SOILS BULLETIN 13

land degradation

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS ROME

F O R E W O R D

Though not generally thought of in such a term, soil is indeed an essential support of human life, not only in relation to our food supply but also for the production of fibre and shelter. Unlike air and water, for which anti-pollution provisions are being established, the use of land is still not guided by any agreed standards. While the demand for land increases at a very rapid rate through population growth, technological progress and industrial development, soil resources remain fixed. The maintenance of their productivity is therefore of paramount importance.

This problem will need to be reviewed at the United Nations Conference on the Human Environment to be held in Stockholm in 1972. In preparation for this Conference, FAO as a UN Inter-Agency focal point prepared the present paper on Land Degradation, with contributions from UNESCO, IAEA and WHO. This paper which is meant as a background document for discussions is felt to be of value in the general field of land development, which warrants its reproduction for a more general distribution.

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LAND DEGRADATION

SUMMARY

SITUATION AND PROBLEMS

Because of the rapid increase in the rate of use of the land as a result of pressures from population and technology, it is imperative that adequate attention be given to problems of land degradation.

Soil erosion has been and remains one of the major causes of that degradation. Losses of fertile top soil result in lowering of yields, especially in countries which do not practice extensive fertilization. Sediment loads in streams and estuaries ruin wild life habitats and cause sedimentation of reservoirs, waterways and domestic water supplies.

The accumulation of salts and alkali threatens productive agricultural lands in arid or semi-arid regions which practice irrigation. The high cost of reclamation and the irreversibility of certain phenomena call for special attention to salinity and alkalinity hazards.

The disposal of organic wastes has created concern about diseases and toxic elements in surface and ground waters, as well as soils and their productivity.

Infectious organisms, although in most instances already present in soils, must be regarded as a form of land degradation as they may result in health hazards and heavy crop losses.

Industrial effluents, such as heavy metals, stack gases of various sorts, and waste water containing many kinds of polluting by-products, are introduced on to the land by air or water.

Because of their interaction with other factors of the environment, pesticides have become a concern. Chlorinated hydrocarbons are of major concern because their persistence may create a situation where they are hazardous to animal health through the introduction into the food chain by, for example, the erosion of soil into waterways.

Radioactive waste originates from nuclear weapons, testing, power generators, and from medicinal and research uses. Contaminated soil may be of concern by inhalation, ingestion or concentration. At the present time stringent controls and standards are imposed in most countries for the dispersal or containment of radioactive wastes. These schemes call for little or no detectable difference above natural radiation levels.

Most heavy metals exist in a natural state in highly insoluble forms and usually do not enter into interactions with other factors in the environment. Land degradation may result from industrial and domestic uses by which the form of heavy metals may be changed.

Fertilizers are a soil improvement factor and a means of maintaining productivity. They can only be a factor in land degradation when applied in excess, which may occasionally occur.

The effect of detergents on land degradation only applies in those areas using land extensively for the disposal of sewage effluent.

Recognizing the relative importance of these land degradation problems, the following categories are suggested as a guide to the use of resources for the solution problems.

Category I (erosion and sedimentation, salts and alkali, organic waste and infectious organisms). The causes of land degradation in this category will require immediate application of available technology and the development of new technology to prevent degradation reaching a state of emergency.

Category II (industrial inorganic wastes, pesticides, radioactivity and heavy metals). These causes of land degradation represent a lower order of magnitude in importance because of their lesser extent, intensity or rate of increase.

Category III (fertilizers and detergents). This category contains those causes of degradation which are of lowest priority. They constitute no widespread immediate hazards to soil nor are there numerous isolated areas requiring attention.

While each of the ten causes of land degradation require attention, they should not compete at the same level for facilities, staff and financial assistance. It is also recognized that in a specific instance one or more of the causes may assume the highest priority. These should then be regarded as being of a highest priority requiring immediate action. Also in a region, one or more of the causes within a category may assume greater significance in relation to the others so there should be a periodic reappraisal to make the necessary changes of priorities.

POLICY GUIDELINES

An essential policy for national governments and international agencies is to develop the recognition of land as a basic and limited resource. There is therefore a need for regulation of its use to provide for orderly growth and development in the light of the competing demands made on its capacities.

National governments should engage in international agreements and cooperation to seek solutions to mutual problems of land degradation and develop international standards. In regard to the latter, the dynamic nature of the environment must be recognized. Therefore, provision should be made for periodic reappraisal of the standards to change them in light of new information. The United Nations and its specialized agencies are in a position to assist in the development of international standards.

Nations must also adopt a policy with regard to the payment of the cost of remedial action and of controlling or preventing land degradation. Should the cost of maintaining environmental quality be assigned to the producer or the government, or some combination of the two? Such a decision will influence consumer buying patterns, industrial and agricultural expansion, and the development of necessary technology to prevent or control land degradation.

National governments should also create the type of social attitude and economic incentives to promote the recycling of waste and re-use of limited resources. The former may be achieved through the use of mass media to develop awareness and motivation and by showing methods of engaging in such disposal. International Agencies such as FAO should inform those coutries currently unaware or indifferent to land degradation problems of the need for remedial action. This may be done through the use of periodic newsletters to national ministries or agencies.

ACTION PROPOSALS

To find and implement solutions will require the cooperation of governments, education and research institutions (local, national and international) and industry. The maintenance of the environment will require constant vigilance and effort from now on. As a means of seeking solutions to the problems, and developing and maintaining a satisfactory environmental quality, the following actions (not necessarily listed in their order of priority) are proposed:

1. Assessment of the Problems. This involves international interests as well as local governments and institutions in the identification of the cause, extent and intensity of the problems to determine needs for the establishment of standards, controls and preventive measures and for specific problem-oriented programmes of research (see 2 below). The authorities would also be required to provide an estimate of the consequences of no action. An important aspect of such assessment would be the measurement of current levels of various factors causing land degradation and the establishment of benchmark data for the evaluation of the rate of change (see monitoring).

2. Goal-oriented Research. In addition to basic and adaptive research, there is a need for goal-oriented research through the multi-discipline approach. Such research should be performed on a contract basis with a provision not to exceed five years. This research may be performed by task forces both at national and international levels. At the termination of the contract the results would be summarized and the necessity for further research determined. If deemed necessary to continue the same line of investigation or to change goals, the new contract would have the same terminating provision.

3. Data collection, summarized and information dissemination system. This system should provide for the automatic review of published research information. This information should be summarized and evaluated with respect to current controls or standards. Such action can hardly be done by individual abstracting services. The evaluation should preferably be entrusted to international organizations in their respective fields of competence, using existing data collection systems.

4. Environmental quality standards. In some instances standards are not available. Where standards are available there may be some question as to their suitability, since it is necessary to make provision for changes in them as new information becomes available. Standards should be established first locally and then on a national basis with the understanding of developing them into regional and global ones. Standards should take into account the assimilative capacity of different environments and the feasibility of controls.

5. Monitoring systems. Monitoring systems are required for the determination of the rate of change of an environmental factor for the purpose of predicting when, where and if a certain type of land degradation problem will arise. Monitoring should be applied both to specific land degradation and to the activities by which different types of degradation are caused. Highly qualified staff will, therefore, be required to provide the interpretation and summarization of the data. The system should rely on local facilities, such as existing experimental and research stations, to provide the mechanics of collecting and interpreting the data. The different types of land degradation require different ad-hoc systems of monitoring. These systems should be linked with wider monitoring networks both sector-wise and area-wise. But they should retain their individuality for specific interpretation at local level. The information should become part of national and international collection systems to assist in determining areas requiring attention and to provide information regarding those factors of international interest. There should also be a provision for periodic checking of performance of local monitoring stations by the national agencies concerned. International agencies should help in harmonizing methods and techniques of monitoring and facilitate exchange of data between countries.

6. Expanded educational and technical assistance programmes. In many countries programmes already exist for agricultural education. In many instances however reorientation of staff may be required to provide more specific education and technical assistance on matters related to land degradation.

7. Legislation. The purpose of legislation is to put into force political and technical decisions with regard to land as a basic and essential resource. The basic laws should provide for the changing of standards without requiring further formal parliamentary amendments. The laws should also spell out the terms of financial contribution or participation of the government and implementation and enforcement. When drafting such laws, international agencies concerned with land use can advise in giving international perspective in the proposed legislation.

Note: Other measures to prevent land degradation are described in the basic papers dealing with "Agriculture and Soils" (item II a (i) "Forestry" (II a (ii)) "Wildlife and Recreational Resources" (II a (iv)) "Water" (II a (v)). These measures are mostly directed towards an improvement of the land use planning process and a better management of land resources as a means of preventing land degradation.

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APPENDICES

1. INTRODUCTION

There is an ever increasing awareness and concern about the environment and the extent of the interrelationships between the three basic resources: land, water and air. A seemingly far removed input into one of these resources can be detrimental to another. Because of the immensity of the environment and the heretofore relatively low rate of use, interests have generally been centred on other aspects of daily activities; thus, food, fibre and shelter formed the popular theme in the late fifties and early sixties. It has now become apparent that this can no longer be the case. As population increases and the spectre of even larger populations looms on the horizon, the rate of use of the environment increases and the consequences of man's activities become more apparent. It has been his activities which have largely contributed to the problem of land degradation, and it will have to be largely due to him that solutions to the problem will be found.

In some cases the technology for the satisfactory solution of environmental problems exists. However, the implementation is prevented by lack of awareness or indifference or inadequate economic incentives. For those situations where technology does not exist, especially with regard to the environmental quality of the three basic resources, the agricultural scientist has the necessary expertise to provide solutions. Agricultural scientists have inevitably had a vested interest in the maintenance of environmental quality through their investigations of factors in the environment. However, because of the intricacies and the all-encompassing nature of the environment, there is a critical need for an inter-disciplinary approach in establishing standards and controls, and in seeking solutions to environmental problems.

One concern of agriculture and industry is that the standards or controls may be so stringent that there will be no way to implement them. Or the cost of so doing will be so high as to create economic hardships. Therefore, it is necessary to allow the widest latitude possible for the adoption of alternatives for the control of environmental factors within the quality standards.

