemicals in excess, and includes nitrates that are normal dietary components. At high concentrations in food or water, nitrates can cause a blood disorder (methemoglobinemia) in infants. Also, nitrites, as reduction products of nitrates, may interact with secondary amines to form nitrosamines. Some of them are carcinogens, teratogens, or mutagens.

Toxic chemicals in fungi on plants or in crop plant products comprise the second group, of which aflatoxins and cycasins are notable examples. The yields of these toxins can generally be considerably influenced by technological factors, such as conditions of harvest, storage, and processing. The third group consists of complex organic and inorganic mixtures, such as air and water pollutants, which comprise a wide range of undefined as well as defined components.

Finally, there is the group of synthetic chemicals—agricultural chemicals, notably pesticides and fertilizers; food additives; fuel additives; household chemicals; industrial chemicals; and in a somewhat specialized class therapeutic and prophylactic pharmaceuticals, as well as habituating and addicting drugs.

Pollutants may have a wide range of adverse biological effects, from health impairment to death. The possibility that chronic toxicity is also manifest in immunological impairment or psychological disorders has yet to be determined, although there is already suggestive evidence to incriminate carbon monoxide in these regards.

Some pollutants produce any one or more of these types of reactions, and may interact with one another outside the body as well as inside the body to produce otherwise unanticipated synergistic toxicity.

Naturally occurring chemicals. There are many naturally occurring chemicals that are hazardous to man. The toxicity of some, mercury and arsenic, for example, was known in ancient times. In recent decades, information from a variety of research investigations has indicated that many others play a role in human health and disease. Some trace elements are an important part in human nutrition and in many physiological reactions. But excesses and deficiencies of certain metals such as cadmium, selenium, chromium, lead, copper, zinc, lithium—or of radiation—may be related to major degenerative diseases such as heart disease, muscular dystrophy, diabetes, multiple sclerosis, cancer, mental illness, or congenital malformations. There is a growing awareness that many diseases have geographic patterns which seem to relate somehow to the physical environment and its different geologic metal-containing areas. This awareness has led to a corresponding recognition of the need for interdisciplinary teamwork among the geochemist and the medical scientists.

Some of the observations that have resulted from this multipronged investigative effort are described briefly herein.

For a long time *arsenic* was believed to produce cancer but recent research with animals and lack of evidence in man has dispelled this notion in the United States. Major sources of arsenic intake are food, especially crustacea, and beverages, particularly wines. Except for some isolated sites, the arsenic content of water supplies is extremely small. But in Europe there have been claims that arsenic does induce cancer. Arsenic has long been known to counteract selenium toxicity and it has been added to poultry and cattle feeds to suppress selenium toxicity in areas where selenium content of soil and water is high. But in hamsters selenium does not suppress the monster-forming effect of high levels of arsenic. It is possible that the different United States and European views of arsenic as a cancer-inducing agent may result from differences in exposures to these two antagonistic elements in the two regions of the world and to the quantities and chemical forms of these substances taken in.

Certain tumors (mesotheliomas) have been known for decades but it was not until 1965 that *asbestos* was found to be a causative agent, most likely because it is a source of certain trace metals and certain chemical compounds (such as benzpyrene). Benzpyrene is a ubiquitous air pollutant, a prominent constituent of tobacco smoke, and of charred and smoked foods; the particular trace metals are associated with certain types of asbestos fiber (chrysotile). There is some indication that the cancerous growths are brought about by an interaction between benzpyrene or benzpyrene compounds, an enzyme, and the particular trace metals. The chief source of non-occupational asbestos exposure is not yet actually known; possible sources are asbestos water pipes, asbestos filters for beer, asbestos brake linings, asbestos household iron-holders, asbestos used in some cigars, and asbestos in water supplies (possibly the most continuous source).

Beryllium causes a serious disease, berylliosis, a name only about 30 years old. Also it is known to induce tumors in animals but has not been found to do so in man, although vigilance is being maintained regarding this. Beryllium poses no threat to health from water or food sources, for it is poorly absorbed from the gastrointestinal tract and is highly insoluble in water either in or outside the body. The potential environmental threat is from the vicinity of beryllium production plants, for the use of beryllium as an industrial material is increasing rapidly.

Another chemical hazard is the trace element *cadmium*. In 1965 it was shown that the kidneys of persons dying from hypertensive complications had increased amounts of cadmium or increased ratios of cadmium to zinc, as compared with persons dying from other major diseases. This discovery has been substantiated experimentally in animals. The chief sources of cadmium are believed to be drinking water and food grown in soils containing cadmium from certain fertilizers; from beverages that have been in contact with galvanized zinc (container coatings) which contain small amounts of cadmium; and from vegetables, coffee and tea (all of which usually contain small amounts of cadmium). Drinking water is not thought to be a large source. Whether or not cadmium induces renal hypertension seems to depend also on the intake of zinc and selenium, antagonists to cadmium. In hamsters monster-formation induced by cadmium is antagonized by selenium. The highly lethal effect of cadmium on fish is increased (synergized) by cyanide.

A very important advance was made in 1960 when it was found, in some forty-eight states of this country, that water with relatively more dissolved salts, so called "hard water," was associated with lower death rates from cardiovascular and coronary heart disease. Not all states showed this correlation and the correlation was somewhat better for coronary heart disease in white men 45 to 64 years old, by state and in the 163 largest cities that had about 58% of the total national water supplies. Mortality from all other causes showed no such correlation. Prior to this discovery, state-to-state variations in cardiovascular deaths were unexplained on either a dietary, racial, or social basis. Evidently something in hard water, or the lack of something in soft water (relatively low in dissolved salts), influences the death rate. Of the various trace elements for which correlations have been worked out, only cadmium and *chromium* (Cr^{3+}) have been revealed as trace elements affecting cardiovascular disease. As pointed out in another chapter, this discovery raises the possibility that perhaps in time the prevalence of cardiovascular disease may be decreased by adding certain trace elements to water supplies.

Lead poisoning has been known from ancient times, but its clinical manifestations were classified about 110 years ago. Lead exists in many forms in man's environment and its industrial use is practically ubiquitous. Occupational safeguards have limited its harmful effects, but a special hazard is the use of tetraethyl lead as an antiknock and power-increasing agent in gasoline. Tetraethyl lead is highly toxic when inhaled or absorbed through the skin, and predominantly causes cerebral or central nervous system symptoms. It pollutes the atmosphere. The toxic lead-bearing household paints have been largely eliminated but still, in this country, thousands of small children eat dangerous amounts of flaked household lead paint, mostly in the older and poorer parts of large cities; some die and others develop mental retardation, cerebral palsy, convulsive seizures, blindness, and various other disorders. Research is being directed toward safe and effective physiological deleading procedures, and recently chromium as a trace element in food appears to decrease lead toxicity in some animals—and presumably in man. Evidence suggests that chromium (trivalent) acts as an antidiabetic and antiatherosclerotic agent through its role in sugar and fat (glucose and lipid) metabolism.

Inorganic *nitrates* and *nitrites* are a health concern because they contaminate drinking water. They are a special hazard to infants up to 6 weeks of age; and also to Alaskan Eskimos and Indians, those who have a particular genetic blood disorder. The young infants are susceptible because they have not yet developed certain metabolic enzymes, they have a more readily reactive hemoglobin which decreases after birth, and they have a small blood volume relative to fluid intake. Milk from cows that drink nitrate-polluted water can be an added threat to children. Although nitrates are used in preservation of some meats and fish, such food is not a common part of infant diet. The toxic effect of nitrates in infants is a blood disease and, if intake is not stopped, death. Although in this country community water supplies are monitored in accordance with standards set by the Public Health Service, well water on farms has no such surveillance. Any increase in the use of nitrate fertilizers and superphosphate wastes, both being sources of nitrites produced by bacterial action, will necessitate even greater surveillance and increase the hazard of nitrates and nitrites in well water on farms.

