RESTORING THE QUALITY

OF OUR ENVIRONMENT

Report of The

Environmental Pollution Panel

President's Science Advisory Committee

October, 1965

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INTRODUCTION

> Environmental pollution is the unfavorable alteration of our surroundings, wholly or largely as a by-product of man's action, through direct or indirect effects of changes in energy patterns, radiation levels, chemical and physical constitution and abundances of organisms. These changes may affect man directly, or through his supplies of water and of agricultural and other biological products, his physical objects or possessions, or his opportunities for recreation and appreciation of nature.

The production of pollutants and an increasing need for pollution management are an inevitable concomitant of a technological society with a high standard of living. Pollution problems will increase in importance as our technology and standard of living continue to grow.

Our ancestors settled in a fair and unspoiled land, easily capable of absorbing the wastes of its animal and human populations. Nourished by the resources of this continent, the human inhabitants have multiplied greatly and have grouped themselves to form gigantic urban concentrations, in and around which are vast and productive industrial and agricultural establishments, disposed with little regard for state or municipal boundaries.

Huge quantities of diverse and novel materials are dispersed, from city and farm alike, into our air, into our waters and onto our lands. These pollutants are either unwanted by-products of our activities or spent substances which have served intended purposes. By remaining in the environment they impair our economy and the

quality of our life. They can be carried long distances by air or water or on articles of commerce, threatening the health, longevity, livelihood, recreation, cleanliness and happiness of citizens who have no direct stake in their production, but cannot escape their influence.

Pollutants have altered on a global scale the carbon dioxide content of the air and the lead concentrations in ocean waters and human populations. Pollutants have reduced the productivity of some of our finest agricultural soils, and have impaired the quality and the safety of crops raised on others. Pollutants have produced massive mortalities of fishes in rivers, lakes and estuaries and have damaged or destroyed commercial shellfish and shrimp fisheries. Pollutants have reduced valuable populations of pollinating and predatory insects, and have appeared in alarming amounts in migratory birds. Pollutants threaten the estuarine breeding grounds of valuable ocean fish; even Antarctic penguins and Arctic snowy owls carry pesticides in their bodies.

The land, water, air and living things of the United States are a heritage of the whole nation. They need to be protected for the benefit of all Americans, both now and in the future. The continued strength and welfare of our nation depend on the quantity and quality of our resources and on the quality of the environment in which our people live.

The pervasive nature of pollution, its disregard of political boundaries including state lines, the national character of the technical, economic and political problems involved, and the recognized Federal responsibilities for administering vast public lands which can be changed by pollution, for carrying out large enterprises which can produce pollutants, for preserving and improving the nation's natural resources, all make it mandatory that the Federal Government assume leadership and exert its influence in pollution abatement on a national scale.

We attempt here to describe the problem, to distinguish between what is known and what is not, and to recommend steps necessary to assure the lessening of pollution already about us and to prevent unacceptable environmental deterioration in the future.

THE EFFECTS OF POLLUTION

Health Effects

Pollution affects human health and comfort in a number of ways. Under some circumstances, fortunately now rare, it brings overt clinical disease or even death. More commonly, however, it produces lesser effects, such as difficulty in breathing and impaired lung function from inhalation of polluted air, irritation of eyes, nose, and throat, unpleasant tastes or odors, psychological or behavioral effects.

Excessive air pollution for short periods (acute episodes)

Hazards from atmospheric pollutants have been demonstrated most vividly in episodes of acute exposure. There are many reliable reports of individuals and small groups made ill or even killed by occupational or accidental exposure to toxic fumes, vapors, pesticide aerosols, smoke, or high concentrations of dust. A few community catastrophes have resulted from combinations of fog, temperature inversion, and air stagnation, coupled with unusually large amounts of ordinary combustion-produced atmospheric pollutants. In these rare but tragic episodes, fatalities occurred predominantly among the elderly and those with pre-existing cardiac or pulmonary disease.

Certain communicable diseases, such as tuberculosis, influenza, and the common cold, are transmitted by airborne microorganisms.

Prolonged exposure to ordinary urban air pollution

While we all fear, and many believe, that long-continued exposure to low levels of pollution is having unfavorable effects on human health, it is heartening to know that careful study has so far failed to produce evidence that this is so, and that such effects, if present, must be markedly less noticeable than those associated with cigarette smoking. Attempts to identify possible effects of ordinary urban air pollution on longevity or on the incidence of serious disease have been inconclusive. Special attention has been focused on lung

cancer, which is known to be closely associated with tobacco smoking, and with the inhalation of radon, other radioactive materials, nickel carbonyl, chromates, asbestos and other chemicals. There are consistent findings of a greater incidence of lung cancer in the cities than in the country, and it is possible that urban air pollution is a contributory factor in this disease. But its role is uncertain except in special situations, such as proximity to industrial plants that handle known carcinogenic materials.

Urban atmospheric pollution can aggravate asthma and some other chronic respiratory illnesses, and can cause transient eye and respiratory tract irritation. Evidence from animal studies suggests that exposure to air pollution may increase susceptibility to pulmonary infections.

Water-Borne Pollutants and Health

A century ago, our population was ravaged by water-borne diseases, among which typhoid fever, cholera, and dysentery were conspicuous. These tragedies led to today's water treatment methods, which, when applied, control adequately most disease-producing bacteria. Viruses, such as those of hepatitis, remain a problem.

Chemical pollutants in water sometimes threaten human health. Substantial contamination of ground water with nitrates derived from sewage or from fertilized farm fields has been reported in several states. Drinking water with nitrate-nitrogen levels above 8 or 9 ppm,

which are occasionally reached, may cause methemoglobinemia in infants.

Pesticides and Human Health

The tremendous growth in the variety and use of organic pesticides since World War II has caused concern as to their possible effects on human health. Exposure occurs chiefly from ingestion of foods, from direct skin or respiratory contact during use, and from inhalation of airborne materials near treated areas.

Small numbers of persons perish each year in this country from accidental or occupational misuse of pesticides, and from deliberate ingestion with suicidal intent. It is estimated that about 100 cases of non-fatal poisoning occur for every fatal case. Despite the increasing use and variety of pesticides, there is no evident increase in mortality attributable to their use.

Chlorinated hydrocarbon and phosphate ester pesticides have been detected in many surface and ground waters, in amounts ranging up to a few parts per billion. These small concentrations are not known to be a threat to human health. On rare occasions, higher concentrations of pesticides appear in potable waters, usually as a result of industrial discharges. Human illness traced to pesticides in public water supplies has not been reported, but examples of illness from domestic well contamination may have occurred.

Although deaths and overt illnesses from pesticide poisoning are rare, everyone in the United States has a measurable body burden of some of these substances, accumulated mainly from small contaminating amounts in food and water. Some 20 tons of DDT residue is contained in the bodies of the people of this country; the average amount for each individual is thus about a tenth of a gram. Measurable amounts of dieldrin and other chlorinated hydrocarbon pesticides have also accumulated in our bodies. Clear-cut adverse effects on health of these small accumulations have not been recognized. However, animal experiments have not yet demonstrated safe levels for some of the more dangerous pesticides.

In the bodies of greenhouse workers, spray pilots, and others who have received occupational exposures, the levels of pesticides are higher than in most of the people. These workers sometimes show marginal or definite impairment of an important bodily function as a result of pesticide exposures.

Effects on Other Living Organisms

Why do we care?

Man is but one species living in a world with numerous others; he depends on many of these others not only for his comfort and enjoyment but for his life. Plants provide the principal mechanism whereby energy from the sun can serve the earth's inhabitants. In doing so, they

maintain the oxygen content of the air and furnish the basic habitat and food of animals and men. Microorganisms--bacteria, algae, fungi, and protozoa--perform a myriad of essential functions including the purification of air, soil, and water, and the recycling of nutrients. Animals serve man as great converters, changing plant-stored energy into forms of food he prefers and supplying him with a wide variety of materials: leather and furs, oils and pharmaceuticals, ivory and pearls, bristles and wool. Many insects are beneficial, some as pollinators; others as predators on harmful forms; some as makers of silk and honey.

As contributors to happiness and the quality of life, plants and animals provide opportunities for enjoyment of natural beauty, for hunting, fishing, gardening, scientific study, entertainment, and the satisfaction of our human curiosity.

In the control of pollution, plants, animals and microorganisms are directly useful in two ways: First, living things, especially microorganisms, have a capacity for absorption and decomposition of pollutants, with resulting purification of air, water and soil. Second, many species of organisms, each with its own particular range of sensitivity to each pollutant, stand as ready-made systems for environmental bioassay and monitoring, and for warnings of danger to man and his environment.

Because living things are interdependent and interacting, they form a complex, dynamic system. Tampering with this system may be desirable and necessary, as in agriculture, which involves artificial manipulation of the balances of nature on a huge scale. But such tampering often produces unexpected results, or side effects, and these are sometimes very damaging. Many of the effects of pollution fall into this category.