There is a need for a concerted international approach to the establishment of such standards and controls, especially for those sources of land degradation which are of international concern. Similarly, pollutants and other nuisances not only create trouble in the immediate area of their release but may have adverse effects that spread far and wide and across national boundaries. Such a situation not only calls for remedial action but may lead to many complications and liabilities, including legal actions for compensation at national and international levels. For example, it is useless for one nation to establish standards for a particular form of land degradation when the source of degradation originates in an area where there are no standards or controls, or where they are less stringent.

Finally, but not least, is the consideration of the individual in the environment. The public should be educated as to their role and the consequences of their actions. Where possible, the consequences should be spelled out in terms of economic effects on them. They should be taught the principles that work in the environment and the application of those principles to different environmental conditions. Implementation of controls without education is possible but regulation without public acceptance is impossible. The success of a control programme depends upon the knowledge of the public that certain of their activities cause an undesirable change in the environment, adversely affecting all of them.

II. APPRAISAL AND EVALUATION

A. Land Degradation Problems

Technology, which has seemed to be a boon to the world, is a kind of paradox. It provides many of the things which improve the quality of life while contributing in some cases to the decrease of the quality of the environment. For example, through the development of nuclear energy there has been the extension of electrical energy into many countries, providing job and manufacturing opportunities never before available. The same nuclear energy can be used for the distillation of sea water for use as domestic water. There is also a likelihood of arid lands being irrigated with waters distilled by the nuclear reactors, thus making it possible to turn desert areas into productive agricultural land. Nuclear energy has, too, been a source in the development of stable isotopes which may be used in research to understand more fully the mechanisms involved in plant and animal growth and development, perhaps some day allowing great breakthroughs in food production and health benefits. These, and many other great benefits are coming from the use of nuclear energy. Yet there is concern about it as, for instance, in the disposal of radioactive wastes into the environment. People wonder what these effects might be in the long term.

Fossil fuels provide the energy for many electricity generating plants and in so doing their combustion results in the emission of sulphur dioxide, fluorides, radioactivity and other undesirable inputs into the environment.

Technology is also responsible for the production of some of the mineral materials that are deemed necessary by the present day civilization. The manufacture of nitrogen supplied in fertilizers is used to increase the food production of the world. Without this readily available nitrogen the food supply of the world would be much less than the current supply and there would be wide-spread starvation.

Similar analogies may be made for pesticides. Pesticides not only prevent disease and crop losses, they also provide some of the major safeguards for plant, human and animal health. Even so, residues of many of these materials are found in soils, plants and animals, and sometimes they have adverse effects. While many of these effects are open to interpretation, pesticides entering into the water have killed fish, and, it is claimed, various types of wildlife, mostly birds.

Production technology also provides paper, plastics and metal, the uses of which are too numerous to mention except to indicate that these as well as other materials are part of a way of life and it seems unlikely that civilization as it exists today will accept the possibility of doing without them.

The technical discussions in the Appendix deal with several types of materials or agents which can contribute to the land degradatinn problem. Their source, extent and intensity are discussed. It seems appropriate now to attempt to evaluate each of these causes of land degradation in relation to one another in order to identify the association of one with the other. The ranking of the causes of land degradation has been done by the use of several broad criteria. They were the magnitude of the problem, the benefit in relation to cost, irreversibility, and the susceptibility to increase.

Erosion

Of primary interest is the erosion of sediment from agricultural soils and its associated effects on crop production and water pollution. Tremendous amounts of sediment are removed from top soils by surface runoff (water erosion) and to a lesser extent by soil blowing (wind erosion). Erosion is directly associated with the loss of plant nutrients and these plant nutrients are related to the yield. As a result of topsoil loss there is also degradation through the creation of washes and gullies which make the land unsuitable for production agriculture.

In addition to these losses there is also the contribution which absorbed nutrients make to the degradation of surface water supplies. Their contribution to the nutrient level of such water allows algal growth to occur which is the first step of eutrophication of a body of water. The organic matter contribution and sediment load destroys reservoirs and makes the treatment of water for domestic use more costly. The loss of soil nutrients, degrading of the land, and the associated costs make soil erosion a major concern.

2. Salts and Alkali

As already pointed out, the management of saline and alkali soils in the world has been one of the problems that has beleaguered man in his attempt to maintain the land in its highest productive state. The salt and alkali problems are in general associated with irrigated lands. It is estimated that around 13 percent of the cultivated area of the world is irrigated. While this is only a small part of the total cultivated acreage, the production from it provides the major contribution to the world's food supply. A good example of the importance of irrigated agriculture may be seen in California which ranks as the first agricultural state in the United States and has done so for the past 22 years. Eighty-two percent of the cultivated land of California is irrigated. California is in the top four of U.S. producers of almost 70 crops. The main reason for this, of course, is the fact that the climate and good quality irrigation water with proper management enables growers in California to obtain high production levels per acre from a variety of crops, most of which have high cash value.

3. Organic Wastes

Many of the land degrading materials are directly related to inputs from population. Large numbers of people, particularly in urban centres, create land degradation problems. The most recognizeable is that associated with the disposal of refuse which includes domestic, municipal, and industrial wastes. There is also, of course, the problem of sewage disposal. Although the organic content of the sewage effluent is not of primary concern with regard to land degradation, the addition of salts to the effluent from excretia and the use of water softeners, as well as the specific ion effects of boron, make this a source of degradation where it is applied to land.

Other sources of organic waste are associated with agricultural production, forestry and industry, such as concentrated animal wastes, sawdusts and cannery and processing wastes. The magnitude of this problem is large and although the disposal of most of these wastes can be effectively handled by technology, there are no economic incentives for so doing.

Another source of land degradation is the encroachment of urban population centres on agricultural land. If one views agricultural land as a limited resource then encroachment is a form of degradation even though such use may have a higher priority from the urban point of view.

It has been estimated such encroachment in California is proceeding at the rate of 40 to 65 thousand acres per year. Although people require cities and cities require land some planning needs to be done to determine the judicious use of such a limited resource.

4. Infectious Organisms

As indicated earlier, the principal concern with infectious diseases and insects is degradation associated with organisms. The battle against this source of land degradation is also never-ending. Insects and disease cause billions of dollars of crop losses throughout the world each year and, from the degradation point of view, render many acres of land unsuitable for the best adapted crop or the one with highest cash value. Development of tolerant varieties of crops are temporary solutions as disease organisms, by their very nature, are able to mutate and adapt, thereby becoming equally virulent for the new variety. Consequently, a continuing effort has to be made in the development of disease and insect tolerant varieties of crops. But this is a general view of all diseases and all insects, regardless of the manner in which they infect and inflict injury. If one considers the predominant soilborne diseases solely from the standpoint of infestation of acreas previously unaffected, this aspect of degradation looks less important.

5. Industrial Inorganic Waste

The concern about industrial waste in relation to land degradation arises from the release of stack gases and the disposal of inorganic residues. Stack gases which consist of flyash, sulphur dioxide, fluorides, and in some cases heavy metals, are of course subject to meteorological influences. Flyash is also distributed by the influence of gravitation. From the standpoint of land degradation, the fluorides and heavy metals seem to be of principal concern. Fluorides and sulphur dioxide have caused leaf injury to plants resulting in leaf abscission and stunting of growth when deposited on the surface of the plants or absorbed in a gaseous state by plants. When sulphur dioxide reaches the soil it undergoes reactions in the soil which overcome its initial toxic effect and transform it into a useful soil nutrient. Fluoride, when reaching the soil, becomes involved in numerous reactions as well. Most of these restrict the availability of fluoride by precipitating it in a rather insoluble form, thereby limiting plant absorption of this element.

6. Pesticides

Pesticides present one of the greatest technological advances of man, espeically in terms of human health. A major concern with pesticides is their persistence in the soil. Pesticides are used primarily in countries where agriculture can afford their high cost. Technology is creating pesticides of lower persistence in soils as well as the more rapid breakdown of existing pesticides. A principal concern with pesticides remains their adsorption to soil particles and subsequent deposit in streams and entry into the food chain of various wilflife.

Chloronated hydrocarbons are of major concern in this respect since the organo-phosphates are more rapidly decomposed in the soil environment. The effects on human health are not fully known. With present knowledge it has not been possible to determine that any ill effect has resulted from the current levels of chloronated hydrocarbons in the fatty tissue of man. There is evidence however that fish and wildlife have been killed when directly associated with chloronated hydrocarbon pesticides. It seems a question of priorities, weighing the benefits derived against the undesirable effects. The fact that there are undesirable effects would lead one to conclude that technology should develop pesticide materials from which there are no adverse effects. While this seems an insurmountable task, the scientists have embarked on its investigation.

7. Radioactivity

The principal concern with radioactivity is still the fallout of radioactive materials produced from explosions of nuclear weapons. The relative importance of this category from the land degradation point of view will depend upon the future activities of nations. Even if atmospheric nuclear explosions ceased, it would be several generations before radioactivity levels in soils returned to the naturally occurring background radiation levels. It is known that radioactive materials react in soils in much the same manner as other elements. They are subjected to the same exchange reactions, pH effects, and selective exclusion or uptake by plant roots. It has also been demonstrated that radioactivity from fallout may be considerably reduced simply by washing the plant. With the advent of nuclear reactor power generating plants there is concern whether the same sorts of radioactive materials are being produced as from nuclear weapon testing. Assuming a large increase in the use of such generating plants, will they soon be increasing radioactivity levels?

Perhaps the more proper question is to ask how much radioactivity is too much? Countries involved with the use of radioactive materials have set rather stringent control laws on the handling and use of these materials. But in many instances, exposure levels have been established which are several orders of magnitude greater than current background radiation levels. It would be a great step forward if man would stop polluting the environment by exploding nuclear bombs, especially in the air. Then the world would only have to be concerned with the relatively minor pollution from nuclear power generators and other sources.

8. Heavy Metals

Another matter of concern is the appearance of heavy metals in many of the food supplies around the world. The principal manner in which heavy metals reach soils and become involved in their degradation is from industrial and domestic uses of materials as well as from industrial wastes. Most, if not all, soils already contain relatively minute amounts of heavy metals. They are generally in very stable forms and are not considered available for plant uptake. But because of the nature of the source of the metals contributing to land degradation, areas of high population density with corresponding industrial activity and concentrated use of automobiles seem to be responsible for the major contribution of these materials to the environment. By the use of more sophisticated technology it is possible in many cases to evaluate concentration levels of these materials which were previously undetectable. Further, more sophisticated diagnoses are now possible to detect agents of adverse human health effects, showing that heavy metals in the environment may be a major cause for concern. Little evidence is available to indicate that an appreciable amount of heavy metals deposited on soils enters the food chain by absorption by plants. It appears that most of the metals may be absorbed through the leaves.