Toxic chemicals in fungi and plants. Substances produced in the process of growth and development of certain forms of fungi, more commonly called molds, represent another group of toxic chemicals. Molds cause economic loss through deterioration of food fiber, induce plant diseases, and cause certain pulmonary and invasive diseases in man. Mold-damaged foods were once considered harmless and used as animal feeds. We know now that a few molds of grain and other foodstuffs produce toxic chemical substances (metabolites) called mycotoxins.

The oldest mycotoxin is known as ergot, from a fungus that infects cereal grasses, especially rye. Ergot has been the cause of serious epidemics in Western Europe and parts of Russia since the middle ages. The most recent outbreak of ergotism occurred in 1951 in a region in France. There many people were stricken, some died; a large proportion showed central nervous system symptoms such as hallucinations, depression, and self-destruction manias.

Among the substances (alkaloids) identified in ergotized grain are some related to LSD (lysergic acid diethylamide). One of these substances, ergotine, causes contractions of blood vessels (arterioles) and smooth muscle fibers, and is used medically to stop hemorrhage, especially after childbirth, to stimulate labor, in spinal and cerebral congestion, in paralysis of the bladder, and in diabetes (diabetes mellitus). Ergotamine tartrate inhibits certain nerve endings (sympathetic) and has been used to treat migraine.

Other mycotoxins include the aflatoxins, produced by molds on peanuts and other agricultural products. Even in low concentrations aflatoxins cause acute intoxication, liver damage, and cancer of the liver (hepatoma) in animals. Certain molds on wheat allowed to remain in the fields during the winter produce poisons that cause a blood disorder (alimentary toxic aleukia). In 1944, in a district of the U.S.S.R., this disorder affected about a tenth of the population. Another mold on millet can cause an epidemic of excessive urinary secretion (epidemic polyuria). The paucity of knowledge regarding these types of hazard points up the great need for future research efforts.

Industrial wastes. In addition to naturally occurring chemicals and plant and fungal poisons, complex organic and inorganic chemical mixtures made up a third group of environmental hazards. They arise as a result of the pollution of air and water by combinations of community and industrial wastes. Man is now beginning to learn that the atmosphere and waters of this earth, large though they be, are not limitless and cannot with safety be used as sewers and disposal dumps. Air, water, and consequently food cannot continue to be mistreated in this way without rapidly increasing danger to a rapidly increasing population in a limited world. Most people do not realize that the average person in this country takes into his body each day about 30 pounds of air, 4 pounds of water, and 3.5 pounds of food. The unused remains of these are returned to the environment as contaminants or as potential contaminants.

There has been a belated recognition that air pollution is one of the most important sources of chemical hazards, especially in highly urbanized and industrialized societies. More than 200 million tons of toxic material are released into the air above the United States each year, about 1 ton per person. About 60% comes from approximately 100 million internal combustion engines, the other 40% from sources such as factories, power plants, municiple dumps, and private incinerators. The pollutants include carbon monoxide, sulfur oxides, nitrogen oxides, hydrocarbons, and particulates. They produce ill effects in people either by short-term, high-level or by long-term, low-level exposures (see Table 2).

Short, high-level exposures cause acute reactions with increased mortality especially among the elderly and the chronically ill. There may be increase of respiratory infections, irritation of ear, nose, and throat, and impairment of physiological functioning. The more serious effects that may lead to death include an increase in

TABLE 2. *Estimated atmospheric emissions, U. S. 1968, 10^6 tons/year*

Source	Carbon Monoxide	Particulates	Oxides of Sulfur	Hydrocarbons	Oxides of Nitrogen
Transportation	63.8	1.2	0.8	16.6	8.1
Fuel combustion in stationary sources	1.9	8.9	24.4	0.7	10.0
Industrial processes	9.7	7.5	7.3	4.6	0.2
Solid waste disposal	7.8	1.1	0.1	1.6	0.6
Miscellaneous	16.9	9.6	0.6	8.5	1.7
Total	100.1	28.3	33.2	32.0	20.6

the severity of chronic illnesses such as bronchitis, emphysema, asthma, and heart attacks (myocardial infarction). Such an episode occurred in 1930 in a valley in Belgium; 100 persons were stricken and 63 died. In Donora, Pennsylvania, in 1948, 6,000 of a population of 14,000 persons became ill and, during the episode, the death rate was 10 times the normal. During a 5-day fog and smog episode in London in 1952 emergency bed service requests increased 2.5 times and approximately 4,000 deaths were attributed to the air pollution. These are only some of the more dramatic epidemics caused by polluted air. In this country more than 6,000 communities are considered to be affected by varying degrees of air pollution. Inhabitants who show asthma-like responses, the most frequent response to polluted air, tend to have an increase in β- and γ-globulins in their blood, and biochemical studies have shown that asthma patients also have increased γ-globulins.

The insidious long-term effects of low-level exposures to polluted air perhaps are even more significant, for these exposures result in slowly developing difficulties hard to define or measure. Chronic diseases of several kinds, including cancerous growths and genetic mutations, may be initiated, general body defense mechanisms impaired, and physiological function interfered with.

The protective cilia of the respiratory tract, for example, may be slowed down or destroyed by atmospheric sulfur oxides, nitrogen oxides, and ozone and this injury may be associated with and followed by other respiratory disorders and diseases. In the United States chronic bronchitis and emphysema are among the most rapidly increasing causes of death. One in twenty asthma patients is severely affected by air pollution. Lung cancer has been correlated with air pollution as well as with certain other factors, such as smoking habits.

Deaths from pulmonary carcinoma have been correlated with air pollution, taking into consideration a number of pertinent socioeconomic variables, such as smoking habits, economic status, and degree of urbanity. For example among English nonsmokers, a 10-fold difference was found between the death rates for cancer of the lungs for rural and urban areas. Adult British immigrants to New Zealand and to South Africa have been found to suffer a higher incidence of lung cancer than individuals of the same ethnic stock who were born in those two locations. Among Norwegians living in Norway where air pollution is low, the lung cancer rate is also low. Among Americans living in the United States where air pollution is heavy, the rate is twice as high. For Norwegians who have migrated to the United States, the rate is half-way between.

Correlations have alsc been found between air pollution and carcinomas other than pulmonary, such as of the stomach. In addition, deaths from cirrhosis of the liver have been observed to be higher in heavily air-polluted areas, probably because livers already damaged by alcoholism decompensate when exposed to toxins of polluted air. In the laboratory, injection of animals with trace amounts of extracts of urban atmospheric pollutants from some cities, especially those using predominantly solid fuel, produced a high incidence of tumors of the liver, lymphatic system (lymphoma), and lung (multiple adenomas). Such amounts would be inhaled in about 3–4 months by a resident of the cities involved.

Quite apart from frankly evident air pollution and smog, specific gases may be harmful to health. A study in Chattanooga, Tennessee, has linked relatively low levels of nitrogen oxides to the susceptibility of children to the Asian influenza. Evidence from California indicates that a concentration of carbon monoxide in the air of as little as 10 ppm for about 8 hours may result in impaired mental performance because of reduction of ability of the blood to carry sufficient oxygen to the brain. Such levels are common in many cities around the world.