Kinds of Effects on Organisms Other Than Man

In small amounts, pollution can produce effects so subtle as to escape notice. Small changes in the reproductive rates of birds or fish, for example, can result from pesticide pollution at low levels, yet be very difficult to detect in nature. At high levels, damaging effects of pollution become clearly evident, as when fish are killed in large numbers or bees disappear from a locality.

Pollution affects living things in many different ways: In high concentrations, the sulfur dioxide in stack fumes kills trees and crop plants. The mixture of pollutants in urban smog damages spinach, tobacco, and other valuable plants. Domestic sewage and animal wastes can act as fertilizers, stimulating the growth of algae, but creating unfavorable conditions for game fish. Heating of rivers and lakes by return of waters used to cool industrial processes or power plants can favor some living forms and devastate others. Soils and waters can

be polluted by radioactive materials derived from weapons testing, from industrial release, or from naturally contaminated fertilizers or spring waters. Once in soils or water, the radioactivity may then become concentrated in organisms. Sediments released into streams or lakes can reduce the supply of light for plants, and smother fish eggs and other useful forms.

The effects of pollution on livestock and crop plants often show up clearly because farmers quickly notice any impairment of health or yield. Effects on wild forms are much less likely to be detected and are harder to measure. Disappearance or catastrophic diminution of a wild population often occurs before the effects of a pollutant are recognized.

The effects of pollutants on living things are usually complicated and seldom well understood. Organisms are subjected to many different pollutants at the same time, pollutants that may enhance one another, partially compensate for one another, or act side by side.

Because different species react differently, and because the living world is so thoroughly interdependent, pollution produces profound indirect effects. A pesticide directed at a certain insect pest may, as a side effect, destroy a population of beneficial predator insects, so that a population of aphids that the predators had kept small suddenly multiplies and becomes highly destructive. A pollutant may fertilize a lake, creating vigorous algal growth near the surface, which shuts

off the supply of sunlight from deeper-growing plants. The latter then consume the oxygen dissolved in the water, so that microscopic animals perish, and fish, depending on them for food and on dissolved oxygen for respiration, either starve or suffocate.

Pollutants tend to reduce the numbers of species, and to make the relationships of those that remain less stable. Large bodies of water, such as Lake Erie, may be depleted of many useful living forms. Pollution typically reduces the variety and abundance of wildlife serving our recreation and enjoyment.

From the economic point of view, pollution may produce serious adverse effects on living things used by man. Useful crops have been damaged by air and soil pollution, valuable commercial fisheries have been destroyed or diminished, as in the Great Lakes, Raritan Bay, and Long Island Sound, and wild populations of game fish and game birds valued for human recreation have been reduced. In a few instances, milk from herds of cattle fed on polluted forage has been so contaminated as to be unmarketable.

Impairment of Water and Soil Resources

Excess Fertility in Waters

Many streams, lakes, and estuaries in the United States have received such large quantities of mineral nutrients, originating in sewage or domestic animal wastes, that they have become filled with objectionable

growths of algae and other water plants. These commonly result in a deterioration of water quality, making it unsatisfactory for domestic, industrial, and recreational uses, and for fish and wildlife. Hundreds of water bodies, scattered across the nation, are affected to some degree. Only a few outstanding cases--some of the Great Lakes, Lake Washington, the Potomac and the Mississippi--have received much public attention. In rivers, pollution from excessive nutrients is most common below the waste discharge points of large cities.

Nitrates and phosphates, derived from human and animal wastes, detergents, and agricultural fertilizers, are the most noticeable causes of overfertilization of waters, though other nutrients may possibly be important.

Soil Pollution

Soil pollution impairs the yield or the quality of farm products, and can contribute to subsequent air or water pollution.

Long-term pollution of soils has resulted from repeated application of copper, arsenic, or lead in insecticides, fungicides or fertilizers: The accumulation of poisonous metals has been so great in some orchard soils as to destroy for a period of many years their capacity to raise any useful crop. The yields of certain cotton soils have decreased because of arsenic accumulations. Since the most serious problems have come from the heavy me

insecticides, whose use has recently been greatly reduced, future losses are unlikely to be nearly as serious.

Chlorinated hydrocarbon insecticides, such as DDT, dieldrin, and endrin, can also accumulate in the soil. In extreme cases, the accumulations may be so great as to reduce yields of useful crops. More often, the contaminants appear in human food in detectable amounts either by absorption or surface adhesion. Such pollutants can impair the flavor of food products. Their concentration can approach or even exceed the levels allowable under Food and Drug regulations, causing losses of alfalfa, potatoes, carrots, and beets. The life of chlorinated hydrocarbons in soil is shorter than that of metals, the more persistent ones probably diminishing to very low levels in a few years or at most in one or two decades.

Herbicides may persist in the soil and injure crops months or even years after application. Since most herbicides have a relatively short life in soil, long-term losses of soil usefulness are not likely.

Radioactive substances derived from uranium in some phosphate ores may survive the manufacturing process and persist in the finished commercial phosphate fertilizer. Where such fertilizer is repeatedly applied, radioactive decay products accumulate and can be picked up by roots and transferred throughout the plant. Polonium and radium apparently reach tobacco leaves in this way.

The concentration of salt in river waters used for irrigation is increased by evaporation from reservoirs, canals, watercourses, ditches, and irrigated fields, and frequently also by the inflow of salty tributaries or groundwaters, often to the point where the water, as it flows downstream, becomes hazardous for irrigation. If the water is high in sodium, this element tends to accumulate in the clay fractions of the soil, causing excess alkalinity and swelling of the clays. The soil then becomes only slightly permeable to water, and useful crops cannot be grown. Even in the absence of excess sodium, irrigation sometimes deposits so much salt in the soil as to impair crop yields, but if an excess of irrigation water can be used, these salts can be flushed away.

Polluting Effects of Detergents

The large scale use of synthetic detergents during the past two decades has caused foaming and overfertilization.

Polyphosphate detergents, after domestic or industrial use, are carried in sewage effluents into rivers, lakes, and estuaries, where the phosphate is readily taken up by algae and other aquatic plants. If present in sufficient quantities, such detergents can give rise to obnoxious algal blooms.

Many detergents survive for long times in surface and ground waters because they contain hydrocarbon chains that are not easily decomposed by aquatic bacteria and other microorganisms. These long-surviving detergents tend to accumulate in rivers, lakes, and estuaries, and to re-enter domestic and industrial water supplies. In both situations they may produce troublesome foaming. Effective detergents based on other hydrocarbon chains that are readily decomposed by aquatic organisms can now be manufactured economically. Although these degradable detergents have some toxicity for fish, they disappear fairly rapidly from surface and ground waters. Hence they do not accumulate in such high concentrations as the stable hydrocarbon detergents, and they carry a less durable pollution penalty. Most detergents now marketed in this country are of the degradable type. As the older detergents move through the ground water and down our streams, difficulty with foaming will slowly disappear.

Deterioration of Materials and Urban Environments

Airborne soot deposited on buildings, clothing and automobiles, raises maintenance costs by necessitating frequent cleaning and makes our lives more dingy and depressing. Certain gases, such as hydrogen sulfide, darken paint, while others, such as sulfur oxides, accelerate the weathering of buildings and statues. Coal mine effluents flowing into rivers and harbors are often so acid that they corrode

ships' hulls, as well as destroying water life. Other materials, such as phenols, may lend taste or odor to water and require additional treatment steps for municipal water supplies.

The particles of soot and smoke that dirty our cities also lower visibility, obscure attractive views, give gray casts to our days, and make travel more hazardous.

The unpleasant odor of a rendering plant, the noise of a jet airplane or of the other fellow's transistor radio, disorderly jumbles of auto hulks, unsightly trash in a dump, all are irritating and offensive. All will require increasing attention.

Climatic Effects of Pollution

Carbon dioxide is being added to the earth's atmosphere by the burning of coal, oil and natural gas at the rate of 6 billion tons a year. By the year 2000 there will be about 25% more CO_2 in our atmosphere than at present. This will modify the heat balance of the atmosphere to such an extent that marked changes in climate, not controllable through local or even national efforts, could occur. Possibilities of bringing about countervailing changes by deliberately modifying other processes that affect climate may then be very important.

THE SOURCES OF POLLUTION

Deliberate disposal of wastes is a more or less systematized activity. Most such wastes are not toxic, though some may carry

disease. But odors, excess fertility of waters, and offenses against natural beauty are widespread.

Municipal and Industrial Sewage

Two thirds of the U. S. population, about 125 million people, are served by domestic sewers. Sewage from about one-tenth of these people is discharged raw and that from more than another quarter after only primary treatment. In communities with combined sewers, even if treatment plants are otherwise satisfactory, storm water from heavy rains overwhelms the capacity of treatment plants, and considerable amounts of sewage are discharged raw. Separate sewer systems for storm runoff and for sewage, which lead only sewage to the treatment plant and permit storm runoff to bypass it, avoid this discharge. Few of our older cities have such separate sewers, however, and conversion of old systems will be very costly. Even when separate systems are installed, runoff washes oil, gasoline, accumulated street debris, and surface filth into the untreated outflow. In total, sewage discharges correspond to the raw sewage from almost 50 million people.