Heavy metals are influenced by the same meteorological factors as are radioactive wastes. Prevailing winds and velocity and precipitation determine how the materials are distributed from their source and influence their concentration. The heavy metals which seem to be of primary concern at present are lead, mercury and cadmium.

9. Fertilizers

Fertilizers are one of the primary methods of improving soils for the enhancement of food production. But occasionally there are contaminants associated with them which may be a contributing factor to land degradation, In raw rock phosphates, for instance, the occurrence of radioactive elements has been detected which, when applied to soils, could be construed as a form of degradation. These concentrations are extremely low. Continued long-term, high usage could, perhaps, ultimately lead to a significant contribution of radioactivity to the soils. However, the phosphate is generally considered as a raw material in phosphorus production and the treatment of the raw material eliminates to a large extent the problem.

10. Detergents

The effect of detergents on land degradation is perhaps the least of all these discussed. There could be some detrimental effects from the use of sewage effluents with large amounts of detergents in them. Since detergents are noted as a dispersal agent, they could create water infiltration problems of soils but the widespread abuse of soils in this manner is unlikely. It is not therefore conceivable that the phosphorus entering soils in the form of detergents would be of any consequence.

11. Technology

The technology already exists for setting up many of the measures needed to prevent land degradation. For example, the technology and standards are already available for the control and prevention of salt buildup. Similarly, technology is available for erosion control, organic waste disposal, sewage treatment and land use, as well as for population control. For one reason or another, these control mechanisms or methods of disposal have not been fully used. There is little interest on the part of the populance to pay for the cost of treatment or pay more for the things they buy when they have not been convinced that land degradation or loss of production has been a factor in destroying the quality of the environment. In many cases scientists are blamed both for magnifying a problem out of all proportion and for not realizing its importance.

Perhaps one of the reasons for this is that the individual has a tendency to think of the environment in relation to himself. That is, to consider the microenvironment without considering the environment in entirety. Another factor is that individuals have a tendency to think of wastes in the aggregate and not on an individual basis. For example, billions of gallons of sewage are disposed of each day, and if an individual leaves the vicinity for a day, there is hardly a noticeable difference in the amount of material which has to be treated. Therefore, he tends to think of himself as only a negligible contributor to the total and assumes his activity is of little or no consequence.

With the problem of insects and diseases, technology is in a continual state of turnover. There is a constant need for development and re-evaluation of treatments and resistant varieties just to maintain a slight lead in the struggle with these enemies.

In some cases, technology is being developed to provide control or preventative measures or establish standards for levels of certain materials in our environment - specifically, radioactivity, heavy metals, and industrial wastes. While in several instances technology, as a result of recent advances, is available to ameliorate the effects of the entry of such materials into the environment,answers are not available for the solution of all problems.

One of the things that cannot be measured, is the value assigned to one particular aspect of the environment by an individual who may be more willing to accept land degradation than to be a party to the imposition of controls on an industry, which results in the loss of income for the individual employed by the industry. Legislation is one of the techniques available for establishing standards and control and providing impetus for new technology. The participation of scientists through the provision of their technical advice is, of course, necessary. In some cases land degradation standards have been established out of necessity. For example, salinity levels and management procedures were developed in some places without legislation, as the controls were essential to maintain agricultural production.

12. Legislation

There does not appear to be any similar impetus for the implementation of measures to prevent land degradation. If, in fact, there were economic incentives, many of the problems would perhaps have been solved. Legislation can, in one sense, provide economic incentives. Assuming legislative acts reflect the interest of the people, implicit in the enactment is the willingness to pay for the implementation of a control. Legislative regulations can provide for one of two courses of action. It can provide for economic incentives for developing technology for control, or provide for payment of the cost of implementing a control. Both of these provisions are needed and are complementary.

Another approach is enactment of legislation to provide for penalties if certain prescribed standards are exceeded. In many instances this approach would leave the burden of development of less costly technology to the enterprise producing the causative agent of land degradation. While one region may institute such control, not all regions may see the benefit of such action and would not be willing to impose the same stringent restrictions.

It seems likely that the only standards of land degradation imposed at the present time are those imposed by legislative activity. This being the case, then it becomes most important for the legislative body to provide for periodic updating of the standards as new information becomes available, as well as for the choice of priorities and alternatives in land use planning, development and conservation.

13. Appraisal

In an appraisal of land degradation, one consideration is its role in the degradation of the other two resources - air and water. The causes of degradation already mentioned appear to be among those receiving the greatest amount of attention from the scientific community. Bierly has forecast the shift in activity in pollution research in the United States Department of Agriculture and the number of scientists man-years to be expended on various subject areas by 1977. The greatest increase in use of scientists man-years will occur in the disposal of animal, domestic, and processing wastes. The next greatest will be in erosion control or sediment management. Then comes the control of infectious agents equally with the increase in effort put into the area of plant nutrients. From the land degradation point of view, plant nutrients are of little consequence, but from the standpoint of their entry into water supplies they are important.

B. Knowledge and its Application

1. Knowledge Gaps

There are certain gaps in knowledge regarding the state of four specific problems. While much is known and understood of reactions in the decomposition of organic matter in soils, this information has been generally gained through the investigations of incorporation of crop and animal residues. Much of the information relates to the nutritional status of the subsequent crop when the residues have been incorporated at levels which have normally been considered economically feasible.

There is not very much information available on the effects of loading the soil to dispose of waste material and the effects on subsequent crops. The consequences of loading organic wastes of all ranges of carbon-nitrogen ratios are virtually unknown. Another concept of considerable importance, but one for which very little information is available, is that of the effects of small amounts of materials in the soil and their magnification or accumulation in plants and animals. The accumulation is not necessarily at the toxic level but at some subclinical level. In short, does low level long-term exposure produce effects equal to those of short-term high level exposure? The question also applies to pesticides, radioactivity and heavy metals.

One of the problems is related to chronic low level exposure: does the decay or destruction rate reach an equilibrium within the environment and does that equilibrium concentration then have an adverse effect on plants and animals, or does it occur at a low enough level to be of no consequence, assuming a constant input? If the input either increases or decreases, how does this affect the concentration? These are some of the questions that need to be answered.

For erosion control, there appears to be sufficient technology which could, if implemented, control a major portion of the runoff from the agricultural and forest lands; excepting where fire, lumbering, and overgrazing denude large areas of watershed and where such operations destroy the stability of the soil, thus creating erosion problems. Investigations into control of such erosion would be beneficial. Also of interest is the waterborne sediment in streams coming from their banks and beds. Information is needed regarding the stability of the banks and beds. If the control was such that only limited amounts reached major rivers, would the banks and beds soon stabilize and so reduce the sediment load or would their sediment continue to be a major contributor to the stream load?

With regard to radioactivity, the increased use of nuclear reactors as power generators makes necessary investigations into the continual release of their low levels of radioactive wastes. Would an equilibrium concentration of these materials ultimately be reached as has been suggested and would the effect be different from that of a single higher level exposure?

2. New Technology

New techniques will necessarily have to be developed in order to control or prevent some kinds of land degradation. The incorporation of plant residues of all sorts present different kinds of problems. Because of the intensified type of agriculture in the highly productive areas of the world it is necessary to incorporate large amounts of material in the soil. In many cases this interferes with the planting and/or development of the subsequent crop. Techniques need to be developed to overcome the problems created.

One of the problems with sewage disposal is the degradation of the water, making it unsuitable for re-use. Information is lacking regarding the extent of treatment necessary to make it suitable for use on irrigated land. Public health laws prevent the usage of raw sewage on vegetable crops. However, what level of treatment is necessary before this source of water can be used for such irrigation?

With regard to organic cellulosic wastes from industrial, municipal, and agricultural sources, technology needs to be developed to allow more extensive use of these materials. In certain instances, cellulosic material from agriculture has been used in paper and hardboard production. Cellulosic waste from municipal and sources other than agriculture is already being used. There is also a need for developing techniques for handling and preparing this material for entry into a recycling system. If large amounts of cellulosic waste could be recycled, it would ease the problem.

In the case of paper, metal, plastics, rubber, textile, glass, and wood found in municipal refuse, techniques of segregation are currently under consideration, but there is still a need to make this approach economically feasible.

One approach to the control of erosion would be to develop material which could economically stabilize the soil. Thus, wind or water erosion could be prevented without adversely affecting the soil's productivity.

New pesticides could be developed which have as their prerequisite a biodegradability, thereby eliminating persistence in soils. Presumably a short-lived pesticide would be as effective as the current products.

There is a new concern about the types of contaminants which may be present in some of the products used and the foods consumed. It may become necessary to develop technology which will reduce or remove such contaminants from the food supplies.

3. Selection of Alternatives

One of the key factors in the selection and evaluation of treatments which provide solutions to pollution problems is to select alternatives for investigation. In some cases sociological and economic factors determine the selection of an alternative. Take, for instance, the accumulation of soluble salts or alkali in soils. There seem to be few alternatives. One is to allow the salts to accumulate. Another is to leach the salts below the root zone. A third is to use a water source of extremely low solute content. And another is not to grow crops in those areas where salinity control is a problem. A high quality water supply can provide a solution to the increased salinity content of groundwater, but sometimes, in order to maintain production, it is necessary to leach the salts out. In areas where water supplies are not of the low electrolyte content type, perhaps some effort should be made to develop a suitable water treatment or find a different water supply. At current production levels of low cost high quality water it seems unlikely that agriculture will be able to use this for irrigation for a number of years yet.

The alternatives for organic waste disposal are soil loading, incineration and recycling (exclusive of domestic and animal manures). It may also be possible to redistribute organic wastes in an area comparable to the area from which the material was produced. Some combination of alternatives may be best suited for different areas. For example, in a large metropolitan area it would seem more reasonable to incinerate cellulosic material rather than rely on the rehandling and distribution of it over large areas of land. Incineration also seems to hold other advantages. The residue may be more easily sorted for materials which may be introduced into a recycling system. The ash may be used as filler for the manufacture of bricks or blocks for building. Much of this technology is already available but some new techniques would have to be developed.