Elevated levels of carbon monoxide have also been associated with the increased probability of motor vehicle accidents and with the inability of individuals to survive myocardial infarctions. While admittedly several other factors are involved, it is notable that death rates from coronary heart disease are 37% higher for men and 46% higher for women in metropolitan areas with high atmospheric pollution levels than they are in non-metropolitan areas. Cardiovascular death rates are more than 25% higher for male Chicagoans between 25 and 34 years of age than for their counterparts in rural areas. The difference is 100% for men between 35 and 54, and nearly 200% for men between 55 and 64. Since 1940, genetically determined coronary artery patterns have been recognized as playing a significant role in vulnerability to coronary atherogenesis and myocardial infarction. Of the three branching patterns identified, hearts with a left coronary artery pattern are considered most vulnerable to fatal coronary artery occlusion, and those with balanced patterns, least vulnerable. These and similar findings, combined with those that associate atherosclerosis with carbon monoxide, indicate the inadvisability of certain types of individuals residing in areas of high pollution.

In the earlier discussion of lead as an environmental chemical hazard, passing mention was made of the special problems presented by the addition of tetraethyl lead to gasoline for antiknock and extra power purposes. The consumption of leaded fuels has increased tremendously—from 100,000 pounds in 1940 to 450 million pounds in 1967, an increase of 4,500-fold in 27 years. If a uniform distribution throughout the country of its 90 million cars and trucks is assumed, the potential exposure to each of the country's individuals (200 million) approximates 2.25 lb./year; certainly a frightening thought, particularly when lead distribution is not uniform, but is concentrated in areas of heavy traffic.

Confronted with the facts, several investigators made worldwide comparisons of lead concentrations in the blood and urine of man. These comparisons showed: *1*) variations in body concentrations did not exceed 3.5-fold anywhere in the world; *2*) lead values in primitive societies often equaled those in the metropoli; *3*) lead values had not changed in 3 decades; and *4*) there is no evidence that at current lead levels adverse effects of the health of man occur; urinary D-aminolevulinic acid levels of normal populations are well below response levels.

Inferences from the above blood and urinary lead levels are somewhat misleading unless one notes that they are average values. Blood lead values were measurably higher in certain groups, traffic policemen and persons living adjacent to busy highways. In none of these individuals, however, did lead values approach levels considered hazardous.

Nevertheless, the measurable elevations in blood lead found by repression analysis are interpreted as evidence of a measurable contribution to the body lead burden from the atmosphere, heretofore not considered possible of attaining significance in comparison with the daily intake from food and beverage. The evidence is made plausible by the postulation of body absorption of up to 50% of atmospheric lead generated in submicron particle size from motor exhausts. Experiments with animals suggest a need for the larger cities to establish an air standard for lead. At the time of this writing, Philadelphia and New York City set limits on atmospheric lead concentrations. However, this limit (5 $\mu g/m^3$) may prove not to be too conservative, in light of increased toxicity of lead in certain deficiency states observed in advanced age groups and the demonstration in man of the interference of lead in various endocrine functions.

While many other examples of the relationship between general atmospheric pollution and ill-health might be presented, the seriousness of the situation is perhaps most succinctly illustrated by a recommendation of the California Department of Health. They propose that physicians should estimate the contribution that local air pollution conditions may make to the outcome of a patient's illness, and that in areas with high air pollution, some patients may benefit from a preoperative period in a clean-air room or chamber before receiving general anesthesia.

Water pollution. Water is one of the prime necessities for life. Without it, survival beyond a few days is impossible. In addition to oral consumption modern man has another use or misuse of water: as a vehicle for the removal of human wastes, as a great cesspool, for an ever-increasing complex mixture of industrial and related waste materials. As a result, there have been repeated, extensive water-borne epidemics of bacterial diseases, such as cholera and typhoid fever. In the late 19th and early 20th centuries technological means were developed to remove these hazards from water with notable declines in case and death rates. Yet even today cholera and typhoid fever epidemics occur with alarming frequency.

The hazardous aspect of water has been recognized of late as being greater also because of its contamination by viruses. Thus current levels of bacterial purity of water must be maintained and improved, practical methods of removing disease-producing viruses must be developed, effective means of surveillance and control of chemical pollution must be developed and put into practice.

Man is beginning to realize that he is living in an environment replete with agents that induce, promote, and accelerate cancerous growths and genetic mutations. Such substances contaminate man's drinking water as well as urban air and other parts of his environment. Water pollution with hazardous chemicals may be expected to increase as a result of the development of new industrial plastics, chemical sterilizing compounds for use against pests, missile fuels, and other substances.

Many of these substances are unstable; they may break down in water before they become a significant health hazard. But a threat may be posed, according to some epidemiological evidence, by a combination of potentially mutagenic chemical agents with radioactivity in water sources.

The National Community Water Supply Study completed in 1970 made a wide variety of recommendations for the delivery of an adequate supply of potable and safe water. Required is strengthened legislation, forthrightly enforced, to limit or prevent the discharge of untreated human and industrial wastes into the streams and lakes of the nation.

With specific reference to chemicals, inorganic and organic, the study clearly evidences the need: *1*) to simplify and lower the cost of removing excess chemicals known to be dangerous to the public health; *2*) to improve systems to control undesirable concentrations of iron, manganese, hydrogen sulfide, and color as well as organic chemicals causing unpleasant taste and odor; *3*) to develop surveillance techniques or conditioning procedures to eliminate the deterioration in water quality between the time that the water leaves the community water treatment plant and the time it reaches the consumer's tap.

A first step is better monitoring of water quality. Instrumentation for routine continuous monitoring with computerized interpretation must be developed. As of now, the monitoring of drinking water of the United States employs satisfactory but very inefficient methods. A tremendous investment will be necessary if the proper tools and the proper skilled personnel are to be provided so the presence of potentially toxic materials in the environment can be identified. Only then can we begin the epidemiological studies necessary to identify the significance of various toxic substances in water.

The outstanding breakthrough of recent years in instrumentation has been the development of membrane filters for the collection of microorganisms and large molecules. The membrane filter has permitted many research workers to adapt the filter to a wide range of problems, and the uses to which this type of membrane can be put are still being explored. A similar development might come from the application of other kinds of membranes, particularly the cellulose acetate membranes being used in desalination technology, which have possibilities for the concentration of microorganisms and other contaminants. There are numerous voids in existing technology that do not allow measurement of current procedures. Current drinking water standards do little more than mention viruses, neglect numerous inorganic chemicals, and identify only the index that is to cover the entire family of organic compounds. A breakthrough required in the next decade is the development of similar concentration and identification techniques for viruses, and particularly the ability to grow the infectious hepatitis viruses in vitro.

With the trend toward multiple use of water sources, plus the complex types of chemical contaminants, new methods of surveillance and treatment are required. Among the new contaminants that must be dealt with are fertilizers, herbicides, fungicides, irrigation residues from agriculture, detergents from homes and industry, radioactive wastes from power plants, industrial, and research installations, a spectrum of heavy metals, a wide variety of salts, and numerous other materials. Many of these are not readily biodegradable, are unaffected by conventional treatment methods, and build up in water supplies. This makes necessary continuous spot-testing techniques based on a variety of approaches. Some measure particular characteristics such as biological or biochemical oxygen demand and acid concentration. Kits for determination of more than 100 different physical, chemical, or biological characteristics or contaminants are now available. There are also more versatile instruments such as the direct-reading colorimeter with which 20 or more different tests can be made. The gas–liquid chromatograph has proved its value in identifying traces of organic materials in water. Continuous water pollution monitoring of effluents from industrial plants can be carried out by ion-selective electrodes consisting of an ion-selective membrane sealed onto the end of an insulating glass or plastic tube containing an internal reference electrode of silver chloride or calomel. The solution to be measured is placed in the tube and a voltmeter measures the electrical potential developed between it and an external reference electrode when both are immersed in a solution.