Sewage effluents, whether or not treated, carry considerable quantities of phosphorus, nitrogen, and other plant nutrients and are a principal source of the damaging overfertilization of rivers, lakes and estuaries mentioned above. In recent years the phosphate content of these effluents has been rising appreciably, presumably because of use of phosphates in detergents.

Animal Wastes

The excreta of farm animals are a major source of water pollution, entering streams, rivers or lakes either in surface runoff or through underground seepage, and posing hazards to human and animal health from pathogens common to animals and man. In some waters, pollution from farm animal manure has caused fish kills; elsewhere it has resulted in extensive damage to oyster and other commercial shell fisheries.

Odor and fly problems arising from waste accumulations are especially acute in the feedlot finishing of beef cattle and the mass production of poultry, and are made more critical by the encroachment of suburbs into what were farming areas.

Urban Solid Wastes

A frequently quoted estimate for the annual output of urban solid wastes, containing such things as paper, grass and brush cuttings, garbage, ashes, metal, and glass, is 1600 pounds per capital. Currently, this means 125 million tons each year, whose collection and disposal costs about 2.5 billion dollars a year, or around 20 dollars a ton.

Mining Wastes

Large quantities of solid wastes result from mining. In the United States during 1963, more than 3.3 billion tons of waste rock and mill

tailings were discarded near mine sites. In addition, the refining of ores, the combustion of coal, and the production of metals and non-metallic materials result in building vast mountains of slag, ash, and other waste material.

Consumer-Goods Wastes

A large fraction of all consumer goods ends up as urban solid waste, though significant amounts are salvaged and recycled back to industry.

Scrap iron and steel are generated at a rate of 12 to 15 million tons a year, of which about a third consists of derelict automobiles. The fraction recovered for use has declined substantially. Recovery of other scrap metals in 1963 included at least 974,000 tons of copper, 493,000 tons of lead, and 268,000 tons of zinc.

From 25 to 30 million tons of paper products produced annually, about 10 million tons of waste paper were salvaged in 1964 and used to make new paper. In 1962, about 263,000 long tons of reclaimed rubber were used in the United States, about 15 percent of all rubber. The same year about 10% of the 8 billion pounds of plastics produced was recovered and reconverted.

Each year we must dispose of 48 billion cans (250 per person), 26 billion bottles and jars (135 per person), 65 billion metal and plastic caps and crowns (338 per person), plus more than half a billion dollars worth of miscellaneous packaging material.

Only a small part of our solid wastes is salvaged and processed for reuse, even though the industries engaged in reprocessing waste materials operate at a level of 5 to 7 billion dollars a year. The unsalvaged remainder represents a vast potential for litter and pollution.

Unintentional Releases

Almost every action of man releases some materials that may spread into the environment and become pollutants. Many of these materials are increasing in abundance, and are causing problems of growing severity, because the capacity of the environment to absorb and neutralize them does not change. Where deliberate disposal is somewhat systematized, accidental release, except in special circumstances, is catch as catch can.

The combustion of coal, oil, and gas in our homes, vehicles, and factories results in the discharge into the air of sulfur dioxide, carbon dioxide, carbon monoxide, oxides of nitrogen, and partially burned hydrocarbons. Some of these gases, together with gasoline and natural gas vapors, undergo chemical change in air and in sunlight, and become the noxious constituents of smog; others, like carbon dioxide, are accumulating in such large quantities that they may eventually produce marked climatic change. Large amounts of lead are dispersed into the atmosphere from motor vehicle exhausts. Indeed, the pollution from internal combustion engines is so serious, and is growing so fast,

that an alternative non-polluting means of powering automobiles, buses and trucks is likely to become a national necessity.

Particulate by-products, such as asbestos fibers from brake linings and fly ash from chimneys, are giving rise to increasing concern, because of their possible effects on human health. Pesticide mists and dusts often drift beyond the areas of application. Salts and agricultural chemicals may be dispersed by irrigation or drainage waters.

Many of these pollutants released unintentionally or as a by-product are long-lasting, come from a multitude of sources, and are subject to transportation over great distances in air, water, or living organisms. All three characteristics make them very difficult to control.

IN WHICH DIRECTIONS SHOULD WE GO?

Pollution touches us all. We are at the same time pollutors and sufferers from pollution. Today, we are certain that pollution adversely affects the quality of our lives. In the future, it may affect their duration.

Present levels of pollution of air, water, soils and living organisms are for the most part below the levels that have been demonstrated to cause disease or death in people. At the same time we recognize a number of episodes where air pollution has caused

deaths, where disease has been spread by water, where accidental poisonings have occurred from pesticides. The documented cases of pollution-caused injuries to plants, fish, birds and mammals are extensive and the economic loss from these injuries has been considerable. Some waters no longer support any useful fish or invertebrates. Some areas have been rendered unsuitable for useful plants. Many natural waters throughout the country are becoming continually less beautiful and less usable. Air in some of our cities is unpleasant to breathe and obscures our surroundings; our buildings are dirtied and sometimes rapidly weathered. Pollution has denied to some of our farmers the most desirable uses of parts of their lands. Prudence and self interest dictate that we exert ourselves not only to prevent further buildup of pollutants but to reduce present burdens of pollution in our air, our waters, and our land.

Arrangements to deal with pollution have grown on a piece-meal basis, with organizations, programs and legislation created when problems became evident or critical. With this background it is not surprising that current organization is a hodge-podge, with responsibilities widely separated among government agencies, and some unassigned. Some pollutants are dealt with on the basis of the environmental medium in which they occur, for example, pollutants in air and water; others are dealt with on the basis of the kinds of

effect they have, for example toxic materials in food; some are dealt with on the basis of their sources, for example artificially radioactive materials.

With some pollutants there is no Federal authority to act until a problem exists. Such is the case with water pollution and air pollution. With some pollutants there is no Federal authority to act at all, as is the case with pesticide residues on tobacco. With some pollution problems existing Federal authorities constrain the type of action that can be taken, as with water pollution problems that can be approached by the Corps of Engineers only through providing excess water storage for low flow augmentation (usually a costly and inefficient process). With some pollutants such as radionuclides, extreme caution is exercised to assure that unwanted effects in the environment will be prevented; with other materials, such as pesticides, consideration of side effects has been scant in the past.

The situation at the Federal level is more or less duplicated in the states and other jurisdictions.

Careful attention to organization of pollution-related activities in the Federal Government, to the relation of Federal activities and organizations to other political jurisdictions, and to the relations among agencies below the Federal level will be necessary to enable us to cope with pollution in the future.

There are many areas in which ignorance constrains our ability to deal effectively with pollution problems. Examples lie in the deficiencies of our knowledge of the behavior of important carriers of pollution, such as atmospheric gases, surface and ground waters, oceanic currents, and soil particles. Basic research on these topics is necessary in order to clarify our understanding of the movement of pollutants. Some pollutants are carried extensively in living things, moving from one plant or animal to another as food, moving from place to place with the plant or animal. Such movements of pollutants in and through living organisms are important, for example, when we consider means of protecting wildlife, fisheries, and shellfish from pollution. Basic ecological research is necessary if we are to cope effectively with these serious problems.

We now know that the full effects of environmental changes produced by pollution cannot be foreseen before judgments must be made. The responsible judgment, therefore, must be the conservative one. Trends and indications, as soundly based as possible, must provide the guidelines; demonstration of disaster is not required. Abnormal changes in animal populations, however small, at whatever stage in the life history of the individual, or in whatever niche of the species complex, must be considered warnings of potential hazard.

Many kinds of pollution problems could be prevented by the exercise of ecological foresight. Given a reasonable knowledge of persistence, biological effect and expected initial distribution and amount, at least part of the impact on living things can be predicted. In the future, such advance evaluations will be essential.

Disposal of wastes is a requisite for domestic life, for agriculture, and industry. Traditionally waste disposal was accomplished in the cheapest possible way, usually by dumping in the nearest stream. This tradition is no longer acceptable--we believe industrial and agricultural waste disposal must now be accomplished in such a way that pollution is avoided, and that the higher costs of such disposal should be borne by industry and agriculture, and considered as a part of the cost of operation. The pressure to pollute in the past has been an economic one; the pressure to abate must in the future also be economic.

Much can be done by enforcement of the day's regulatory laws, and by modifying the administrative policy under which Federal assistance is provided. For example, pollution from farm animal wastes could be alleviated by vigorous enforcement without technological advances. The same is true of particulate materials in air and sewage effluents in water.

As a basis for pollution abatement, we need to establish environmental quality standards. Such standards imply that the community is willing to bear certain costs or to enforce these costs on others in order to maintain its surroundings at a given level of quality and utility. For each pollutant the elements that must be taken into account are: its effects; technological capabilities for its control; the costs of control; and the desired uses of the resources that pollutants may affect.