Technology is also available for the re-use of domestic waste water. Municipalities may be forced to consider re-use of water as their sources of supply may be insufficient to meet their needs. Providing the need arises, the cost for domestic water will be paid. The same sort of analogy may be applied to agricultural water since people are unlikely to limit agricultural production but would seek alternative or additional supplies.

For agricultural and industrial chemicals, both organic and inorganic, there should be a re-ordering of priorities and a further investigation of materials to be used instead of those which are affecting the environment. The alternative to dispersal is collection of wastes at their site of production. In this connection, the selection of dump sites where the wastes can be concentrated for complete disposal would appear desirable. It may be possible at some future date to reclaim some of the wastes, an action which would be feasible at centrally located disposal sites.

The technology for control and prevention of disease and insect problems is of two main types: the development of tolerant varieties and the use of pesticides. Pestcides still provide a major means of control of insects and weeds. The application of pesticides for the control of soilborne bacteria or fauna, that is soil organisms, has been successful to a limited extent. The primary technique for plant protection for soilborne diseases and insects is the development of plants which are not susceptible to the organisms. In the case of man and animal, immunization provides health protection.

For the fully successful application of technology in combating environmental pollution, it is necessary to be able to predict events. Implicit in the ability to predict is a knowledge of the rate at which action or reaction will take place. The difficulty is understanding the interactions of different parts of the environment on each other and how they may be interpreted as an effect. The idea of prediction on the basis of evaluation of several variables is of particular importance with regard to erosion, salt, radioactivity, heavy metal, pesticides, and fertilizers.

4. Criteria and Standards

One problem of applying alternatives is that in many cases criteria or standards are not available for land degradation. In other cases the standards are so gross and open to interpretation that they are not effective. About the only land degradation factor for which there are workable criteria is that for establishing salt and alkali accumulation in soils. Even these criteria vary with many other factors.

In the case of radioactivity, the standards were set under the threat of nuclear war. In view of the present political climate and the advances in nuclear technology there is need for re-evaluation.

Erosion criteria seem to be rather subjective and there are no finite standards for this type of land degradation.

Standards regarding infectious diseases are largely governed by the criteria of economic effect on the plant. The relation of inoculum level to a measurable response in the crop is largely unknown.

The same is true of insects living in the soil. Those living above ground have been evaluated in terms of population levels and economic damage to crops and largely effective control measures have been established. But this is not the case for below ground insects.

Criteria do not exist for many of the other categories of land degrading materials or substance because they are already present in the soil in a wide range of concentrations in the natural state. What then constitutes "too much"? This is one of the questions which will have to be answered before effective standards may be set.

III. POLICY AND GUIDELINES

A. Information Collection

In any attempt to solve a problem the first requirement is to identify it. This done, it is necessary to summarize all available information on the subject for application to the solution of the problem.

It is important to know not only what to look for but where to look for it. The person collecting the information should be knowledgeable in the particular discipline. This knowledgeability is of great value in the perusal of the literature, since it is possible to overlook critical research which to the untrained individual may seem of little or no consequence in its application to the solution of the problem.

A system of automatic review of journals and texts, etc. is required, assigning knowledgeable individuals from each discipline concerned to review a number of publications. Care has to be taken not to overload the individual who could be a full-time staff member or, perhaps more desirable, a part-time consultant.

Part-time consultants are more desirable from several standpoints. First, it is extremely unlikely that one individual would have command of a variety of languages to peruse all the literature which may be published on any given subject. Second, it makes possible the better use of the money available for fees as a part-time worker costs only a fraction of the salary of a full-time employee. Third, from the information supplied from many individuals, one can better interpret the international significance of a given problem. The collection system requires periodic summarizatinns of information. It is of considerable benefit to have the same man involved for a number of years because the periodic summation should include not only new but an assessment of the old information.

These summarizations are necessary to establish new levels or standards and to up-date old standards as well as to identy changes in the status of a problem. It is also necessary to hold meetings of the literature reviewers, not less than biannually, to discuss land degradation problems from the international point of view. This should result in international guidelines being developed. At the same time such a meeting would provide an excellent opportunity to initiate replacement reviewers.

The inventory and distribution of the data thus obtained could be distributed as periodic reports or in the form of microfilm to each of the major libraries in the world and to governmental agencies interested in such information. If required, it may be possible to provide the reports on a subscriber basis.

B. Goal Oriented Research

The alternatives for providing for adaptive and basic research are: the use of grants or formation of institutes of environmental investigation. In either case, it is essential that the information developed through collection and interpretation be supplied to the persons conducting the research.

In providing grants for research, monies should be allotted to task force groups for the investigation of one particular segment of environmental concern. If possible, it would be advantageous to have as a project leader or co-project leader one of the scientists designated as a collector of information. This arrangement could promote internal and international coordination of effort.

The task forces would have the multi-discipline approach to the problem as environmental research should be conducted with consideration for as much of the environment as possible. As an aid to the coordination of a multi-disciplinary investigation an interagency committee should be established to select, review, and evaluate projects and collate their findings into a compendium.

Institutions of environmental research could be funded in countries with the required facilities, or if it was desirable to locate such a research centre in a particular part of the world, then the necessary facilities and equipment could be provided along with the expert staff. Where possible, these research institutes should be established where the environmental condition to be investigated exists. A committee of experts should select the sites, determine the expenditure of funds, and evaluate the projects periodically.

Another approach to the selection of sites could be made by requesting proposals from existing institutes, agencies, and universities.

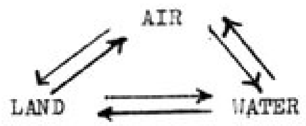
The establishment of institutes or task force groups should not be on a permanent **basis.** In view of the changing nature of the environment each contract should state a time for termination. A suitable period for investigations of this nature would be in the order of five years. If it was deemed by the selection and review committee that the project should continue, then the new contract should also be limited in duration.

C. Criteria and/or Standards

It should be recognized that in the establishment of criteria and/or standards, the principal concern is the effects of land degradation on plants, animals, or the quality of air and water resources. The suitability of standards will depend largely on the ability to develop criteria which can properly measure the effects under a variety of conditions. For a given set of environmental conditions the environment can utilize or absorb a fixed amount of a compound material or element without becoming degraded or resulting in adverse effects. Principles governing the reactions of the polluting material with the environment need to be determined in order to be able to predict effects. One of the essentials of developing predictions is the understanding that principles never change, conditions change, although it must be borne in mind that man's understanding of those principles may change.

This, for example, partly accounts for the wide conflicts which occur in the literature regarding nitrate appearance in surface or ground waters. There are conditions which are favourable for the movement of nitrogen into water supplies and accumulation there. At the same time there are conditions under which nitrogen does not move into ground or surface water. This example is used to point out the necessity of developing adequate criteria for establishing standards.

In establishing criteria one can view matter as being involved in a large equilibrium with the resource triangle of land, air, and water



For a particular entity, it then becomes necessary to define the rates of reaction or equilibrium with the other resource. The equilibrium concept assumes a decay or removal from one resource and inclusion in another.

Except for the case of radioactivity, which might be artificially produced, there is a finite world concentration of an element which exists in an equilibrium. The equilibrium concept has been used for the investigation of parts of our environment, such as nitrogen or sulphur cycles, but to consider the total input and output from a resource into another resource has not been done for the environment as a whole.

It is recognized that in many instances there is the need for standards before criteria can be developed from adaptive and basic research. Such standards should be used only as a guide for environmental quality; therefore they should be established in line with current abilities to evaluate and control a particular entity in the environment. As more information becomes available the standards should be accordingly changed.

The initial establishment of guidelines should be done with a wide base of approval. One way to do this is to collect information regarding standards for each of the proposed environmental factors. This could perhaps be one of the first efforts of the people selected to collect, interpret, and inventory land degradation information. The purposes would be to determine ranges for standards which are currently in practice without regard to criteria necessarily involved in obtaining or arriving at a standard. It should be reemphasized, however, that provision must be allowed for change when new information regarding the level is obtained, as well as for establishing the standard within the current abilities to control or prevent land degradation.

Once the information is obtained on current standards, a compendium committee composed of sociologists, medical doctors, veterinarians, agronomists, soil scientists, economists, food technologists, lawyers and others, should meet to establish, if possible, the initial standards.

Another approach would be to request member nations of the United Nations and non-members to provide such information as they have regarding standards for the environmental problems being considered. Each nation would also be called upon to list the recognized authorities in their country for each of the disciplines named. These people would be among those to be considered for appointment to the compendium committee which would establish the initial standards. Members for the committee should, of course, be recognized as the best authorities available. Regional, environmental and cultural factors and and cost benefit ratios must be taken into account in establishing the standards.

IV. ACTION POLICIES

A. Priorities

The land degradation problems discussed in previous sections of this paper are listed below in three categories. While the ranking within a category may be subject to interpretation from the land degradation point of view, it is believed that these categories represent three distinct levels of concern; therby establishing priorities for action in relation to land degradation problems and their worldwide influence. Within specific equilibrium regions, one or more of the causes of the problems may assume greater significance in relation to the others within a category. It is also recognized that in a specific instance a cause of a problem may assume the highest priority requiring immediate remedial action.

If land degradation control measures are to be implemented it will require the joint participation of government, scientists, and laymen. One of the integral parts of the action programme is communication between these three groups. It is of critical importance to eliminate possibilities of misunderstanding.

B. Social Implications and Education

The scientist should describe the action to be taken in terms familiar to everyone and not in terms understood only by other professionals. There is a need to educate people in the necessity of control measures and management of the environment.

Where the educational level of the people is low, the programme may have to be conducted by audio means. One of the important changes which will have to occur with regard to land degradation is the attitude of those who, at present, do not see the need or are indifferent to the problem.

Suggested Priorities for World Land Degradation Problems

Category	Causes of Problem
Category I	Erosion and Sediment Salts and Alkali Organic Waste Infectious Diseases and Insects
Category II	Industrial Inorganic Waste Pesticides Radioactivity Heavy Metals
Category III	Fertilizers Detergents

In the implementation of an action programme, care must be taken to prevent pollarization of groups with opposite points of view or with legitimate concerns about the effect of these control measures on their livelihood. Care must also be taken to prevent group identification with a problem. For example, high rates of refuse disposal might be considered important by people of the middle and upper income groups but of little or no interest by people of lower income groups.