The need for knowledge about the health effects of water-borne contaminants will require thorough investigation. The concentration levels at which numerous contaminants, such as mercury, molybdenum, or selenium, cause adverse health effects must be determined. Similarly, we must soon determine the effect of the long-term ingestion of low-level concentrations of toxic, organic materials in water. Some of these toxic materials are carcinogenic, some mutagenic, some teratogenic, and some have other toxicological effects. Some of these effects are only identifiable after many years of exposure, and because the effects are little different from other types of exposure and deterioration, the cause and effect relationship is not easily established. This research will be exceedingly expensive.

Recognizing the relatively fixed amount of ground and surface water supply, the increasing water needs of the general population and industry, and the need to reuse the available supply to satisfy future demands, we can no longer afford to wait and see what happens.

The types of research mentioned are essential and minimal. But this generation also bears a responsibility for the health and well-being of future generations. Realistically, answers to many of the currently identifiable research problems must be obtained quickly so planners of our environment can formulate rational, economical, and effective plans for the continued growth, development, and survival of our society.

Synthetic chemicals. A most important achievement in the past 3 decades has been the development of longer lasting, more effective, and more toxic organic insecticides, a breakthrough the significance of which in terms of human health has been of the highest order. It was one of the most spectacular advances in improving man's health the world has ever seen. But in terms of other factors engendered by them, they became a mixed blessing.

It is impossible to say just how many hundreds of thousands of individuals have had the opportunity to live out their life-span or, at least, die of accident, chronic disease, or starvation rather than to die of malaria, typhus, or some other arthropod-borne disease, probably at an early age. The advent of these longer-lasting or more toxic compounds made possible the control of such commonplace diseases as shigellosis that, particularly in the neonatal phase of life, has produced so much misery and death. While resistant strains of arthropods were developed rather quickly and chemical control was not permanently effective, the few years of its effectiveness removed the apathy and the general acceptance of these diseases as routine risks in many parts of the world. Chemical control of flies, for example, is not as effective or as desirable as improved sanitation, but the latter had been hard to sell prior to the demonstrated benefits of flyless life through pesticides. The real impetus of the increasing use of pesticides, of course, has been the tremendous benefits they have brought in production of food and fiber.

We are now faced with the necessity—not merely the desirability—of evaluating the unanticipated effects of the host of chemicals which have been in widespread usage in ever-increasing amounts since World War II. These chemicals are not limited to pesticides—pesticides comprise only a small part of the problem. Many more chemicals are used as food additives, drugs, other household materials, and a complex of industrial effluents that get into the air, food, and water on which man depends. The enormity of the task is not only beyond our economic ability, but almost beyond comprehension, when we know that hundreds of these substances have the potential for interaction with one or more other substances. With limited talents and resources, problems must be selected that are representative of many others and attempts made at their solution.

An illustration is provided by the antibiotic griseofulvin. This pharmaceutical is administered by mouth over long periods to humans with certain fungal skin infections. In the laboratory, griseofulvin produces a high incidence of liver tumors in mice at total doses far less than those used therapeutically in man. Meanwhile, a comparatively inert and nontoxic compound, piperonyl butoxide (PB), used in agricultural pesticidal formulations to augment or synergize the effects of pyrethrums has been developed. The action of PB appears to inhibit detoxifying enzymes in the insect; thus the insect becomes more sensitive to the insecticidal effects of pyrethrum. Piperonyl butoxide administered alone to infant mice was neither toxic nor carcinogenic. However, when administered together with a variety of other agents at nontoxic levels, including griseofulvin, 3,4-benzpyrene (a polycyclic carcinogen widely distributed in the environment), and certain Freons (fluorocarbons with a wide range of domestic and industrial uses), the combination produced a marked synergistic toxicity; additionally, in the case of Freons, combined administrations with PB also produced liver tumors.

These results suggest the need to consider interactions, synergistic and otherwise, between unrelated and related agents when testing for effects of environmental pollutants.

One of the most serious problems that we are facing is not generally recognized, i.e., measuring the long-term hazards of popular materials. Pesticides, for instance, are usually evaluated to acute toxicity. The upper limit of tolerance is established in test animals by administration of high dose rates over short time periods. Often acute toxicity levels are far above exposures man would ever encounter. But we are beginning to recognize more and more chronic hazards—problems resulting from long-term exposure to low concentrations of these chemicals. Thus, acute or short-term hazards are no accurate measure of chronic or long-term hazards. We must develop methods of evaluating both acute and chronic hazards before irreparable damage is done to mankind or his environment.

It may prove to be true that some substances are carcinogenic, irrespective of dosage, but since so many known carcinogens are widespread in our environment, we must develop means to assess our risks. The idea of identifying carcinogens by high dosages administered to exquisitely sensitive animals was predicated on the hope that if such substances were so identified, perhaps man could avoid them and, further, that unless we could identify a no-effect level we should assume that none existed. Carcinogenic food additives and pesticides could be banned and naturally occurring carcinogens could be avoided. This idea developed before our analytical capabilities had included a capacity to recognize the wide distribution of very small amounts of known carcinogens.

We now know we cannot avoid them entirely. We need to assess the relative risks entailed to guide our future actions. Unless we do so, we are heading for an early demise of the industrial research and development of pesticides, food additives, and other useful chemical compounds. The already high cost of such research is being driven to new heights. Many companies are sharply curtailing development of new products simply because their research resources are wholly engaged in defensive research to prove the safety of established products. This is the dilemma—not only benefit versus cost but also benefit versus risk. These companies are committed to the premise that products must be as safe as is possible, that risks should be minimal. They firmly believe that a long record of wide usage has proved the safety demanded.

The alternatives are not simple but they suggest that the Federal dollar must be spent either *a*) to develop and safety test new compounds (after which companies will vie with each other in efficient production), or *b*) to develop protocols for testing that are reliable and feasible for the companies to undertake or to contract for with commercial research laboratories. Otherwise, these extra costs will increase product prices markedly. Another approach might be legislation to permit industrial collaboration which otherwise could be viewed as industry-wide price fixing, outside the public interest. Science can study, but only the public can make such decisions.

A new approach to research must be developed. While

Federal laboratories have increased tremendously in scope and ability during the past 2 decades, and additional Federal funds have been devoted to the development of research potential and manpower in our universities and nonprofit research institutions, these growth curves have lagged behind the growth of research and development in industry. Today, this trend is being reversed. Even when allowances are made for the promotional aspects of the "D" in "R and D," industry has provided the bulk of the funds. In some segments of industry, however, such as aerospace, tax dollars support much of these industry expenditures.

With decreasing Federal support, it was hoped that industry, through product sales, would take over. But the Food and Drug Administration has the policy of requiring industry to pay the bill for testing—a cost passed on to the consumer, who is also the taxpayer. In this application, this policy appears sound. However, regulatory demands for more elaborate testing to insure safety are adding unprecedented costs to industry's research effort.

These alternatives are based on present methods of requiring industry expenditures for safety testing. But if a new factor could be introduced into safety testing, i.e., industry, government, and academic cooperation, if tax dollars could be used to develop, test, and evaluate protocols for establishing safety, the cost to both industry and the consumer who pays the taxes, directly or indirectly, could be reduced. This can be accomplished only if communications among industry scientists, regulatory scientists, and academic scientists are vastly improved and a concerted effort made to coordinate existing knowledge as well as discoveries derived from research.

At this moment, there is great need for reliable methods of extrapolating from animal experiments to man. While one could hardly expect this extrapolation to be either direct or simple, it would help tremendously if we could determine with repetitive reliability the dosage levels at which no chronic adverse effect can be expected in man. How this can be done is a subject of much discussion at present. From this discussion will emerge theoretical approaches to the solution. Federal funds are needed to test these approaches. Once reliable methods have been demonstrated, industry risk funds again will be expended. The probability of this will be vastly enhanced if the scientific community, government, industry, and academic, can become cooperatively involved.