These complex problems cannot be handled without a sufficient number of trained technicians, engineers, economists, administrators and scientists, and without the requisite scientific, technical and economic knowledge. The manpower and knowledge now at hand are insufficient for the complete task, though much can be accomplished with present resources. Our government has a clear responsibility to insure that persons of ability and imagination are attracted into this broad field and trained in its intricacies, and that scientists and engineers are enabled to produce the knowledge and technology that will give the people of our country a clean, a healthy, and a happy environment.

A. PRINCIPLES

WE RECOMMEND THAT THE FOLLOWING PRINCIPLES BE ACCEPTED FEDERALLY, LOCALLY, AND NATIONALLY:

A1. The public should come to recognize individual rights to quality of living, as expressed by the absence of pollution, as it has come to recognize rights to education, to economic advance, and to public recreation. Like education and other human rights, improved quality of life from reduced pollution will be costly to individuals and governments.

A2. The responsibility to each pollutor for all forms of damage caused by his pollution should be effectively recognized and generally accepted. There should be no "right" to pollute.

A3. The roles of all governmental authorities, local, state, and Federal, in pollution problems should be complementary and mutually supporting. While enforcement of pollution control is primarily a regional, state or local responsibility, there is much that the Federal government can and should do to support and supplement regional, state and local actions.

A4. Federal agencies should give special attention, in all operations they conduct, support, or control, to avoiding and managing pollution, both to reduce it and as an example to others. State and local agencies should follow the Federal example as rapidly as possible.

A5. All agencies and organizations concerned with pollution should strengthen programs that lead to better public understanding of pollution and its problems. Today there is particular need for better understanding of the nature and extent of soil contamination and of the nature of the values currently damaged by pollution.

A6. All concerned should recognize the quality of human life and the presence and growth of other living things as the major values currently damaged by pollution. Many threats to human health have been recognized and largely controlled. While more subtle human effects are possible and should be sought for, demonstrable threats to human health constitute a small part of today's damage from pollution.

A7. The special importance of the automobile as a source of pollution problems should be clearly recognized. The automobile is our most rapidly growing cause of many and diverse pollution problems.

A8. As our pollution problems become steadily more serious, it should be generally recognized that we must consider our balances and choices within successively larger and more complex systems. Garbage disposal by burning, land fill, or household grinding, for example, sends the resulting pollution to our air, to our soil, or to our waters. In the last analysis, we cannot treat even these three broad classes of pollution separately.

A9. Each department or agency having responsibility for both enforcement and research in pollution should provide administrative and budgetary separation sufficient to minimize interference between its research and development activities on the one hand, and its investigative and enforcement activities on the other. While due regard for the advantages of mutual support is essential, smooth functioning of enforcement and control, combined with minimum interference with research, requires adequate separation.

A10. In making decisions about resource use and community development, including transportation systems, urban renewal, irrigation, drainage, and agricultural practices, information about effects and behavior of pollutants should be an essential consideration. The effects of pollution, both close at hand and far away, should not only be discussed, but should be part of all comparisons of costs and benefits.

A11. The filling-in of shallow waters essential in life cycles of fishes and shellfish must be regarded as an important kind of pollution.

A12. The control of pest populations should increasingly depend on an integrated combination of pesticide use with a wide variety of bio-environmental techniques. The increasingly serious problems of pest control cannot be solved by excessive reliance upon pesticides, biological control, or any single available technique. For success in

developing reasonably long-term rather than extremely short-term solutions to these problems, all available techniques must be integrated into a unified approach.

A13. Unnecessary use of pesticides should be avoided whenever possible. Pesticide use is necessary under many circumstances, but is almost invariably accompanied by undesirable side effects, and often by hazards. Accordingly, we should always use pesticides no more frequently and in no larger quantities than we must.

B. ACTIONS

B1. We recommend that careful study be given to tax-like systems in which all polluters would be subject to "effluent charges" in proportion to their contribution to pollution. Federal and local efforts to reduce pollution of air, soil, and water have traditionally rested upon a mixture of prohibitory regulation and persuasion. The public interest can often be served by reducing pollution below the levels where these means are appropriate and effective. Effluent charges have enhanced effects because individual polluters always have a prospect of financial gain from further reductions in their contribution to pollution.

B2. We recommend that the U. S. Department of Agriculture require and use, as one of the bases necessary to support registration of a pesticide, information on the persistence and fate of the chemical in all relevant segments of the environment. Present registration procedures take account of persistence as related to tolerances on food, but have not always done so for non-food uses, or, for uses that might result in food residues in years subsequent to the use of the material. (See also Y1)

B3. We recommend that the Department of Agriculture require that reregistration proceedings of agricultural pesticides at prescribed intervals be conducted with the same thoroughness and rigor as were

used for the initial registration and without prejudice from the approval of registration for the previous term. Present registration procedures call for reregistration of pesticides at 5-year intervals. Review of data tends, unless specific problems are known to have arisen during the time the preceding registration was in effect, to be less rigorous at the time of reregistration than during the initial registration. Special steps are necessary to assure that review of data at reregistration does not become perfunctory.

B4. We recommend that the Department of Agriculture implement fully the principle that -- in all proceedings concerning the registration of pesticides for agricultural use, whether the registration be initial, or at the prescribed interval for reregistration, or questioned or reopened because of new evidence -- the burden of proof is deemed to fall on the registrant. Even though the intent of the present law is clear, the finding of new evidence that casts doubt on the validity of the registration and causes registration to be re-examined is, in fact, too frequently taken to require the Department to be able to prove that the registration is not valid, thus effectively shifting the burden of proof.

B5. We recommend that the Department of Agriculture take all possible steps to encourage modification of present pesticide practices by:

(a) Replacement of wasteful "routine-treatment" schedules by "treat-when-necessary" schedules.

(b) Recognition that 100% control of most pests is not required to prevent economic losses.

For example, substantial reduction in insecticide use, in specific cases as much as 50%, can be made by applying our present knowledge of pests and their control. Treat-when-necessary spraying often requires more judgement, but lowered costs for pesticides can often make the provision of specialized advice economically worthwhile. (see also Y11)

B6. We recommend that the Federal Aviation Agency condition its issuance of licenses for aerial application upon demonstrated familiarity by the licensee with the precautions necessary for avoiding hazards, that such licenses require use of pesticides in accordance with USDA registered labels, and that they be subject to suspension or revocation for uses not authorized on pesticide labels. Increasing amounts of pesticides are applied from the air by flyers subject to Civil Air Regulations. Nearly 6000 aircraft are now involved. Pesticides sold in interstate commerce must be registered for specific uses and bear approved labels with suitable instructions for use and precautions as to safety. Not all major pesticide misuses occur in aerial applications, but the substantial fraction that do could easily be brought under Federal regulation.

B7. We recommend that the principle of requiring registration before use should be extended to the addition to motor fuels of substances which are not eliminated by the combustion process. Widespread use of automobiles has made motor fuels the single most effective way to expose almost all our people to air pollution from combustion resistant substances such as metals, and, as well, to escaped gasoline and combustion products. Lead has long been an additive, one whose environmental concentrations before leaded gasoline were never adequately measured; phosphorus and boron have been added for a few years; nickel is now beginning to appear. (see also X6)

B8. We recommend that the U.S. Public Health Service intensify its surveillance of body burdens of lead and trends of lead in air, water, food and, in cooperation with the U.S. Department of Agriculture, in soil. The toxic properties of lead have been recognized since ancient times, and lead continues to be one of the major occupational poisons. The average person has a substantial amount in his body from absorption of lead through the lungs and intestinal tract. In persons heavily exposed to automotive exhausts, the body levels approach the concentrations known to have deleterious effects. The steadily increasing use of leaded gasoline calls for continuing assessment of levels in the environment and in human body fluids. (see also B9, Y1, and Y2)

B9. We recommend that a pilot survey and studies be made to assess the significant methods of entry and the accumulation of lead from vehicle exhausts in various soils and plants, especially those located close to heavily travelled highways. The Department of Agriculture, in collaboration with the Public Health Service, should conduct the survey and studies. (see also B8, Y1, and Y2)

B10. We recommend that a tax be devised to provide an incentive for eliminating the long-term storage or holding of junk automobiles. An annual Federal or state license might be imposed on all automobiles except those currently licensed for road use; or a personal property tax might be placed upon junk cars. A tax approach has fewer difficulties than any of the subsidy approaches considered by the Panel. A national eye-sore results from the storage, until such times as the scrap steel market makes it profitable to sell them, of automobile hulks which have already been processed for removal of spare parts. Speeding the processing will reduce the number of hulks in storage and simplify screening of the necessary remnant. (see also Y5)

B11. We recommend that an appropriate ad hoc group of Federal, state and local officials be established to determine how best to attack the problems caused by the outmoded combined sewerage systems in the great cities of the United States. This group should give particular attention to research, development and demonstrations needed to reduce combined sewer problems. They should also consider cost sharing arrangements for different projects and mechanisms for coordination and review. (see also Y8)

B12. We recommend that the Department of Housing and Urban Development direct a substantial proportion of its support for community facilities to assisting cities to use present technology to clean up such obviously critical solid waste practices as open dump burning and unsanitary land fill. Consideration should be also given to maximum use of these funds to encourage innovation in coping with solid wastes disposal problems. (see also Y5)

B13. We recommend that Federal agencies participating in city and regional planning and development insist that minimization of pollution be a required goal. Planning for cities and regions has achieved increased importance in recent years, but most of the emphasis has been placed on land use, distribution of residences and businesses, parks and greenbelts, transportation and location of industry. Insufficient attention has been paid to waste disposal and to

the provision of measures which will minimize air, water and soil pollution. Planning for cities and regions should include effective measures for disposal of wastes without causing unnecessary pollution. (see also X5 and Y5)

B14. We recommend that the Federal Government, in its own facilities and in those that it contributes to financially, take such measures as are necessary to insure that provisions for waste disposal are adequate to minimize pollution of air, water and soil. The government itself builds a large number of installations such as military bases, hospitals, office buildings, power plants, research laboratories, and the like. Moreover, the Federal Government contributes funds to construction projects undertaken by states, municipalities, universities, school districts, and defense industries. All such facilities should be planned and constructed to minimize the contribution of waste disposal to all forms of pollution.