C. Need for Alternatives

One of the basic reasons for failure to comply with standards by industries or persons is that the standards are too stringent and there is no mechanism for effecting the control, no alternative allowed in this event, and no means of absorbing immediate increased costs.

There is little doubt that cleaning up the environment is going to increase costs for agriculture and industry. At the present time, if many of the proposed mechanisms for waste disposal or prevention of land degradation were implemented, agricultural and industrial production costs would increase considerably. Agricultural and industrial costs are rapidly coming to the point where increased production can no longer offset increased costs. Consequently, alternative policies need to be established to allow the widest possible latitude for adaptation of control measures within accepted standards for various regions. Government and private enterprise must work together to establish suitable alternatives.

One of the problems of establishing such alternatives is the multi-disciplinarian aspects of the environment. There should be provision for the establishment of a coordinating group within each agency responsible for collating the information obtained from various research groups and determining the implications for environmental quality. This committee would be similar in action to the previously discussed compendium committee. In the establishment of alternative approaches, it would be necessary to make provision for emergency conditions and the procedures to be followed where such events occur.

D. National and International Controls

The implementation and enforcement of control measures need tax monies to support them. The collection and distribution of tax money requires legislative action. Even if individuals assessed themselves to provide money for pollution control it would be undesirable. In some regions, because of their affluence, they would be able to buy more control than the people in other regions. This is an ineffective way of controlling land degradation since certain aspects are not influenced by boundaries. Taxation therefore as a source of funds is necessary.

In some cases the activity of a nation may produce a cause of land degradation of world concern. For such situations it is necessary to establish international standards which can be enforced. The assessment of concern regarding such problems of land degradation and persuasion to commitment by nations to implement controls should be a function of the United Nations. Assuming an acceptance of the proposed standards, the individual nations would have to enact the appropriate legislative action.

In national controls of international or regional significance, the standards might have to be more stringent than the general standards. For more local controls the standards need to meet competing demands and the assimilative capacity of the land, air, and water resources available. Flexibility must be allowed local governments.

If maximum standards were accepted internationally, obviously the subsequent legislation and enforcement would have to take place at the national level. However, in the legislation there would have to be provision to allow for monitoring by an accepted world organization as the means of double checking the effectiveness of the control measures on the environment.

In many instances local authorities (as, say, State governments) do not have the expertise available for the establishment of standards or guidelines, therefore national governments and international agencies should provide leadership in the establishment of standards for all phases of land degradation. But, as already pointed out, locally applied standards, penalties, or controls must depend upon the status of the problem in each area.

The necessity for world coordination of activities in the control of land degradation specifically, and environmental quality in general, has been recognized by the United States National Academy of Sciences. One of their recommendations has called for the formulation of natural resource policies for the nation, continent, and world through whatever governmental structures or covenants that would best serve the purpose. The necessity of cooperation and agreement upon international legislative actions to control the world environment cannot be over-emphasized.

E. Economic Implications of Policies

As previously indicated, the cost of implementing land degradation controls is a primary inhibitor to the application of technology to the solution of current problems. The alternatives for assigning costs for the implementation of appropriate control measures are: to assign the cost of disposal to the producer or to assign costs to the user through the use of tax money. In either case the user pays the cost.

In those industries for which the implementation of controls would create economic disaster, international and national funds should provide for the immediate application of technology for the improvement of the environment. These funds should be lent at the lowest possible rate, with repayment on the most equitable basis possible, consistent with good financial management.

Those countries or industries requiring financial assistance should submit to the lending agency a plan of implementation as a condition of the acceptance of financial help. The plan would have to be approved by a regulating agency, perhaps the compendium committee, as providing suitable and proper methods for tackling the problem.

F. Monitoring System

As it is not likely that a medical doctor would be able to discuss authoritatively or be in a position to predict nitrogen transformations in soil and its movement into the groundwater or a soil scientist diagnose methemoglobinemia, there is the need for experts of several disciplines to determine which measurements are required to be able to diagnose the status of an environmental problem. In some cases it may be necessary to assess the esthetic quality of a cause of land degradation. The question then arises, how do you measure the esthetic quality? Since this is a matter of personal and subjective judgement, the only reasonable approach is to rely on public expression of concern.

A monitoring system should have two principal concerns: the rate of change of a variable, and the level of concentration. The rate of change is of value in that it can forewarn of land degradation problems. Establishment of the level is necessary in order to evaluate compliance with existing standards. A monitoring system could be part of the normal activities of an Environmental Research Institute (as proposed) or of a nation. Another possibility is the use of such a system through the establishment of groups of experts at educational institutions, private research laboratories, and industrial laboratories. A monitoring system should be part of an international and nationally coordinated system. The systems should complement each other, eliminating much of the duplication effort, therefore reducing costs. Monitoring information should be supplied to each of the participating agencies as well as to non-participating regulating agencies.

Expert participation in the monitoring programme is required for two main reasons. First, in many instances it is difficult to distinguish between effects resulting from several probable causes. Because of the similarity of effects it is necessary to interpret the data, a job best done by experts. Second, analysis of the information collected to determine its meaning with relation to changes in levels and rate of change is needed and should be forwarded to the proper agencies for implementation of appropriate action.

The experts should have trained observers and technical help to assist in the collection of information. Assistance from automatic recorders would allow the monitor to obtain more information from a wider area, possibly reducing the large number of monitoring experts required.

G. Strengthen Existing Organizations

As already suggested, it may be feasible to fund additional staff at established educational institutions or governmental organizations. In many countries, there already exist arrangements for providing assistance to, and the education of persons involved in, the management of their environment, as in the case of the farmer who is reached through a series of educational and direct assistance agencies. In general, urban planners and industrial managers have not had similar organizations to call upon. It is desirable to broaden many of the existing organizations to provide for a wider public. The initiation of such an educational and technical assistance system assumes that the agency or the people concerned are associated with the control problem and would receive all available information on environmental standards.

If the cost were to be borne by the government, there would be a greater necessity for the type of staff capable of adapting control measures to a variety of conditions. In this case the educational programme takes on a different light and becomes a "how to operate" drive.

The pattern and functions of an Agricultural Extension Service might serve as an example of an organization to provide technical assistance, as well as education regarding the environment. Many countries have such organizations into which the environmental specialists are easily fitted. In many instances, especially with regard to land degradation, much of the expertise in solving land pollution problems already exists in such types of organizations.

As part of an education programme the applied techniques of control methods may be demonstrated through pilot studies. There is not so much the need of facilities for this as there is for staff of sufficient expertise to be able to demonstrate and discuss environmental control.

V. LEGAL AND INSTITUTIONAL ASPECTS 1/

Legal and institutional aspects of land, including soil degradation control, are important components of the whole range of problems relating to the rational use, management, and conservation of the land. They constitute a means of implementing policy decisions to promote development compatible with the need for conservation.

These components may be viewed either at the different levels at which they operate - local, regional, national, and international - or according to the functions they perform, such as in policy making and in executive and control matters or with reference to the specific character of the factors of degradation involved.

The problem is to see how best to devise a methodology for coping with all aspects involved and which are inter-connected, inter-disciplinary, and inter-sectoral.

In their present status, legal provisions to control land and soil degradation as well as the related institutions responsible for such control are, generally speaking, use or mis-use oriented; such is the case of soil conservation legislation and institutions, watershed and drainage legislation and institutions, municipal and urban laws and institutions. It is submitted that such a sectoral approach may not always be conducive to adequate planning for the rational development and conservation of the land. Land and soil conservation legislation and institutions should be viewed within the larger land use planning; the purpose of which is to ensure harmonious and adequate allocation of land and soils for agriculture, town development and housing, industrial development, recreation, etc...In turn, land use planning laws and institutions will form an important component of the overall national planning of available natural resources such as water, minerals, bioresources, air and human beings.

The legal provisions relating to the control of soil degradation are more specifically aimed at ensuring the protection, conservation, and reclamation of soils in order to satisfy present and future demands for every purpose of utilization, taking account of the constraints imposed by population growth and behaviour. But unless there is a definite policy regarding land as a basic and essential natural resource the investigation, utilization, and conservation of it will be retarded, misdirected and wasteful.

Consequently, some countries are considering establishing basic land and soil policies which vary from country to country according to the specific needs and factors prevailing locally. Declarations of policy are contained sometimes in constitutional laws or more generally in laws regulating land use, soil conservation, agrarian laws, etc. In many countries such policies are often contained in land reform laws.

A. Existing Situation

Although the importance and urgency of the problems related to land and soil degradation have been generally recognized in most countries, legislative action to meet such problems is relatively recent. There is a clear tendency for such legislation to expand its scope but in many cases it remains incomplete or even non-existent, and emphasis is mostly put on soil erosion.

Soil conservation legislation is most highly developed in the United States, in European countries, and in India, Japan, Pakistan, and Australia. Certain European countries, such as France, Western Germany, Switzerland and the Scandinavian countries have a long tradition of soil conservation and have improved their legislation on the subject over the years.

In certain Asian countries, recent legislative action combines soil conservation and agrarian reform measures - and tends to be of a more compulsory nature, thus falling into line with the trend of numerous other legislative systems. In the same region, Japan, Ceylon, the Federation of Malaysia and India have specific legislation for the prevention of soil degradation.

The Latin-American countries are becoming more conscious of soil degradation in view of the increasing pressure of population and have adopted national land, soil and water conservation programmes. Mexico and Venezuela for instance, have a soil and water conservation law which provides for the adoption of measures aimed at controlling soil degradation (31.12.1945). But, generally speaking, provisions on soil conservation are contained in land settlement and land reform legislation, as well as in legislation dealing with other natural resources, such as water.

1/ Prepared by the FAO Legislation Branch, Legal Office

A similar situation is also frequently to be met in certain Near East countries, although the relevant factors on the problems posed by land degradation are sometimes different.

The United States have an extensive experience with soil conservation, since the conservation programme is based on the Soil Conservation Act of 1935.