This cooperation might well be regarded as the outstanding hoped-for breakthrough in the future since it is the essential ingredient to the success of developing safety standards. Now, no proof of safety exists; we only assume safety in absence of evidence to the contrary.

Meanwhile, it is reasonable to expect the following specific advances to take place:

a) continued development of biological pest control. Research on pest predators, radiation sterilization, and chemical sterilizants has increased the potential of control through means other than conventional pesticides, and thus reduced the risk that they offer to human health.

b) continued development of specific pesticides. The development of agents which have control effects on specific pests permits more precise use of pesticides and reduces the necessity for widespread coverage of agricultural areas with a general purpose agent irrespective of local essential requirements.

c) development of relatively safe, nonpersistent pesticides. The nonpersistent pesticides in current use are, for the most part, toxic to man in the form in which they are used. Fatalities are not uncommon in children who have access to material, and accidental poisonings occur in the applicators and other workers in recently treated crops. Safe forms of nonpersistent pesticides should be under development.

d) development of integrated chemical and biological control programs. The most effective and safest combinations of chemical and biological control agents for various crops are under investigation and should lead to optimal combinations in the next decade.

e) development of presently unavailable data on the more subtle and slowly produced effects of synthetic chemicals and pharmaceuticals individually and in combination on the basis of epidemiological retrospective and prospective studies of very large samples of humans.

f) development of more effective and time-compressing methods of laboratory animal assays of synthetic chemicals and pharmaceuticals.

The principal effect of the six developments just mentioned would be reduction of the chances for the initiation or the promotion of long-term degenerative disease processes such as carcinogenesis. To this should be added a corresponding reduction of the chances of teratogenesis and mutagenesis from the action of certain agricultural and household chemicals, as well as pharmaceuticals, on the human reproductive system.

SUMMARY AND CONCLUSIONS—CHEMICAL HAZARDS

The overall picture of significant environmental chemical pollutants and the disease states which either have been proved or are highly suspected to be related to them has been summarized in Table 3. It is noteworthy that these diseases head the list of causes of morbidity and death as well as of shortening of life expectancy. The following conclusions have been drawn with reference to chemical hazards to man:

1) Airborne pollutants possess greater potential for contributing to man's deteriorating health with age than do waterborne and foodborne contaminants together.

2) As a rule, pollutants express their effects only through interaction with other agents or with some preconditioning factor(s) within the host (a natural consequence of their extremely low ambient levels) be they infectious agents, trace-element deficiencies, or genetic defects of metabolism. Thus environmental pollutants must definitely be in-

TABLE 3. *Disease states for which evidence points to environmental pollutants as either direct or contributing causes*

Disease	Geographic Distribution		Relative Incidence Index[a]	Etiologic Pollutants and Associated Conditions	Direct	Contributing
	General	Localized				
Accelerated aging	+		High	Ozone and oxidant air pollutants	+	
Allergic asthma		+	High	Airborne denatured grain protein and other	+	
Cardiovascular disease Atherosclerotic heart disease	+		High	"Hard" waters and hereditary tendency, Cr-deficiency states, CO(?)		+
Berylliosis		+	Very low	Airborne Be compounds	+	
Bronchitis		+	High	Acid gases, particulates, resp. infection, inclement climate		+
Cancer of the G.I. tract	+		Medium	Carcinogens in food, water, air and hereditary tendency		+
Cancer of the respiratory tract	+		Medium	Airborne carcinogens and hereditary tendency		+
Dental caries		+	Low	Se	+	
Emphysema	+		Medium	Airborne respiratory irritants and familial tendency	+	
Mesotheliomas	+		Low	Asbestos and associated trace metals and carcinogens (air, water) (other fibers?)	+	
Methemoglobinemia infant death		+	Low	Water-borne nitrates and nitrites	+	
Renal hypertension		+	Low	Cd in water, food and beverage in As and Se-low areas(?)		+

[a] A composite index derived from an estimate of incidence, geographic extent and seriousness of effect. (From Stockinger (11).)

cluded among the multiple factors in the causality of chronic degenerative disease.

3) Acceleration of aging is the dominant characteristic of the effect of many of the top eight of the environmental pollutants. The imposition of such effects on the normal process of aging, whose complexities are only beginning to be understood, compounds the difficulties in either determining causal relationships or assessing the degree of contribution from environmental pollutants.

4) Finally, decidedly in the overall evaluation are the counteractants, the natural antagonists existing both in the environment and within the host. To measure only the pollutants without the counteractants can lead to an overestimation of the health problem. The homeostatic mechanisms leading to adaptation provide the balance to counteract the effects of pollutants at existing levels in the United States among the majority of the population. It is only when this balance is upset through predisposing disease or genetic fault (susceptibility) that environmental pollutants exert effects on man.

Major difficulties militating against the adequate solution of these environmentally induced disease problems include our inability to isolate the effects of any one chemical pollutant from others to which we are exposed, the long latent period for some cancers (e.g., 18 years for aromatic amine-induced bladder cancer), the longer latent period for genetic effects (e.g., more than one generation), our grossly inadequate base-line data due to the lack of national registration systems for cancer, birth defects, genetic defects, occupational disease, and the like, and the gross insensitivity of our animal testing procedures.

Realization of these concepts and also of the high total costs of human disease clearly indicates the need to strengthen anticipatory and preventive approaches, apart from improving our techniques for testing, recognition, and measurement.

What is required is an adequately supported interdisciplinary investigation to determine the distribution of the respective chemical hazards in the environment and their availability to and effects on plants, animals, and man; to consider ways and means of standardizing data collection and analysis and computer storage and retrieval; to establish avenues of communication and ways of disseminating information among the interdisciplinary groups; and to promote interdisciplinary national and international education in regard to the chemical environment and its effect on health and disease. The efforts of such an investigating group would provide an extremely important start toward the hoped for identification on a statistically sound basis, those correlations between geochemical and disease patterns that do, in fact, exist.

PHYSICAL HAZARDS TO MAN

Physical hazards in the environment probably represent the oldest recognized by man. The impact of various geological perturbations such as earthquakes, volcanic eruptions, floods, and tidal waves must have been dramatically evident. Yet, while natural disasters represent one of the major areas of threat to the existence of man, civilization and its resulting urbanization and industrialition has brought with it a number of physical threats that make the natural hazards appear minor. Three outstanding man-made threats to himself are radiation, noise, and accidents.

Radiation

Man has always been exposed to radiant energy, from the sun and from minerals. The extent of the role natural radiation has played in the evolution of man is a conjecture. The discovery of artificially produced X-rays by Roentgen in 1895, and successful nuclear fission in the 1940's, significantly added to the problem of radiation.

The new sources of radiant energy range from large-scale applications of nuclear energy, especially for electric-power generation, through lasers and microwave technology in industry, to the use of radionuclides and X-rays in the healing arts, the rapidly increasing use of microwaves by the communications industry, and in electronic equipment in the home. Our scientific knowledge and protection against this radiation is still at a very early stage. The extensive use of X-ray and other devices based on radiant energy has added appreciable exposure loads to large numbers of patients. Between one-third and one-half of all critical medical decisions are dependent on radiological information. However, only one-sixth of the world's population has access to modern radiology. As a result, throughout the world, including the United States, a large proportion of diagnostic X-ray films are inferior, uncertainly exposed, insufficiently collimated, poorly developed, and, therefore, difficult to interpret.