B15. We recommend that Federal agencies neither expend funds on or grant financial aid to any construction project or program which does not include effective measures for minimizing the production of dust and sediment. Temporary disturbance from highway and building construction now contributes large amounts of sediment, in some watersheds more than half the total. Much of this can be prevented.

B16. We recommend that, especially in marshlands and coastal areas, minimizing the impairment of natural drainage patterns should be an important consideration in the building of Federally-supported highways. These areas are remarkably productive, some producing six times as much organic matter per acre as average wheat land. Nearly 60% of our total harvest of sea foods (which supports 90,000 commercial fishermen) depends on these areas; unnecessary alterations can, through pollution, destroy this food supply and degrade important recreational resources. (see also Y10)

B17. We recommend that funds be made available to acquire title, either directly or through the states, to important coastal marshes, lagoons and estuaries which could then serve incidentally, as national and state parks, national monuments, wildlife refuges and public recreational areas. Critically important protection against pollution can be combined with preservation of some natural areas as well as changes in others to allow intensified recreational and other uses. (see also Y10)

B18. We recommend that interstate and Federal-state river basin development compacts and agreements cover related estuaries and marshes. Many marshes and estuaries lie at the mouths of large river systems or are measurably influenced by the effluents from such systems. Prevention of pollution and other destructive changes in these

water bodies should be one of the most important elements in Federal-state river basin development. Although their importance as breeding grounds for fish and shellfish is less obvious, similar considerations apply to the shallow inshore waters of the Great Lakes. (see also Y10)

B19. We recommend that the Federal Government, working in cooperation with the states, encourage formation of unified authorities for planning and carrying out the optimum development of waters and marshes that are threatened by destructive encroachment or severe pollution. San Francisco Bay, the Great Lakes and New York Harbor are examples where planning has been retarded by the existence of multiple local governments along the shores. In many cases state or Federal participation in such authorities is needed to reflect the interests of those who, though they live at a distance, will suffer from the distruction of the area, perhaps through effects on fish and shellfish populations. (see also Y10)

B20. We recommend that the Federal Government, working in cooperation with the states, encourage the formation of compacts and unified authorities to deal with air pollution within natural airsheds. The boundary-crossing nature of water pollution has long been recognized through the development of interstate compacts and river-basin authorities. The growing extent of air pollution has now made similar actions important with respect to airsheds. (see also X5)

B21. We recommend that the Department of Interior undertake a new program, which is likely to require the establishment of an appropriate organization, for gathering and making information available about effects of environmental changes on those lands and waters that are peculiarly its responsibility. Knowledge needed to protect man, domestic animals, and crops seems to be rather adequately circulated, at least within the Federal Government. By contrast there seems to be no adequate provision for either securing or distributing necessary information relating to most other living organisms, especially those inhabiting our broader and less-populated lands and waters. (see also C4, and Y10)

B22. We recommend that Federal agencies concerned with water quality should make detailed studies of the sources of salt coming into our western rivers and should seek ways of isolating these sources from the rivers wherever possible. (see also Y1)

B23. We recommend that water quality as well as water quantity be taken into account in the planning and design of river basin developments in the arid and semi-arid regions of the United States. Because the value of irrigation water diminishes as its salt and particularly its sodium content increases, greater emphasis should be placed on water quality by Federal and state agencies in the planning and design of river basin developments in the arid and semi-arid

regions. In all cost-benefit computations, reductions in downstream salinity should be valued along side increases in available waters. (see also Y1)

B24. We recommend that the amelioration of salinity problems be taken into account in formulating agricultural policies. Incentives or controls which tend to reduce the number of cultivated acres, and the acreage in crops with a long growing season will, by reducing total consumptive use of water be beneficial in minimizing salinity problems (see also Y1)

B25. We recommend that issuance by the U.S. Army Corps of Engineers of permits for dredging, and decisions concerning the Corps' own operations, be conditioned on the anticipated effects on all resources, not on effects on navigation alone. Dredging authorized by permits may, and often does, have disadvantageous effects on other resources, both in the areas from which spoil is removed and in those where it is deposited. Other resource agencies, Federal, state and local, should effectively participate in decisions related to issuance of permits for dredging, or to direct operations by the Corps.

B26. We recommend that efforts be increased to establish the scientific bases upon which standards of environmental quality can be set. There is at present a great lack of exact information on the impact of environmental factors on people and other living things. A

great deal of intensive research will be required to establish the relations between levels of pollution and consequences. This information is essential to the establishment of standards, which provide the intended balance between protection of the community and the economic burden upon those whose easiest course is to pollute. (see also Y2 and Y10)

B27. We recommend that the U.S. Public Health Service encourage and lead major engineering and scientific organizations and societies to work actively, both on their own account and as advisors to the Federal Government, on problems related to standards of air quality. The problems of adjusting standards to what is reasonable and possible as well as desirable or necessary involve many diverse technical problems, in which engineers and scientists can contribute much. Moreover, the experience and knowledge gained in such discussions as representatives of professional groups often spreads to those professionally concerned with the actions that must be taken by individual pollutors to abate or control pollution. Professional involvement has been notably less for air pollution than for water pollution. (see also X4)

B28. We recommend that the Federal Government encourage the development and adoption of codes governing noise insulation in apartment buildings. Pollution of apartments by noise from either

adjacent tenants or outside sources is a national commonplace. At least two countries have effective codes regulating this problem. Local governments should have access to codes which they can adopt with adequate reliance on both their effectiveness and their reasonableness.

C. COORDINATION AND SYSTEMS STUDIES

Organization for cooperation in identifying both new pollution problems and new aspects of old ones, for accumulating and distributing information about pollutant effects needs to be strengthened. Broader studies of pollution from waste disposal, combining aspects usually studied separately, are now essential.

C1. We recommend that the following steps be taken to provide for early identification of broad problems involving pollution and to avoid gaps and imbalances in their study: (a) The Federal Council for Science and Technology should establish a Committee on Pollution Problems, composed of its own members. (b) The National Academy of Sciences - National Research Council should be asked to establish an Environmental Pollution Board, to be supported by government grant. (c) This NAS-NRC Board should meet jointly with the FCST Committee at least once a year to discuss newly recognized broad problems and current changes in the apparent importance of those previously recognized. (d) This Board and Committee should cooperate, through working level mechanisms such as joint panels, to identify the most pressing broad problems, and the general character of new knowledge or techniques needed to study or ameliorate them. (see also X2)

C2. We recommend that the Department of Agriculture establish an appropriate unit to assess the pollution status of the Nation's soils, to correlate all research, control, abatement, and monitoring concerned with soil pollution, to make suggestions as to new or additional courses of action, and to report their findings annually to the Congress. No broad gauge, systematic evaluation of the status of the contamination of soils now exists. Since soil pollutants are subject to absorption by plants which serve as food for man and animals, a knowledge of their distribution and content is essential. (see also Y1)

C3. We recommend that there be established a policy-level interagency committee to bring together those facts about Federal programs of financial aid to local governments in connection with waste disposal that are needed to ensure that these programs are consistent in goals, are in technical balance, and are collectively directed toward the problems of greatest national concern. The Departments of Health, Education and Welfare, Commerce, Housing and Urban Development, the Interior, and Agriculture should be represented; the Bureau of the Budget might provide a Chairman. Estimates of required expenditures to provide secondary treatment of wastes for 80 percent of our population by 1975 are on the order of $20 billion, of which Federal funds will be a substantial part. Because the Federal financial aid related to pollution abatement is dispensed by so many agencies there are possible overlaps and conflicts.