In Africa, soil conservation programmes have recently been adopted by Mali and Zambia, and are being actively carried on by many other countries.

The common feature of the legislation reviewed above is that it is based on a few concepts which are, inter alia: limitation of individual ownership and rights of use; control of land and exploitation; exercise of the right of eminent domain; state ownership and control on forests and grazing lands. These concepts are apt to deal with such recognized degradation agents as water and wind. The problems created by new factors of degradation would require a different set of measures.

B. Infrastructural Constraints

From an analysis of the present situation it is notable that there are many institutional and infrastructural constraints. Particularly, since soil conservation administration is generally use or function- oriented rather than resource-oriented, there is an impeding obstructive or retarding effect on the control of land and soil degradation.

Traditional and modern infrastructures of human society or community, especially as regards their legal and para-legal forms, happen to affect in a negative way the distribution, the development, and the protection of land and soil.

These traditional concepts of ownership, rights of use, and ways of acquisition of such, may lead to elusive and abusive utilizations of soil and subsoil. On the other hand, traditional social restrictions (tribal and feudal systems on resource utilization) and religious restrictions prevailing in many developing countries prevent an adequate development of soil, with the consequence of its deterioration.

The same observation is true of modern concepts related to territorial sovereignty and political boundaries, and federal, state or local divisions which do not take sufficient account of ecological or natural units.

As has been mentioned, soil conservation administration is use or function oriented. This concept results in a sectoral approach of problems related to soil degradation control. In most countries, several ministries or departments, as well as sometimes autonomous or semi-autonomous authorities, are directly or indirectly responsible or interested in sectoral aspects of soil conservation and control of soil degradation. These generally include Ministries of Agriculture, Public Works, Planning, Transport and Communications, Public Health, and such authorities responsible for surveys, land use planning, development and conservation of soil, water management, afforestation, grazing, fire control, etc.

The results of this situation are highly detrimental through lack of efficient planning, overlapping of functions and responsibilities, waste of financial and human resources, and uncertainty as to the successful implementation of projects.

C. Land and Soil Degradation Control and Conservation Legislations

Land use legislation in general, and soil conservation legislation in particular, are the means through which it is possible to implement the decisions and orientation framed at the national level by the policy making bodies, on the basis of the political, technical, economic, social, legal and institutional factors prevailing in the country as regards the various requirements of soil protection.

Adequate legislation should necessarily include provisions with respect, inter-alia, to the following items:

(i) Clear statement of purpose; it should not limit itself to propose conservation of land in general but should identify the various approaches (physical - economic) to be adopted, as well as the level of conservation to be practised.

(ii) Identification of the various pollutants and degradation agents and the measures to apply to control them.

(iii) Establishment of priorities (agriculture - municipal - zoning - industry) to prevent conflicting policies and actions, especially when agricultural production is at issue.

(iv) Power to declare protected zones or areas in the case of emergency circumstances, and the right to control and prevent waste, misuse, and over-exploitation.

(v) Government financial contributions or participation through tax exemptions, subsidies, credit facilities and compensations.

(vi) Creation of institutions and authorities responsible for land and soil conservation policy-making, execution, and implementation at any required level (local, regional, national) commensurate with the countries' means in terms of finance, staffing, etc...)

(vii) Coordination and interconnection between different legal enactments directly or indirectly affecting land and soil, such as: land reform, land settlement, mining, urbanization, protection of landscape, forestry and water.

(viii) Educating the public to appreciate land and soil conservation.

(ix) Implementation and enforcement; police powers; settlement of disputes; penalties and similar factors.

Since soil conservation legislation is not an abstract and easily transferable set of norms, and in view of the prejudicial impact it may have in certain cases upon the whole management of land resources development and utilization, it must be conceived as a direct implementation of land use policy and treated as such. Further, land use planning must be viewed within the framework of the overall national planning of all available and related natural resources.

D. Land and Soil Control Institutions

Legislation by itself does not constitute the panacea for solving problems connected with soil conservation, and will be ineffective and inefficient if not complemented by adequate structures, which have to be considered at any required level.

1. Organization at the National Level - Appropriate institutions are required to deal, at the national level, with the rational use and management of land and soils. This could be achieved by establishing a National Land Resource Council or Commission responsible for dealing with the overall policy aspects and the technical, economic, and legal aspects of land and soil development and conservation activities.

A Land and Soil Council should be composed of those ministers having sectorial responsibility for soil and land use. Such a body should ensure coordination at the highest political level for: framing the overall land and soil conservation policy of the nation, determining priorities, and deciding on actions to be taken to control land degradation.

A Land and Soil Board or Commission should be composed of various specialists responsible, in the various departments and authorities, for sectorial aspects of land and soil development and conservation activities. This body should ensure an institutionalized and compulsory inter-ministerial coordination, and assume advisory and/or executive functions.

The action of the two above mentioned bodies should be complemented by a Central Land Administration, with functions inter-alia to:

- execute the political and technical decisions taken by such bodies;
- evaluate and coordinate the projects related to land and soil development and conservation;
- standardize and pool information and data relating to land and soil, including degradation;
- prepare a plan of actions for the rational use, management, and conservation of land and soil.

2. Organization at the Lower Level – Regional institutions may be envisaged, either as Branches or Departments of a unified land and soil conservation administration or as more or less autonomous bodies. Such lower level institutions should follow as much as possible ecological and national conditions.

At the user's level, land and soil conservation should be eventually placed under local leadership by means of soil conservation districts, whose function should be to assist and guide the population in solving problems related to the control of soil degradation.

E. International Legal Machinery

Legal action at international level to ensure adequate control over land and soil degradation can be undertaken (1) through separate inter-states conventions and treaties, (2) through a basic framework treaty establishing uniform legal standards, or (3) through legal assistance provided by international organizations.

1. International conventions – this traditional method may be of limited application because it lacks flexibility, whereas many problems related to land and soil degradation control requires solutions subject to constant up-dating and adaptation to technological changes. On the other hand, such problems often require simultaneous action at the national and local levels, frequently affecting private rights, thus entailing the conversion of international treaty texts into national laws and regulations.

2. Enactment of international uniform standards – This method separates the "basic treaty" which provides an institutional framework from the "technical rules" which provide detailed standards and can be periodically amended by an international expert body without requiring further formal ratifications by member states.

This flexible formula has been widely utilized in recent years by international organizations.

3. Legal assistance – This way of action, which consists mainly in providing assistance for the drafting and administration of more resource-oriented land and soil legislation, is especially adapted to the needs of developing countries.

VI. REMEDIAL MEASURES

There are several degrees of action which can be taken for controlling land degradation. Degradation itself may not appear to require emergency measures. However, there is a difference between emergency measures and the need for immediate attention. Emergency measures implies the all-out concentration of activity to correct a situation or provide a control. Immediate activity implies a need for rapid application of technology to prevent the degradation problem from reaching emergency status. This definition applies to Category I.

There will be some isolated critical areas needing emergency attention as, for example, in an accidental release of radioactive waste or the disposal of industrial or domestic affluents in such a manner as to create an immediate degradation problem.

In a sense, all ten degradation problems listed require immediate attention. The reason for separating them into three categories is to list the priorities if resources are not available to provide solutions at the same time for all ten.

A. Category I

1. Erosion is one of the most widespread forms of land degradation and is of general concern. The fact that erosion generally occurs rather slowly and may not create immediate problems is one of the reasons for it not being considered for emergency measures.

As pointed out previously, large savings can result from implementing control measures to prevent soil erosion. Such controls consist of those techniques for preventing soil loss and surface runoff in watersheds. Current control measures include the use of various forms of mulches, primarily crop residues to prevent soil perturbation by rainfall. The disposal of organic wastes too may prove to be an effective measure for controlling soil loss. It is not likely that the same approach can be used on non-agricultural lands because of the inability to incorporate these materials into the soil, thereby creating an esthetically unsuitable condition.

Preventive measures consist principally of structural and cultural techniques to retard and stabilize the soil and lessen the erosive force of wind and water. On forest and grasslands, the principal measures consist of controlling fires and over-grazing and of reseeding. These areas do not readily lend themselves to the use of organic waste or mulches. The cost of implementing control measures varies from perhaps a small amount for changing a cultural practice to a much higher one for using organic wastes and mulches. Techniques need to be developed or improved for the stabilization of disturbed soils and of stream-beds and stream-banks, these latter being among the major sources of sediment load for larger streams and rivers.

2. In the case of salinity and alkalinity, suitable criteria and standards have been established and effective control measures are in current use in some areas. In other areas, such technology has not been practiced although control measures are available at costs which are economically feasible. In some instances, salt or alkali build-up can be prevented by proper irrigation management with knowledge of a plant's salt tolerance, the salinity level of the water, and soil characteristics which promote good drainage and leaching. One of thedilemmas in which agriculture finds itself is how to accomplish leaching without moving the salt into the groundwater, thus contributing to its degradation.

There are essentially two approaches to regulating salts in soils: (1) the use of nearly pure water for irrigation, thereby eliminating the salt load added to the soil, and (2) a requirement that agricultural water supplies consist only of those unsuitable for uses at lower salinity levels. The latter approach is not the most desirable but is the least costly since the use of pure water may require sophisticated water treatment techniques. Even with pure water, there would be certain irrigation management problems to be overcome as, for example, a lowered infiltration rate resulting from the use of low electrolyte content water. The length of time required to overcome this physical phenomena, if it can be overcome, is not yet known.

3. With organic waste, the immediate concern is to use current technology in the treatment of these materials. Current technology is capable of disposing of the present levels of organic wastes, but the costs of such disposal prohibits this. Incineration and re-cycling seems to be the two most desirable techniques for handling the wastes. Incineration would, of course, have to comply with air

quality standards. The immediate action should be to pass legislation for control measures adequate to meet established standards and to provide for costs of implementation. In many instances, municipalities and industries have already established incineration or other disposal techniques. These should be evaluated for acceptability in the light of established standards and adequacy for handling an increased volume. Where necessary, funds for expansion or improvement of existing control measures should be provided. In some cases, technical as well as monetary assistance will be required. It may also be necessary to provide for operating costs in the initial stages until support can be obtained through local legislation. Part of the costs of implementation, operation, and maintenance may be assigned on the basis of national and local participation. It could conceivably be of international interest to participate in the implementation of control measures, in which case aid might be provided by means of technical assistance or financial help, or both.