There are great disparities in the amount of radiation exposure used for comparable procedures and in the levels of genetic radiation doses. Even one X-ray during pregnancy has been found to increase significantly the chances of a child developing cancer during the first 10 years of life. This risk is greatest during the first trimester but exists throughout the pregnancy of the mother. Thus, in a study at the University of Oxford of 15,298 children born between 1943 and 1965, half had died of malignancies before the age of 10 years. The other half served as matched controls. Almost twice as many of the children who developed cancer had been exposed to X-rays before birth as had the children in the control group. If only one X-ray had been taken the increased cancer risk was 1.26 to 1. If five films had been taken, the increased risk was more than double, 2.24 to 2. X-Rays taken during the first trimester of pregnancy led to more than an eightfold increase in risk of childhood cancer.

A recent World Health Organization Expert Committee found that "the types of cancer in man that are directly or indirectly due to extrinsic factors are thought to account for a large percent of the total cancer incidence." It concluded, "Therefore, the majority of human cancers are potentially preventable."

The rapidly expanding use of ionizing and nonionizing radiation for weapons manufacture, power development, industrial uses, communications, and other purposes introduces to the air, water, and land a pollutant awesome in its potentials and implications. Merely the problem of safe disposal of the large amounts of radioactive wastes is beginning to appear overwhelming. Added to this are the dangers of leakage from stored materials, of radioactivity transmitted to cooling waters, and the problem of thermal pollution of streams and lakes, possibly eventually of even the ocean itself.

Of the total radiation exposure to which people in this country are subject, 45 % is from natural sources, such as from minerals and from the sky (cosmic); 55 % is from man-made sources, most of which (45 % of the total) is from medical equipment. Industrial and occupational sources account for 7 % of the total, and television screens, luminous clock-watch dials, and fallout plus fission testing, account for 1 % each. It is important to remember that radiation cannot be directly detected by the senses and that the effects of radiation are irreversible. There is no immunity against radiation; parts of the body escaping damage from one exposure do not have an increased tolerance for future exposures.

Radioactive minerals provide real radiation hazards for the men who mine them. Among a group of 907 white uranium miners with more than 3 years of underground experience, death rates were 17.8 times the normal rate from heart disease, 5 times the normal from respiratory cancer, and 4.5 times normal from nonautomotive accidents; of 6,000 men who have been uranium miners, it is estimated that 600 to 1,100 will die of lung cancer in the next 20 years.

Two outstanding achievements of recent decades in the field of radiological health have been the development of an understanding of the genetic effects of ionizing radiation and the development of a logical basis for standards in radiation protection. Some of the genetic changes that can be effected by radiations and other hazardous agents are discussed in another chapter. The development of standards in radiation protection has resulted from the cooperative efforts of many people and a number of different organizations.

In radiation standards development perhaps the best references are found in the published reports of the Federal Radiation Council, the National Committee on Radiation Protection and Measurements, the International Commission on Radiological Protection, the United Nations Scientific Committee on Atomic Radiation, and the standards hearings of the Joint Commission on Atomic Energy.

Research on the genetic effects of radiation provided an experimental basis for determining the limits of radiation exposure to large groups of people and for improving national and international standards. A nuclear test ban treaty was stimulated by the data accumulated. While human health was not improved in the sense of curing radiation sickness, it was improved in a preventive sense. Undoubtedly millions of people are enjoying better health today because of the improved standards that have been developed.

These research developments and higher standards have, from a preventive standpoint, led to a better basis of control in the nuclear industry, in military applications of nuclear energy, and in the medical use of radiation as in X-ray machines. For the most part, the scientific community and the government agencies involved deserve great credit and recognition for meeting this important problem in a most orderly way. Yet, even more could have been achieved more effectively if organized medicine had taken a more constructive approach toward a critical review of its practices and had encouraged a greater effort in establishing medical X-ray standards and techniques for compliance with them. Many physicians provided real leadership in the effort but more valuable human data could have been obtained if physicians had participated to a greater extent. Had it been possible earlier to have openly and freely discussed such things as plutonium, tritium, iodine, and krypton from the standpoint of radioactivity, earlier recognition could have been given to the problems involved in the use of these and other radioactive substances in the medical and bioscientific areas.

Although there continues to be some criticism of the established standards most of the knowledgeable scientists and organizations find them acceptable, while continuing periodically to reevaluate them relative to necessary improvements. The adequacy of ionizing radiation standards could be made better in the future if additional information were available on the long-term effects of the radiation on animals and man, obtained through long-term animal studies and epidemiological studies of human populations. Such studies would require long-term investments, best assured as a national commitment to this purpose.

Because of the extensive work already done in the field of ionizing radiation, dramatic breakthroughs in this area are not very likely to occur in the near future. It is anticipated, rather, that painstaking research will produce new information in regard to such things as the genetic effects of radiation, the problem of radiation exposure during pregnancy, and radiation problems related to tritium. It is more likely that breakthrough types of advancement may occur in the field of nonionizing radiation, which has been investigated to a less extent, or perhaps in the area of sonic radiation (ultrasonics) and its biological effects. Perhaps the achievements to date in the field of ionization radiation and the ionizing radiation standards will serve as a stimulus and a model for advances in the more slowly developing field of nonionizing radiation.

A system should be established which makes it mandatory to allow scientists within the government or working under government contract to publish their findings without restriction in appropriate scientific journals irrespective of administrative clearance (other than national security). This would help the scientists and would provide a forum for discussion in the scientific community. It would also protect those administratively responsible because it would minimize the import that scientific papers represent on agency position. The scientific efforts of the personnel of an agency should not become automatic determinants in the development of policy, and administrative considerations should not be allowed to prevent the results of scientific research efforts from reaching the appropriate scientific community.

ENVIRONMENTAL HAZARDS

Another of man's environmental physical hazards is noise. This immediately gives rise to perplexing questions: What is noise? Can it actually produce ill effects? If so, how, under what circumstances, and with what other factors? Are any ill effects reversible? How might they be prevented? These question indicate noise to be the least understood of the environmental hazards. The only way to delineate the noise problem of a community is to note the sociological changes that might occur. If this could be done, then it might be possible to judge whether noise is totally, partially, or not at all responsible for any changes. Noise is more difficult to deal with than most other nuisances or environmental factors because it is partly subjective. In any society, each individual must necessarily accept a certain amount of annoyance, inconvenience, and interference. The essential question is how much and at what point may actual harm become a possibility.

There are three measurements of noise as a hazard to health: its intensity, its frequency, and the length of exposure. Depending on these, the environmental circumstances and the individuals involved, the effects of noise fall into four general categories: annoyance, disruption of activity, loss of hearing, and physical or mental deterioration. Annoyance is the most widespread response to noise. Some claim that annoyance is not related to health, but the issue is academic since noise abatement can be justified from either standpoint. An annoyance condition may aggravate existing physical disorders. Noise which disrupts sleep can lessen the body's resistance to disease or physical stress, and noxious noise generally disturbs one's feelings of well-being. Excessive sound can lead to somatic manifestations such as stomach problems, including ulcers, and allergies such as hives. In certain instances excessive noise is thought to aggravate mental illness. Evidence has also been found that exposure to certain types of noise causes constriction of the blood vessels near the skin surface, an effect that does not disappear with adaptation to the noise.

Noise can cause the blurring or masking of speech and other wanted sounds. Thus, noise from machinery may interfere with instructions to a worker. A number of hospitals, especially near airports, have noted an apparent effect on the ability of patients to convalesce. In the field of education noise disrupts attention and hinders concentrated mental effort.

The greatest physiological effect of noise is hearing loss, temporary or permanent. Temporary impairment of hearing, called auditory fatigue, occurs after short exposure to intense noise. Exposure to a continuous high level of sound with inadequate recovery time between exposures may lead to permanent hearing damage.