C4. We recommend that the Departments of Health, Education and Welfare, Agriculture, and the Interior establish and improve procedures for making available, through various government and private mechanisms, information needed to protect man, domestic animals, crops, and other living organisms from pollution. It is especially important to provide this information to those who have the responsibility for making decisions relating to pollution, its control and abatement. (see also B21, Y10)

C5. We recommend that the National Academy of Sciences and the National Academy of Engineering jointly undertake, with Federal support, an intensive study of the broad area of disposal of sewage, trash, and garbage, emphasizing both a systems approach and the types of innovation needed to give stimulus to solid waste technology. Even a brief examination shows that many interesting possibilities have not been explored to the point where we can balance their advantages and disadvantages in dealing with increasingly serious problems. (see also Y5)

C6. We recommend that the NAS-NAE jointly undertake a similar study of sewage treatment and water supply as a single combined system. We have realized for many years that the water intakes for downstream cities are often largely supplied by the sewage outfalls of upstream cities, yet we have not tried to face the purification of wastes and supply of water as a unified problem.

C7. We recommend that, after the completion of these two studies, the NAS-NAE jointly undertake an intensive study of the interaction between various disposal systems as they affect the inter-relationship of solid, liquid and gaseous pollution of the environment. One of the most prominent results of any study of pollution as a whole is the extent to which we must and do choose between polluting the air, or the water, or the land. As soon as somewhat broader foundations are available, an initial study of the combined system can contribute much to our guidance.

D. BASELINE MEASUREMENT PROGRAMS

In addition to continued and expanded monitoring of those portions of the environment where dangers to health, life, and amenities are judged to require particular attention, there are needs for year-by-year information on the average condition of our environment, on atmospheric changes possibly affecting climate, on base-line values for pollutants just entering a period of growth, and on natural populations in relatively unpolluted areas.

D1. We recommend that: (a) Immediate steps be taken to plan and institute a National Environmental Quality Survey, which would provide benchmark data on the average condition of the environment of the people of the United States as a whole. (b) An agency should be set up to carry out planning, including sample design, and analysis of the National Environmental Quality Survey. This agency should be isolated from all enforcement or action programs and should make the greatest possible use, through transfer of funds, of expertness in carrying out measurements of environmental quality already developed in Federal, state and local governments. (c) Because of clear separation from enforcement and action, and because of long experience with sampling design and analysis, particular consideration should be given to setting up this agency in the Department of Commerce.

Today no agency or program is concerned with the average condition of our environment, yet we have recognized pollution as a national problem and its abatement and control as national goals. If we are to recognize how fast we are gaining or losing in this struggle we need measurement of both where we stand and where we once stood. (see also Y3)

D2. We recommend that the Environmental Sciences Service Administration and its collaborators continue, for at least the next several decades, their series of precise measurements of the CO_2 content of the atmosphere. Within a few generations we are burning the fossil fuels that were laid down in the earth over 500 million years. About half of the CO_2 (carbon dioxide) produced remains in the atmosphere, where its effects on our climate are likely to be significant. We need to know how fast the atmospheric share increases. (see also Y4)

D3. We recommend that temperatures at different heights in the stratosphere be routinely monitored on a world-wide basis. The influence of CO_2 content on the balance between heat received from the sun and heat radiated to space is important to us because it changes the average temperature of the air near the ground. Average temperatures in the stratosphere will change many times as much. Monitoring stratospheric temperatures offers earlier measures of overall effect and further insight into its details. (see also Y4)

D4. We recommend that the opportunity of measuring base-line values for concentrations of nickel and its compounds in the atmosphere be seized now before the use of this motor fuel additive becomes more extensive. It is important to establish the present levels of this element in the environment and in the human body, so that we may detect and follow any increases with confidence.

D5. We recommend that quantitative base-line population densities be established by systematic sampling of certain natural populations in diverse relatively unpolluted habitats to establish a basis for comparison with populations under pollution stress. Today it is difficult to recognize that a natural population is under severe stress, unless that stress is so severe as to bring it close to regional extinction. Base-line density information is needed if we are to detect stresses with important consequences. (see also B21, Y10)

E. DEVELOPMENT AND DEMONSTRATION

There are many opportunities to combat pollution through refinement or further development of existing technology and adoption for use of the improved methods or equipment.

Development of improved equipment and methods for pollution control will only be useful if the developments are applied. Demonstrations and full-scale trials, supported or insured with Federal funds, will be essential in many cases since there will be risks, real or imagined, of unsatisfactory operation. This is particularly true when these developments are for use by municipalities or individuals.

E1. We recommend that the Federal government exert every effort to stimulate industry to develop and demonstrate means of powering automobiles and trucks that will not produce noxious effluents. Less complete steps to reduce pollution from automobile exhausts will certainly play an important role. We must strive for more acceptable mass transportation. We must follow carefully the results of California's imposition of special regulations, and be prepared to extend those that prove effective to other smog-ridden localities. But we must also be prepared, as soon as reasonably may be, to take more drastic action if, as, and when necessary. The development of alternative means of mobile energy conversion, suitable for powering automotive transport of all kinds, is not a matter of one year or a few years. Yet if fuel cells, or rechargeable batteries, or other devices are to be developed in time to meet the increased threat, we need to begin now.

(see also M6)

E2. We recommend that the Federal Government stimulate industrial development of more economic processes for exclusion of sulfur compounds from stack effluents. Oxides of sulfur constitute a major source of air pollution in this country because large quantities of sulfur-containing coal and oil are used for fuel. Removal is becoming a matter of increasing importance; less costly means of removal will contribute to lessening pollution. (see also X6)

E3. We recommend demonstration of the feasibility and economy of new developments for abating or controlling pollution through their use at Federal installations. Opportunities exist, for example, at the coal-burning generating plants of the Tennessee Valley Authority, and at large military installations which have many of the complex waste disposal problems typical of urban places. (see also Y5)

E4. We recommend stimulation by the Federal Government for development of container materials which have adequate storage life, but which will degrade rapidly when discarded. The accumulation of present types of non-reused containers, whether made of metal, glass, or plastic, is a substantial and difficult part of the solid waste problem. The development of containers with adequate storage life which will nevertheless degrade rapidly when discarded is not likely to be an easy task, but the advantages of success are great. (see also Y5)

E5. We recommend that the Federal Government, through the Department of Agriculture, the Agricultural Experiment Stations, and private industry accelerate the development of improved equipment and methods for applying pesticides more selectively. Such equipment and techniques will allow for adequate or even improved pest control yet lead to a decrease in total environmental contamination. (see also Y11)

E6. We recommend that the U. S. Department of Agriculture engage actively in the development and demonstration of new or better equipment and methods for the handling, treatment and use of farm animal wastes. Disposal of these wastes is a major and ever-growing problem on U. S. farms, and there are yet no methods generally satisfactory for the handling, treatment and disposal of the animal manures originating in many types of livestock or poultry operations. Traditional use as agricultural, garden, or greenhouse fertilizer is no longer adequate because of increasing concentration in the production of manure (see also Y8)

E7. We recommend that the Bureau of Mines increase its studies to speed the recycling of junk auto steel, including means for developing more uniform scrap, and for storing junk auto hulks in excess of current market demands of the iron and steel industry. Variability of composition of the junk steel currently available makes processing costly and may lower the quality of the final product. Furthermore, steel is a valuable mineral resource and its conservation through storage for future use is a desirable goal. (see also Y5)

E8. We recommend that the Department of Health, Education and Welfare initiate development and demonstration projects for new and improved systems of collecting and transporting solid wastes to show what can be done to approach the problem from other than traditional methods. (see also Y5)

E9. We recommend that the Federal Government stimulate development and demonstration of new and improved methods of treating solid and liquid wastes, including methods of nutrient removal. In particular, HEW should be authorized to establish pilot plants followed by construction of prototypes for demonstration, for the purpose of improving existing solid and liquid waste treatment systems. (see also Y5)

E10. We recommend that HEW utilize its contracts and grants in the sewage treatment field to emphasize involvement of biochemists and biologists in the development of improvements and innovations in the technology of sewage treatment. The existing systems of sewage treatment are relatively primitive and have developed without many insights that can be contributed by modern biologists and chemists. Imaginative scientists should be able to devise new approaches to problems of sewage treatment. (see also Y5)

E11. We recommend that the Federal Government draw more heavily on the experience and technological skills of private industry

in developing instruments and devices for measurement of pollution. A variety of incentives, different in different cases, may be necessary to provide necessary stimulus. Such incentives might include contracts for the development of specific hardware or systems; deliberate actions to make consumers want the product developed (such as legislation requiring the device or establishing tolerances that could be met only with the device); underwriting of demonstrations to prove the utility of the device; or waiving of the government patent rights in specific instances where vesting such rights in the government would remove the incentive to develop or market the device (as might be the case with small volume, low cost devices).

E12. We recommend that the Federal Government ensure increased attention by manufacturers to satisfactory "fool-proof" automation of recording instruments for measuring pollution. The high cost of supervising and maintaining the proper functioning of (supposedly) automatic recording instruments is to a large extent responsible for the inadequate coverage of many areas that need to be guarded. Through establishing adequate standards and purchasing from adequate specifications, among other actions, the Federal Government can do much to improve instrument quality.

E13. We recommend that the Federal Government encourage the development of atmospheric instrumentation needed for warning systems.

In our growing metropolitan areas it becomes increasingly more important to be able to predict strengths and locations of intense pollution, caused either by adverse meteorological conditions or acute releases of poisonous chemicals.