Organic wastes from agriculture require a different set of controls. Once again, the technology is available for the disposal of these wastes, but the costs involved prevent its widespread use.

The disposal of domestic sewage is another problem of immediate concern, mostly to do with water rather than land degradation. The by-products of treatment plants as well as raw sewage ultimately are disposed on the land. Part of the cost of operation should include the additional cost for land disposal.

Curative measures consist of educating the public to persuade them to limit their use of cellulosic waste and to stress its reuse. An educational programme may stress such matters as the reuse of paper sacks or boxes and the voluntary segregation of refuse to permit introduction of this material into a recycling system at minimum cost. It is not likely that the volume of human and animal waste will decrease, so there is a need to develop more economical techniques for handling this material. The use of reclaimed products from such wastes would require an extensive educational programme to gain acceptance. For example, sodium chloride (table salt) could be reclaimed from animal and domestic wastes. This is but one example of many such uses of the minerals contained in these wastes.

4. The ranking of <u>infectious diseases</u> and insects along with other sources of land degradation is a problem. As infectious diseases and insects form a population of organisms which have always been present in soil, is their presence a form of degradation? Or, is land only degraded by the introduction of an organism into a soil previously uninfested by that organism? If one assumes the latter, then infectious organisms would rank rather low in the area of land degradation. On the other hand, if the presence of infectious organisms in soils constitutes a danger to crop production and animal and human health, then their ranking would be high in relation to some other forms of degradation. In the most strict and critical sense, they do not constitute land degradation but they do form a constituent of soils and their activities do result in severe economic losses in terms of crops and health; therefore they should be considered high on the list of those items requiring control.

Current control methods dealing with diseases and insects seem partially successful, and the cost to the producer is relatively low when considering cultural practices or biological control techniques. The use of soil fumigants and other pesticides represent a cost of production which can range from relatively low to very high. Soil fumigation for the purpose of growing strawberries is an example of high cost.

The control measure which seems to have the greatest hope is the development of varieties of crops tolerant to infectious organisms or insects. Along with future development of such tolerant varieties is the need to also develop more specific pesticides with lower toxicities and greater biodegradability.

B. <u>Category II</u>

The land degradation problems presented in Category II represent a lower order of magnitude and relative importance because of their lower extent and intensity, or rate of increase, or both. This category should not compete on the same level for facilities and financial assistance with Category I. But this does not preclude the possibility of Category II materials constituting a very real land degradation danger for a locale; which may make it necessary for national and international funding agencies to provide for the use of area control measures in critical cases. But there need not be the same degree of general investigation and concern as with the Category I problems.

1. With <u>industrial inorganic wastes</u> the principal control measures consist of containment, reuse, or treatment before release. Each of the three methods increase costs and the consumer either pays higher prices or higher taxes.

Future measures should consist of improved technology to permit a more economical operation. Perhaps such an economic incentive can be provided so that previously unwanted wastes become desirable and natural resources. This may come about through the introduction of new technology for the treatment of heretofore unusable or unwanted by-products.

2. The appearance of pesticide residues in plants and their persistence in soils has led to concern about the uptake of these materials by plants and their redistribution into water supplies. However, under normal usage they constitute very little danger as a form of land degradation.

In many instances pesticides are used as a preventive rather than as a control measure. This is especially true of fungicides and systemic insecticides. Because of an inability to predict accurately when and where an infestation may occur this is a necessary feature of their use and it is unlikely there will be any change in this practice. Perhaps bench mark data may be obtained to ascertain when and if these pesticides reach unacceptable soil levels. This approach requires investigation to establish such limits.

A third approach is to not use pesticides at all but much more work is required before tolerant plants or other biological controls can be developed. In some cases it may even be impossible to develop a useable biological control method.

The development of more specific and less persistent pesticides is necessary to alleviate the present concern. Pesticides of greater specificity may require more frequent applications of different types than is necessary with the broader spectrum pesticides. In addition to more material, possibly of a toxic nature, being present, both the cost of materials and of application would probably be increased. For pesticides generally the principal control is the use of the material in the prescribed manner.

3. The widespread distribution of radioactivity, even though extremely low in intensity, is the principal reason for its inclusion in Category II. There is also the possibility of its growing in importance through the increased use of nuclear power generators. With regard to control measures, this is one instance where international and national controls and standards have already been established and are being implemented. Also, stringent preventive measures to control nuclear waste release into the environment have already been imposed. The controls and preventive measures and standards were established when the principal concerns were the threat of nuclear war and the possibility of accidental releases of radio-active wastes. While the former threat seems removed, the latter remains an ever present possibility. There is also today a questioning of the adequacy of the standards in relation to low level chronic exposure to radioactivity and the entry of radioactive elements into the food chain of man. The apparent need, then, is to establish the level at which accumulation becomes a hazard in the food chain. Perhaps this sort of information is already available but is not generally known. If it is available, it should be conveyed to the public to allay their fears.

4. Heavy metals are natural constituents of soils and are similar in that regard to radioactivity, and like industrial inorganic wastes, they are generally concentrated in areas surrounding population centres as a result of man's use of them.

There are reports of uptake by plants of toxic heavy metals at relatively high concentrations. There are also reports that some plants do not absorb heavy metals at all. The confusion lies in the differing abilities of plant species to exclude or absorb certain elements - a mechanism not well understood although often demonstrated. Also, it has been pointed out that in some of the instances where heavy metals are absorbed, they do not represent toxic levels in plants. In other, where absorption reaches a toxic level, there is a built-in mechanism which prevents the plant reaching maturation. This also prevents the use of that plant as a food source, thereby eliminating it as a widespread health hazard.

As with the other land degradation sources in Category II, there may be critical areas where immediate implementation of control measures are necessary. Known control measures are similar to those used to combat the effect of radio-activity - that is, the dilution of the heavy metal primarily by soil manipulation.

Preventive measures consist of containing these materials at their source where they are derived from industrial uses or eliminating them from materials used by people. It may be necessary to develop replacement materials for those heavy metals which are deemed hazardous. Replacement metals or other materials should be investigated as to their effects in the environment before being so used.

C. Category III

This category contains those sources of land degradation which are of the lowest priority. They constitute no widespread immediate hazard nor are there numerous isolated areas needing attention. With fertilizers, there are two of main concern – nitrogen and phosphorus.

1. The movement of phosphorus in soils is extremely slow and, except for its movement into surface waters in association with sediments, it does not constitute a hazard to land, air or water. Its presence in water even in association with sediments is in extremely low concentrations. There is also mounting evidence that phosphorus in water is not the controlling factor for eutrification of our surface waters.

2. The principal concern of nitrogen in fertilizers is with inefficient use. Through inefficiency, high levels of nitrogen may accumulate in plants, resulting in toxic levels for animals. However, this toxicity has not been demonstrated for humans.

The excessive application of nitrogen may contribute, under certain conditions, to the nitrogen content in surface and groundwater supplies. But there have also been several investigations which show that, under some conditions, even with excessive use, nitrogen from fertilizers does not reach such water supplies.

Along with oxygen and silicon, nitrogen is one of the most abundant and ubiquitous elements in the world. Methods for controlling and preventing nitrogen concentrations through fertilizer usage call for the efficient use of the fertilizer. Considerable information exists concerning the techniques for such efficient use which results in savings in production costs and usually increased production.

Future measures for prevention of land or water degradation consist of developing criteria for predicting nitrogen movement under a continuum of conditions regardless of the source of nitrogen. The development of soil and tissue testing techniques will assist in ascertaining optimum rates of application and timing of application to promote most efficient use of the element.

3. Detergents are of a minor importance in land degradation. The principal adverse effect which could be created by the use of sewage water containing detergents would be the associated sodium and its dispersing effect on soils. The phosphorus in detergents, although more water soluble than sediment associated phosphorus, is not, as already pointed out, the principal contributor to eutrification of water.

Finally, it should be stressed again that the three designated categories of land degradation problems do not represent a permanent assignment of priorities, but are a temporary assessment. The maximum time that these should be considered in their present category is five years. At the end of that time there should be a re-assessment of categories and a re-assignment of priorities in relation to the current need. It is hoped that, as a result of successful alleviation of some of the present day problems, the priorities will not then be the same.

APPENDICES

I. SALTS AND ALKALI

EXTENT

The most classic of land degradation problems that has faced man around the world has been that of controlling, preventing, or reclaiming saline and alkali soils. Usually, saline and alkali soils are associated with arid and semiarid regions where rainfall is not adequate to provide leaching of the soil profile. This does not preclude the possibility of finding them in other areas. Blovskya finds saline soils are common to the meadows of Yakutia, USSR. The salinity has accumulated due to poor drainage resulting from a rather shallow multiannually frozen parent material usually at the 10 to 30 cm depth. Another feature of the arid and semiarid areas of the world is that in order to have agricultural production in these areas the soils have to be irrigated.

Egorov et al found that one of their main problems of irrigation farming in the cotton belt of the USSR was that of salinity. From 1945 to 1961 the amount of weakly and medium saline soils increased from 49.6 to 85 percent. In a second category, called strongly saline soils, the percentage decreased from 50.4 to 15 percent of the Vakhsah Valley. This is the kind of trend in salinity which has been observed in other areas of the world. That is, the strongly saline soils are generally reclaimed in order to obtain production, whereas the producing nonsaline or weakly saline soil has a tendency to accumulate salts.

In developing a soil map of the Near East, Dudal found the most characteristic feature of soils in that region was the wide occurrence of saline soils. In the United States, Bower and Foreman estimated that about one-fourth of the irrigated soils were salt or alkali affected to the point where productivity was lowered. There is little doubt that salt and alkali affected soils are widespread throughout the world.

SOURCE AND INTENSITY

In some instances the salinity is the result of geologic weathering. For the most part, especially on irrigated soils, the source of salinity is due to the application of irrigation water. Estimates of the world irrigated acreage for 1967 was 401.8 million acres (Water Encyclopedia). Irrigation water supplies come from two sources. They are surface runoff, impounded or a portion of the stream flow, and groundwater. Occasionally drainage water is collected and reintroduced into surface streams, thereby becoming, in the context of this report, considered as surface water.