In terms of the measurements of intensity, frequency, and length of exposure, their effect on hearing loss is as follows: intensity—exposure to sound pressure levels of over 80 decibels is hazardous, but there appears to be no permanent hearing hazard for levels below 80 decibels. Frequency—the inner ear is more susceptible to damage at middle and especially higher frequencies in the audible range than at low frequencies, and damage increases with increased exposure time. In addition, a fourth factor is the susceptibility of an individual's inner ear to noise-induced hearing loss. Individuals vary in this regard, but about 3% of the general population may be classified as highly susceptible. A survey between 1959 and 1961 by the Public Health Service of the population of the United States showed that the rate of hearing impairment per 1,000 persons was 7.6 for those under 25 years of age, 22.2 for those aged 25 to 44 years, and 51.2 for those between 45 and 64 years. Continued exposure to loud noise was believed to be the major cause of the increase as years of life passed. This is in agreement with the estimate that about 18 million Americans suffer total or partial deafness and that among working males two-thirds of the hearing loss is caused by noise. The progressive loss of hearing as age progresses is known as presbycusis.

Research on hearing acuity has been carried out among the Nilitic tribes in the Sudanese desert. These people live in probably the most noise-free area on earth. They have no musical instruments and apparently do not even sing. Remarkable hearing acuity has been observed, exemplified by their ability to communicate with a normal speaking voice over long distances and a sustained hearing acuity not only among the adults but also in the aged.

However, in the field of noise as an environmental health hazard, the progress made is the result of patient studies that often appear pedestrian but which are necessary if realistic damage–risk criteria are to be established. To assess the physiological effects of noise, one must either find a population of persons whose necessary noise exposures can be measured in detail or expose experimental animals under controlled conditions. Because of individual differences in susceptibility to damage by noise, either course involves a large number of subjects and is, therefore, expensive.

Although no breakthroughs can be indicated, progress has been steady. It is now known how much steady 8-hour/day, 5-day/week noise can be endured with negligible risk to hearing. We are on the way toward determining equally reliable damage–risk criteria for intermittent noise exposure and for impulsive noises such as gunfire. The quantification of the relations between the physical and temporal characteristics of intense sound and the degree of both temporary and permanent losses in hearing thus induced has been a significant accomplishment in the past 30 years. Now there is some agreement that hazards to the hearing from exposure to noise can be predicted with confidence. As a result it has been possible to set tolerable limits of noise exposure in both industry and in the community. Noise-induced deafness is a pervasive disease and social handicap that is now suffered by millions.

Once it could be shown that a level of 80 decibels or higher was hazardous, it was easier to convince workers that the use of ear protection devices was good sense. This, of course, is more of an educational achievement than a research one, but there now are young drop-forge operators, riveters, jet mechanics, and policemen who still have normal hearing because they use these ear protections.

Perhaps the most significant results achieved in the past 3 decades have been the *negative* ones—that is, studies that show that some of the effects attributed to noise on an anecdotal basis are only folklore. Research on the effects of noise on sleep and on the neurovegetative system continue, and should continue, even though results are ambiguous. Study of the physiological changes in the cochlea associated with noise damage should also continue, even though there seems to be little hope that we will ever uncover any sort of ameliorative agent that will reduce significantly or partially restore the damage done by noise.

In the future, some of the more subtle effects of noise on mental and physiological stress may be discovered and measured. This would permit the specification of tolerable limits and the exercise of noise control. Present research data are very controversial and need clarification. *1*) How much noise energy is tolerable as a daily dosage if the exposure is intermittent instead of continuous? *2*) Are very young or very old people more susceptible than others to damage from noise? *3*) In the case of persons with noise-induced hearing losses so severe as to cause trouble understanding ordinary conversation, how can the information in the speech signal be recoded so that understanding is restored? *4*) Is hearing loss, as measured by changes in auditory threshold, really an adequate measure of the damage actually done by noise? (Recent animal research has indicated that extensive irreversible damage to the hair cells of the cochlea may occur without affecting threshold significantly; if this is confirmed, it could be considered a genuine breakthrough.) *5*) Is an ear that has already been moderately damaged more susceptible to further insult than an unsullied one? *6*) Are there any long-range consequences of repeated autonomic excitation by noise?

In addition to progress in the acquisition of physiological and anatomical knowledge, there is need, of course, for significantly improved technology in noise abatement with reference to heavy industry, housing, streets, highways, and planes. This appears to be coming to a head rapidly as a result of the burgeoning aerospace industry and its present and potential effects on the environment of man and other creatures.

Injury

With the decline in mortality rates from communicable diseases, the relative importance of injury as a cause of death has increased. Accidental injury, suicide, and homicide rank 4th, 12th, and 14th, respectively, among the leading causes of death. The 10-year trend (1958–1967) shown in Table 4 makes it clear that little recent progress has been made in reducing the hazards.

Although morbidity data have no real meaning with respect to homicide and suicide, the attack rate for accidental injuries is approximately 25%—exceeding the common cold in frequency. Some 52,000,000 annual injuries require medical care or at least 1 day of restricted activity. Injury victims require more general hospital beds than any other class of patient (20,000,000 bed-days/year) and require 80,000 man years of professional care.

The sophisticated statistics of the injury problem are not matched by the availability of control measures. Research on behavior, both aberrant and delinquent, has not yet provided enough information to move confidently with preventive programs. Research on injury epidemiology, agent modifications, and environmental adaptation, coupled with safety education, has produced some tangible benefits for injury control.

A most important development has been in precise methods of analysis of the causes of accidents. The epidemiological and biostatistical methods used in the study and control of disease have been applied to accidents. We now get valuable information on the major categories and specific kinds of accidents and injuries, those experiencing them, conditions of occurrence and the interrelationship between persons, environmental factors and specific agents producing the injury. This information is useful in designing methods to reduce accidents.

Another advance has been the development in the field of human factors engineering (ergonomics), the major

TABLE 4. *Death rates in United States from accidental injury, suicide and homicide between 1958 and 1967*

Cause of Death	Death Rate									
	1967	1966	1965	1964	1963	1962	1961	1960	1959	1958
Accidental injury	57.2	58.0	55.7	54.3	53.4	52.3	50.4	52.3	52.2	52.3
Suicide	10.8	10.9	11.1	10.8	11.0	10.9	10.4	10.6	10.6	10.7
Homicide	6.8	5.9	5.5	5.1	4.9	4.8	4.7	4.7	4.6	4.5

Source: Vital Statistics of the United States 1967.

objective of which is to reduce accidents and injury by better integration between man and the equipment he uses, paying attention to biological and psychological as well as physical factors. Originally developed in relationship to safer design of complex military and aerospace equipment, the ergonomic principles have been applied increasingly to civilian transportation and industrial operations.

Advances have been made in the development of greater protection of an individual from injury by redesigning equipment, such as machine-tool guarding, the padding of automobile instrument panels, recessing knobs and strengthening door locks on cars. Air-bag restraints are now being developed. However, illustrating the great need for behavioral research, only one in three drivers actually uses seat belts even where the law requires them.

Over the past 30 years there was a gradual improvement (decrease) in accidental death rates on a population basis. But improvements can be definitely cited only in the rates of injury in industrial work situations, and here the improvements seem to be getting less. The outstanding exception to improvement has been in the death rate due to motor vehicle accidents. The death rate remained the same for 20 years until 1960, but during the last 10 years it has increased possibly due to increased exposure to hazard and inadequate controls.

Much useful information on fatal and nonfatal accidents has been provided by the National Health Survey. Home accidents have been found to result in about half as many deaths as motor vehicle accidents, but they account for more than twice as many bed-disabling injuries and about seven times as many less severe nonfatal injuries.

Significant advances in accident prevention and injury control have been made by the application of biological and human factors information in air transportation and military flying. This information has been obtained by studies on human factors in relation to equipment design, from research on flight physiology and aerospace medicine, from the development of criteria for the medical and psychological selection of flying personnel and for maintaining their health and efficiency, and from especially intensive and extensive analyses, including autopsies, of accidental occurrences. The Armed Services schools of aviation medicine and the universities have helped to train the personnel for this work. No corresponding trained group exists for the control and treatment of highway injuries.