E14. We recommend that the Federal Government stimulate development of a method for assigning a numerical index of chemical pollution to water samples. The method should be sensitive to most chemical pollutants, and its results should be roughly proportional to the unfavorable effects of the pollution on man or aquatic life. Such an index will allow us to follow many important changes in general water quality in a way similar to that in which the coliform count has enabled us to follow changes in pollution by untreated sewage. (see also X3)

F. RESEARCH

Much research is already being conducted and planned that will contribute to our understanding of pollution processes and problems and to our ability to abate and control pollution. In almost every instance, this research is worthwhile and needs to be continued. We have not identified any exceptions of a magnitude worthy of notice here, and anticipate that the normal processes of program review and internal competition for funds will be sufficient to keep these research programs in good order. We have, however, been able to identify a number of areas in which increased research effort will be both important and worthwhile. We do not believe that our list is complete, rather we anticipate the appearance of other clear needs as our national attack on pollution strengthens and broadens.

WE RECOMMEND THAT THE FEDERAL GOVERNMENT EXPAND SUBSTANTIALLY ITS INHOUSE AND SPONSORED RESEARCH IN THE FOLLOWING BROAD AREAS:

F1. On the acute biological effects of common air pollutants. Our knowledge of the effects, on either human beings or experimental animals, of realistic concentrations of gases or gas-particulate combinations is very limited, particularly under conditions, such as the presence of disease, which might enhance toxic effects or increase susceptibility. Much needed data can be obtained from human volunteers and

from appropriately selected samples of industrially-exposed and nonindustrially-exposed populations. (see also Y2, Y10)

F2. On the effects on man and animals, particularly as revealed by epidemiological studies, of chronic low-level pollution, with special emphasis on lead, asbestos, oxides of nitrogen, carbon monoxide, and sulfur compounds. Increased support should be made available for epidemiologic studies of possible health effects of chronic low level pollution. Because of the importance of competing factors in morbidity and mortality (as when the effects of cigarette smoking appear to overwhelm possible effects of community air pollution) emphasis should be placed on refinement of methods, and on study of populations most seriously exposed to the pollutant. If studies of long-term exposure of animals are to be effective, high standards of environmental maintenance and animal care must be met. (see also Y2 and Y10)

F3. On the effects on wildlife and fisheries, directly and through their habitats. A reasonable amount of information is available for the direct effects of a few compounds on a few species of animals. In most instances when judgements of allowable amounts of pollution have to be made, the necessary basic information is lacking. (see also Y10)

F4. On the effects of common pollutants on beneficial insects, crops, forests, domestic animals and birds and agricultural lands. While much has been done, information is inadequate on immediate and long-term effects of many pollutants for many species. There is even less information available on their effects on soils and their fate in different kinds of soils. (see also Y1 and Y10)

F5. On bioenvironmental pest control. Greater emphasis should be placed on research aimed at methods of reducing pest populations to the low density levels which are required for men's health, welfare, and crop protection by manipulation of the pest's environment or ecology, by altering the pest's physiology, genetics, or behavior and especially by employing various combinations of these. (see also Y11)

F6. On the metabolism, flow in the environment, natural degradation, and long-term deposition of pollutants, especially pesticides. (At least HEW, USDA, and Interior should be involved in a coordinated study.) Little is known of the metabolism and natural degradation of a wide variety of pesticides and other pollutants. Similarly, with few exceptions, the flow and fate of organic pollutants in many habitats and the long-term deposition of these substances are largely or totally unclear. (see also Y1 and Y10)

F7. On research that may contribute to the development of new pesticides, that have high specificity and rapid degradability.

Damage to non-target organisms and hazard to humans could be minimized or eliminated by use of chemicals with greater specificity, perhaps approached through different mechanisms of toxicity. The use of pesticides which are more rapidly converted into innocuous products than those currently employed for many purposes will avoid or minimize environmental contamination. (see also Y11)

F8. On investigations of the role our coastal lowlands (estuaries, marshes, and lagoons) play in the life histories of many important fishes and shellfish and how they are affected by accumulated river pollution and related man-made alterations. Greater knowledge is needed of our coastal lowlands because many of our most valued commercial and game species such as prawns, menhaden, bluefish, weakfish, croaker, mullet, and channel bass, spend their juvenile stages in the estuarine zone. Oysters, clams, crabs and terrapins are all permanent residents of estuaries. (see also Y10)

F9. On the development of more objective techniques to measure the tolerance levels of different organisms to pollutants and to identify and assess the changes in abundance and distribution of organisms making up biological communities under pollution stress. Information on the tolerance limits of various organisms is urgently needed to interpret and understand changes in biological communities caused by pollutants. (see also Y10)

F10. On the chemical and physical nature of the pollutants produced by reactions in the atmosphere, and their biological action. The prominence of automobile pollution in recent years has led to the recognition of the great importance of chemical change after emission into the atmosphere in the production of irritating and otherwise objectionable materials. A better knowledge of these reactions is of decided benefit in the intelligent control of this source.

F11. On intensified studies of the species composition of plant and animal communities, aquatic and terrestial, and the interactions among species and between organisms which make up plant and animal communities, including the influence on these communities of physical, chemical and biological factors, singly and in the aggregate. At present little is understood concerning the structure and function of plant and animal communities. Our vital living environment must be satisfactorily understood to adequately protect it from various physical, chemical, and biological pollutants. (see also B21 and Y10)

F12. On the mechanisms controlling sizes of pest populations. The success of pest control by pesticides or bioenvironmental methods, separately or as an integrated whole, depends upon our understanding of the fundamentals of pest-population dynamics. Development and testing of population models should be undertaken for representative types of organisms. Information developed from such studies should

lead eventually to the ability to predict population trends accurately. The diversity of the information required for an understanding of population processes will make cooperation of ecologists, physiologists, biomathematicians, microclimatologists, geneticists, microbiologists, biochemists, chemists, morphologists, and taxonomists necessary. (see also Y11)

F13. On the development of techniques which will enable more accurate sampling of organisms in the natural environment. Limited ability in detecting the effects of relatively low levels of pollution is a major technical deficiency in the field study of the effects of pollution. Relatively small changes in numbers of individuals of a species would often be the natural indicator, but present methods are adequate to measure such changes for only a few species. (see also Y10)

F14. On the biology and chemistry of the aquatic environment, the relative contribution of various sources of nutrient elements, and potential means for the effective control of the aquatic plants that flourish in enriched waters and of over-enrichment itself. Objectionable growths of algae and larger aquatic plants are appearing in many bodies of water that now receive increased amounts of nutrient elements, especially nitrogen and phosphorus, because of man's activities. The behavior and sources of these nutrients, their relationship to algal blooms and possibly even their identities are frequently uncertain. (see also Y9)

F15. On the behavior of farm animal wastes in storage, in soil, and in water, and on the physical, chemical and biological properties of such wastes. The properties of animal manures produced today are either totally unknown, or, because of different farm feeding practices, differ substantially from those studied years ago. In order to devise efficient disposal practices, the characteristics of the wastes and their behavior in environments into which they are deposited or through which they pass must be understood. (see also Y8)

F16. On research directed toward the development of techniques for predicting local air movements, with special reference to urban areas and concentrated pollution sources. We do not yet know enough about the movements of smaller bodies of air to predict the consequences of releasing pollution into the air from smokestacks or pollution-generating disasters. This knowledge is needed both in setting tolerances for routine releases that depend appropriately on meteorological conditions and in managing evacuations necessary because of pollution-generating disasters. (see also X1)

F17. On conserving and increasing water supplies in semi-arid parts of the United States as a means of ameliorating salinity problems. Special efforts should be made to increase water-use efficiency by crop plants, to increase runoff and underground flow from watersheds, and to decrease evaporation and seepage losses from reservoirs, canals, fields and unwanted plants. (see also Y1)

F18. On studies of the oceanic and biological processes by which CO_2 is removed from or returned to the atmosphere. Use by land plants and absorption in the ocean restrains the increase of atmospheric CO_2, which may have significant effects on world-wide climate, to only half the amount we release. If we are to understand the consequences of the releases that we will make in the future, it will be essential to understand, in some detail, the mechanisms which so greatly reduce these consequences. (see also Y4)

F19. On taxonomic investigations basic to studies of the biological environment. The identification and reference services now provided by the Smithsonian Institution's Oceanographic Sorting Center should be expanded to cover a much wider variety of organisms and habitats. At present many investigations of plant and animal communities are limited by inadequate knowledge of classification for certain types of organisms and a severe shortage of systematists who can provide identification and reference services. (see also Y10)

G. MANPOWER

Men and women of widely differing abilities, education and interests are needed to solve the problems of pollution and to protect our human environment.

In the long run, improving both numbers and quality of highly trained manpower engaged in key actions, from research to enforcement, will do the most for us, and merits the highest priority.

Besides the general improvement of education, especially in science and technology, the following specific policies, authorizations and actions should be implemented. (see also X1)

G1. We recommend that every opportunity be seized to acquaint young people with careers in fields related to environmental pollution. Students in elementary schools, high schools, and colleges should be exposed to the problems of environmental investigation and the opportunities for stimulating intellectual adventures which might alter their career choices. The dissemination of knowledge of the less well known scientific disciplines and effective presentation of the personal satisfactions to be found in them are important tasks for university and government scientists.

G2. We recommend adoption of a policy by Federal agencies that a consideration in the awarding of research grants related to environmental research should be the intention of the grantee to stress the training of students through involvement in such research.

Although training grants are an invaluable mechanism in the production of future research workers they are not as generally available as research grants and are usually less flexible for securing the part time involvement of students. Employment of students in research projects not only assists the student financially but acquaints him with a field about which he might not otherwise learn. While in some cases the work might be, in the short run, more efficiently performed by skilled technicians, the contribution to recruitment of future scientists from graduate and undergraduate student assistants is, in the long run, far more significant.

G3. We recommend that the Departments of Agriculture and the Interior be authorized to award, on a competitive basis, extramural contracts and grants to universities and other qualified institutions for research and research training in scientific and engineering fields supporting their missions. These contracts and grants should be used at least in part to support the education and training of graduate students in fields concerned with environmental pollution in which there are critical shortages of professional manpower. Disciplines which contribute to our knowledge of biological control of pests and of interspecies relationships should be given high priority.

G4. We recommend that the Departments of Health, Education and Welfare, of Agriculture, and of the Interior be authorized to provide grants covering up to 100% of costs to universities, or other non-profit institutions for the construction, remodeling and equipping of facilities needed for projects, institutes, or centers to be devoted to research and research training in environmental health, environmental science and environmental engineering. Present patterns of Federal support of universities are for the most part confined to research and training, on the assumption that adequate facilities are already available at universities. Where facilities are not available, the university is expected to provide them as its share of the endeavor. However, the universities are now confronted with educational responsibilities which greatly overtax their capacity to support them by conventional means. Few universities are in a position to contribute significantly to the large and complex efforts needed in the environmental pollution field, without an exceptional degree of support from the Federal Government.

G5. We recommend that the Department of Health, Education and Welfare increase its program of grants and contracts with universities, including schools of medicine, public health, engineering, public administration and agriculture. This program should support educational programs involving combinations of in-service experience,

formal education and participation in basic and applied research. As soon as the Departments of Agriculture and the Interior have legislative authority for such grants and contracts, they should establish similar programs. In particular, a variety of training grants should be provided to schools of medicine and schools of public health to support expanded programs in the teaching of preventive medicine and its constituent disciplines: Practical field training in epidemiology should be supported through residencies in certain of the larger well-staffed city-county health departments and in certain State health departments. Support to schools of public health and medicine should be continued for specialization in epidemiology, and residency field training should also become a part of this training. Grants should be provided to schools of medicine or public health for the support of summer field training programs in preventive medicine and public health, particularly epidemiology, in order that medical students may acquire practical field experience and, it is hoped, an interest in preventive medicine as a career.

G6. We recommend that contract and grant support be provided to selected, progressive colleges of agriculture to enlarge and intensify their research and teaching to cover all aspects of the biological basis of human life in a world of many species. These

broadened programs would encompass, but not be restricted to, agricultural as well as biological problems relating to environmental pollution and natural populations.

G7. We recommend that the Department of Health, Education and Welfare and the National Science Foundation increase their support for traineeships and fellowships for graduate students in the pure and applied environmental sciences, and in those areas of behavior sciences and engineering relevant to pollution problems. As soon as Agriculture and Interior have legislative authority for such support, they should establish similar programs. Modest support is already available in some of these areas. Broader support is necessary to bring in promising students from a wider variety of fields and to give them the depth of training needed for research and teaching in the environmental sciences related to pollution.

G8. We recommend that the Department of Health, Education and Welfare provide long-term support to between five and ten universities to establish interdepartmental research centers for environmental studies, which would devote the greater part of their effort to research directly or ultimately related to pollution problems. In the support of these centers, funds should be made available for research by graduate students, post-doctoral research workers and faculty members as well as for equipment, facilities, technicians, and administrative services. To allow adequate planning and recruiting,

grants to a single center should overlap, lasting as long as seven years. The centers should be encouraged to conduct faculty and graduate seminars and to recruit visiting investigators. They should be sufficiently large to contain a critical mass of scientists and engineers, able to form and reform cooperative teams to attack problems of their choice. The scope of these centers should be broader than that of the environmental health science institutes now planned or funded by the Public Health Service. This kind of effort is needed because of the broad scope of environmental pollution problems and the range of disciplines which must interact and contribute in the solution of these problems.

G9. We recommend that the Department of Health, Education and Welfare provide research and training grant support for greatly broadened studies pertinent to the solid waste field. Studies in systems engineering, public administration, environmental sciences and similar areas should be supported. This effort should be directed toward the involvement of academic faculties and graduate students as a means of spreading interest in this field across the entire educational community. (see also Y5)

G10. We recommend that the Federal Government establish a policy which encourages Federal research workers in the field of environmental pollution to make use of training and retraining

opportunities. A system similar in intent and operation to the sabbatic leave program of universities should be initiated. Provision should be made for reimbursement to the host institutions for expenses incidental to the leave program. (see also Y11)

G11. We recommend that each Federal agency concerned in its program with pollution, plan and budget specifically for the support of activities which contribute directly to maintenance and improvements in competence and skills of its scientists and engineers. Items such as travel and subsistence in connection with scientific meetings and to and from training assignments should be included. Once established, the budgets for these activities should not be diverted to fund on-going operational programs.

G12. We recommend that the National Science Foundation and the Public Health Service examine the adequacy of their present programs to provide for one-year fellowships allowing state and university research workers and teaching personnel to develop new skills and competence in pollution and related fields. The rapid pace of technologic advance and the emergence of new problem areas in environmental pollution make it essential to provide means for research workers and teachers to acquire sound additional training through fellowships at institutions with active research and training programs in pollution-related fields.

G13. Periodic refresher courses on new developments in all methods of pest control should be given for all extension personnel, commercial field men, and others who assist farmers with their pest problems. No matter how effective techniques of pest control may be, if they are to be adopted and used successfully by growers it will be necessary to educate extension specialists and county agents in their use. Effective use of integrated control will require almost all extension personnel to change from relatively simple single concepts to a broader approach based on principles of applied ecology. This change is necessary if the farmer is to receive adequate guidance in pest population management. (see also Y11)

G14. We recommend that the Public Health Service increase its support to the Communicable Disease Center. Epidemiologists are in very short supply. The Communicable Disease Center is by far the leading training center for epidemiologists in this country, probably the world. This increase should allow its Epidemic Intelligence Service to accept an annual class of 50 professional officers a year, with an increase by 10 additional trainees a year so that by the end of five years each new group would consist of 100 trainees. (see also Y2)

G15. We recommend that the National Science Foundation and the Public Health Service establish summer institutes in the environmental sciences for high school and college students and teachers. A summer program is one of the most effective ways to acquaint students and teachers with the environmental sciences, and to stimulate a lasting interest in this field.

G16. We recommend that the National Science Foundation direct more of its support for undergraduates to programs that will enable them to work in environmental science laboratories both during the academic year and during the summer. In an effort to draw promising young men and women into the field of environmental sciences, it is of great importance to stimulate the interest of the students at an early date before their direction of study and career choices have been satisfied.

G17. We recommend that the National Science Foundation and the agencies with missions in environmental pollution (HEW, Agriculture and Interior) support programs to develop a very much broader recognition of the opportunities for intellectual adventure in the environmental sciences related to pollution. This recognition should extend to students, teachers and guidance counsellors at all levels from elementary school to college. Visiting lecturer programs, special segments of conventional courses, teaching aids and educational publications can all contribute to this end. It is essential to enlarge the community of awareness,

G18. We recommend that interaction among scientists working in basic and applied areas be fostered through regional, national and international conferences designed specifically for this purpose. A genuine attempt to forge communication between scientists working in the basic areas and those who are concerned with applied problems should distinguish these gatherings. Careful planning, structuring of the formal program and provision of abundant opportunities for informal discussion, will be needed. The selection of participants is crucial. Diversity of approach and active participation can help to generate many new perspectives. The Gordon Research Conferences are a highly successful model for intensive though informal exploration of scientific problems.

H. INCOMPLETENESS OF RECOMMENDATIONS

The recommendations we have made, many though they be, are not an exhaustive list. Even with the aid of some 11 subpanels, whose reports follow as appendices Y1 to Y11, one group cannot hope to cover the diverse field of pollution exhaustively. Moreover, it is essential, we believe, to focus attention on recommendations of greater importance and urgency. Accordingly, it has been necessary to set aside many recommendations which we think are valuable and significant, including many findings set out in individual subpanel reports, with which the Panel is in general agreement.

As examples, consider findings that the possibilities of deliberately compensating for the effects on climate of the increase in atmospheric CO_2 should be thoroughly explored (see Y4), and that comprehensive plans for diverse uses of shore lines and coastal water bodies should underlie modifications made by Federal agencies (see Y10).