In automobile accidents the impact of the steering wheel and column is a major source of injury and death. A very substantial reduction in driver injury has been achieved by designing steering wheel rims and spokes so they would deform rather than break under impact and by using larger steering wheel hubs that would spread the impact forces. Another important development has been the seat belt, developed when studies showed that ejection from the car was a frequent factor in producing death or serious injuries. Seat belts reduce injuries and deaths, yet efforts to induce the majority of car occupants to use them have been unsuccessful. More recently combined lap-and-shoulder belts have been developed to both prevent ejection and reduce injuries inside the car, and they have proved very effective. In Sweden, in 28,000 accidents analyzed, no deaths of lap-shoulder belt wearers occurred at impact speeds less than 60 miles per hour, while fatalities did occur among non-wearers beginning at a 26 mile per hour impact speed.

In the United States, educational programs have helped reduce other types of injury by changing human behavior. In one Arkansas county within 1 year the incidence of burn injuries requiring hospitalization was cut to half of the 5-year average. The injuries were caused by improper wiring in the home, misuse of petroleum products, and proximity of flammable materials to heating units. In one county in South Carolina, hospitalization for poisoning accidents was reduced by 29% as a result of a 3-year educational project for parents of young children. In a Philadelphia area, a small-group educational program was carried on for a year relative to injuries occurring to members of the several groups or their families. In 1 year inpatient admissions to the hospital had decreased by 17%, and admissions from the areas in which the members of the discussion groups lived decreased by 26%. Some studies in the circumstances relating to injuries from falls of older persons, accidents with a high death rate, have provided helpful information relative to the severity of skeletal degeneration (osteoporosis) in these people, frequency of bone fractures, some of which were found to have preceded the accidental fall, and the like. Other studies have indicated that fluoridation of water supplies may retard the skeletal degeneration and perhaps decrease the frequency of bone fracture injuries in the elderly. A Swedish study showed that the rate of fractures was much higher in postmenopausal women than in men of comparable age.

Accidents lead all diseases as a cause of death between the ages of 1 and 37 years, yet research on the causes of accidental death has been relatively unsophisticated. Opportunities for the necessary professional training for accident research have been very limited. In 1969, only two of ten schools of public health offered training for this area. Nor have sustained funding patterns for non-transport accident research and control been developed. Currently only 1 dollar goes for research on accidents as compared with 300 dollars for medical research. There is no basic reporting system to provide data for the evaluation of community programs; systems for epidemiological intelligence or surveillance have not been developed on a geographically balanced basis. No central repository exists for information on injuries and rapid retrieval systems for data are only in development stages.

A significant reduction in the total number of accidents in the near future is unlikely but recent developments may eventually bring improvements. New concepts from the fields of biostatistics, medicine, engineering, and psychology are providing impetus for experimental studies and the design of safety programs. Work is underway to determine injury thresholds of the human body relative to impact forces, data important to the design of protective devices. Neurosurgeons have studied head injuries from a variety of high impact accidents. Public interest has increased somewhat and there has been national legislative activity such as the highway safety acts of 1966, legislation relating to fabric flammability and other hazards to child safety, product safety, and consumer protection; these can provide impetus for increased attention to accident potentials in private and industrial sectors. Health personnel and the medical profession seek to improve emergency medical services. But there is an urgent need for a strong centralized national accident prevention program to *1*) conduct research, *2*) provide technical assistance to states and communities, *3*) train personnel, and *4*) supply financial support. The savings could, in the long run, be enormous. An effective prevention and control program for accidents could result in *1*) an annual prevention of 30,000 fatal injuries, *2*) the saving of 60,000 people annually through prompt medical care, *3*) the prevention of 10,000,000 accidental injuries each year, *4*) the annual saving of 2,000,000 hospital bed-days now needed for accident victims, *5*) the annual savings of 8,000 man-years of medical care services, and *6*) an annual 3 billion dollar reduction in direct costs to accident victims. Accidental death and disability truly represent the "neglected disease" of modern industrialized society in this country.

SUMMARY AND CONCLUSIONS—PHYSICAL HAZARDS

These are but some of the environmental hazards with which modern man must contend. They have given rise to the rapidly growing field of Environmental Medicine which applies the principles and knowledge of biological and epidemiological research to an understanding of a complex of physical, physiological, and psychological disturbances. The results of these disturbances now constitute the major portion of accident conditions which come to the attention of the medical practitioner, unfortunately too often too late.

Patterns of morbidity and mortality are changing. Evidence from data obtained from past efforts may not be relevant to future events. People, their hazards, and their diseases are changing. The illnesses that will be experienced within a few decades will not be the same as those of today, much less of yesterday. Environmental factors certainly enter into their causation, but to what extent and in what manner is still largely to be determined, and only by means of research.

Environmentally induced chronic diseases are now known to have certain characteristics. *1*) Typically they result from low-level exposures, insufficient to produce acute reactions. *2*) They tend to develop insidiously over long periods of time. *3*) By the time they are clinically recognizable, the conditions are often irreversible. Emphysema, asbestosis, some cancers, teratogenic anomalies, and environmentally induced hearing loss are good examples.

Several years ago the direct health effects of environmental hazards on man were summarized by the President's Science Advisory Committee. Five categories of increasing severity were listed as follows: *1*) annoyance, irritation, and inconvenience, which while certainly real, produce effects that are uncertain and almost impossible to measure; *2*) physiological effects of unknown clinical significance, which occur on a transient basis and the cumulative effect of which is quite uncertain; *3*) worsening of existing diseases or disability and increasing the general level of sickness, the determination or evaluation of which is quite open; *4*) effects of a general increase in the death rate, again quite open; and *5*) the initiation of specific progressive disease, an area also with many questions unanswered.

The general conclusion was that the human effects of environmental hazards were very poorly understood but, because of the obvious importance of the effects, delay in intensive and extensive study could not be avoided.

In any consideration of most needed research in this field, four fundamental characteristics of environmental hazards stand out. *1*) They tend to be ubiquitous. *2*) They tend to be multifaceted as to sources and effects. *3*) They are generally insidious in their action time frame. *4*) They often act in concert and may potentiate one another.

Despite these characteristics it has been customary for science, industry, and government to study and deal with environmental hazards separately. For example, is mercury hazardous, in what physiological way, at what levels, and with what effects? The same question is asked about lead, pesticides, individual pharmaceuticals, sulfur oxides, and so on, each separately, each usually in terms of acute effects, and each in terms of toxicity alone, ignoring possible carcinogenic, teratogenic, mutagenic, and psychic effects. This approach has led to the fallacious tendency to decide that X is the toxic or dangerous level of a particular substance or hazard and that in order to be conservative perhaps one-tenth of that amount should be designated as the minimum toxic level. This ignores the fact that humans are not exposed to one substance alone but to an extensive and cumulative spectrum of hazards, each of which might even be minimal but the total burden or effect of which might be critical or overwhelming.

From an overall viewpoint, present efforts for the study of environmental hazards to modern man may be considered to fall into these categories: *1*) the search for and application of new experimental and clinical methods of defining health risks from known or potential environmental contaminants and hazards; *2*) more intensive studies of synergistic potentials of the innumerable combinations of environmental hazards with particular consideration of the development of toxicity, carcinogenicity, tetragenicity, mutagenicity, physical injuries, and psychic stress; and *3*) the categorization of physiological and biochemical hazards in terms of human population and risk.

Obviously any sound approaches to eventual protective measures must be based on the results of such essentially biological research.

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