The consideration of water quality in evaluating the encroachment of salinity in soils is very critical. For although it is true, one usually cannot change the source of water supply, one can change management practices to account for the amount of salts being added. Therefore, losses of production can be prevented from salt accumulation, or if it is known that salt levels are high, one can change the crops grown and use a more tolerant plant, see Table I.

The salinity in water supply is usually expressed as electrical conductivity (EC) in terms of millimho per centimeter (mmho/cm) or as EC x 10^3. One mmho/cm is approximately equivalent to 700 ppm of total soluble salts. The average of 700 ppm is derived from the average of the electrical conductivity measurements versus concentration of a variety of single salt solutions. Salt concentrations at one millimho per cm conductivity varied from 400 ppm for magnesium chloride to 1000 parts ppm for sodium bicarbonate. Conductivities for other single salt solutions fell in between this range. Consequently, an average value of 700 ppm is used for a solution of mixed salts. A water having a conductivity of one mmho/cm would contain approximately 1900 pounds of salts per acre foot of water. This should be viewed only as a guide and not as an absolute value.

Much of the water applied is lost through evapotranspiration and only a very small amount of the salts are taken up by plants. Consequently we have an accumulation of salts in a soil profile resulting from irrigation. Another problem which leads to salt buildup is inadequate drainage. Water can rise by capillarity carrying along with it dissolved salts. As this water reaches the root zone or the soil surface from the water table, the water is consumed through evaporation and transpiration leaving a salt deposit. In many saline soils the capillary movement of water containing salts is dramatically illustrated by the evaporation of the water resulting in a salt deposit on

Table 1 - Salt tolerance of crops relative to the electrical conductivity of a saturation extract[1/] [2/]

High Salt Tolerance (18 to 10 mmhos/cm)	Medium Salt Tolerance (10 to 4 mmhos/cm)	Low Salt Tolerance (4 to 2 mmhos/cm)
	field crop	
Barley(grain)	Rye	Field beans
Sugar beets	Wheat	
Rape	Oats	
Safflower	Rice	
Cotton	Sorghum	
	Corn	
	Sunflower	
	Castor beans	
	vegetable crops	
	Tomato	Radish
Garden beets	Broccoli	Celery
Asparagus	Cabbage	Green beans
Spinach	Bell pepper	
	Cauliflower	
	Lettuce	
	Sweetcorn	
	Potatoes	
	Carrot	
	Onion	
	Peas	
	Squash	
	Cucumber	
	fruit crops	
Date palm	Pomegranate	
	Fig	Pear
	Olive	Apple
	Grape	Orange
		Grapefruit
		Prune
		Almond
		Peach
		Strawberry
		Lemon
		Avocado
	forage crops	
Alkali sacaton	White clover	White Dutch clover
	Yellow clover	
Salt grass	Perennial ryegrass	Alsike clover
Bermuda grass	Dallis grass	Red clover
	Sudan grass	
Rhodes grass	Alfalfa	Ladino clover
Canada wild rye	Tall fescue	
Western wheat grass	Wheat hay	
	Oat hay	
	Orchard grass	
Birdsfoot trefoil	Meadow fescue	
	Reed canary	
	Sour clover	

1/ Adapted from Diagnosis and Improvement of Saline and Alkali Soils; Electrical Conductivity is expressed in terms of millimhos per cm at 25° C.

2/ In order of decreasing tolerance assuming 50% yield reduction.

the surface of the soil.

Saline soils are characterized rather arbitrarily as soils which have an electrical conductivity of a saturation extract of more than four mmhos per cm at 25 degrees centigrade and an exchangeable sodium percentage of less than 15. Saline soils are often recognized by the presence of crusts of white salt on the surface of the soil. Saline soils are generally flocculated, and in some cases the surface of the soil may appear powdery or aggregated and very loose. One of the principal effects of salinity is to reduce the availability of water to the plant by the high osmotic concentration of salts in the soil solution. Considering total salts without being concerned with the type of salts present is not taking into consideration the whole problem.

Another important aspect of water quality along with total salts is the sodium absorption ratio (SAR). The SAR of an irrigation water is used to express the relative activity of sodium ions in exchange reactions with the soil, as compared to calcium and magnesium, and is used as an index of the sodium hazard of an irrigation water. Formula 1 shows the calculation for SAR:

(formula 1)
$$SAR = \frac{meq\ Na^{+}}{\sqrt{\dfrac{meq\ Ca^{++} + meq\ Mg^{++}}{2}}}$$

The SAR is also related to the exchangeable sodium percentage (ESP) of the soils which is indicative of the problem associated with alkali soil.

Alkali soils are generally characterized by having exchangeable sodium percentages of greater than 15. The exchangeable sodium present in the soil has a marked influence on the physical and chemical properties of the soil because of the large ionic radius of the hydrated sodium ion and the low charge density. When excess sodium is absorbed on the cation exchange sites the clay minerals in the soil have a resultant net negative charge on the soil particle which results in repulsion of soil particles and dispersion. Upon drying a single grain structure creates small pores which have the effect of reducing the infiltration rate of the water and limiting the aeration of the soils. This loss of structure and aeration produces impermeable soils of high bulk density and interferes with plant nutrition resulting in stunted plants. Sands may not be physically affected by exchangeable sodium since their particle size prevents the extremely small pores from developing. This is characteristic of soils of heavier texture.

In addition to the two previous factors in evaluating water quality there are specific effects due to presence of some ions.

Specific ion effects are characterized by the content of ions such as boron or lithium in irrigation waters. Occasionally sodium for some plants has a specific ion effect. Shown in Table 2 are the relative tolerance of plants to boron and permissable irrigation water limits of boron. The uptake of boron by different plant species was investigated by Tanaka, his results are shown in Table 3. The data show that monocotyledonous plants do not have the boron absorption capacity that is exhibited by the dicotyledonous plants.

The exchange sensitivity of citrus to a low level concentration of lithium was reported by Haas in 1929. Appreciable concentration of lithium has been found in grape leaves and citrus leaves in Arizona ranging from 1 to 28 ppm in grapes, varying with the season and in citrus leaves all values exceeded 30 ppm. The normal lithium content of citrus leaves is about 5 ppm (Smith et al).

The effects of exchangeable sodium percentages on various crops are listed in Table 4. While the major effect of exchangeable sodium is considered to be the effect on particle dispersion and physical condition of the soil it can be seen that the extremely sensitive, and also perhaps the sensitive, plants may be affected by the specific ion effect of sodium. This effect can be overcome to a certain extent apparently by the presence of calcium in the nutrient soil solution. LaHaye and Epstein found that calcium played a vital role in the regulation of the salt economy of plants, and specifically in the selective transport or exclusion of sodium by plant cell membranes. They showed the sodium concentration decreased by one third as the calcium sulfate concentration in the aerated nutrient solutions was raised from 0.1 to 10 millimole. Over the same range of calcium sulfate concentrations the sodium content of the stems in brittle wax bush bean plants dropped by

Table 2 - Relative tolerance of plants to boron and permissible limits for irrigation waters[1/] [2/]

Irrigation water limits[3/]		
Tolerant 1.00 to 3.75 ppm	Semitolerant 0.67 to 2.50 ppm	Sensitive 0.33 to 1.25 ppm
Asparagus	Sunflower(native)	Pecan
Palm	Potato	Black walnut
Sugar beet	Cotton	English walnut
Alfalfa	Tomato	Artichoke
Onion	Radish	Navy bean
Turnip	Field pea	Plum
Cabbage	Olive	Pear
Lettuce	Barley	Apple
Carrot	Wheat	Grape
	Corn	Kadota fig
	Milo	Persimmon
	Oat	Cherry
	Pumpkin	Peach
	Bell pepper	Apricot
	Sweet potato	Orange
	Lima bean	Avocado
		Grapefruit
		Lemon

1/ Adapted from Diagnosis and Improvement of Saline and Alkaline Soils

2/ Plants at the top of the list within a group are more tolerant than plants at the bottom of the list

3/ The effect of boron concentration in parts per million conditioned by soil characteristics and management practices

Table 3 - Boron Adsorption by Plant Roots [1]

Plant Species	Boron Adsorption Capacity (ug/g)
Cucumber (Cucumis sativus L.)	30
Sunflower (Helinathus annus L.)	28
Radish (Raphanus sativus L.)	19
Tomato (Lycopersicon esculentum Mill. L.)	15
White clover (Trifolium repens L.)	11
French bean (Phaseolus vulgaris L.)	11
Lucern (Medicago sativa L.)	10
Wheat (Triticum aestivum L.)	5
Italian rye grass (Lolium italicum L.)	4
Oat (Avena sativa L.)	4
Corn (Zea mays L.)	4
Barley (Hordeum vulgare L.)	3

1/ Taken from Tanaka

Table 4 - Tolerance of Various Crops to Exchangeable-Sodium-Percentage (ESP) [2]

Extremely Sensitive [3] ESP=2 to 10	Sensitive [3] ESP=10 to 20	Moderately Tolerant [4] ESP=20 to 40	Tolerant [4] ESP=40 to 60	Most Tolerant [4] ESP=more than 60
Deciduous fruits	Beans	Clover	Wheat	Crested wheatgrass
Nuts		Oats	Cotton	Fairway wheatgrass
Citrus		Tall fescue	Alfalfa	Tall wheatgrass
Avocado		Rice	Barley	Rhodes grass
		Dallisgrass	Tomatoes	
			Beets	

2/ Adapted from Pearson; most sensitive plants are at the top of each group.

3/ In addition to soil physical effects there may also be specific ion effects of sodium.

4/ Stunted growth of more tolerant crops may be due to adverse soil physical conditions rather than nutritional effects.

a factor of about 2.5. More dramatic drops in the sodium content of leaves, changing from 3.2 milligrams per hundred milligrams of dry weight at 0.1 millimole of calcium sulfate to 0.2 milligrams per hundred grams of dry weight at 3 millimoles of calcium sulfate.

The bicarbonate concentration appears to be important in low conductivity waters where the calcium and magnesium may be precipitated out of solution by the carbonates thereby increasing the sodium hazard of water. Classification of irrigation water according to residual sodium carbonates (RSC) are shown in Table 5. Values greater than 2.5 may create soil alkali problems.

Some recommended limits for various compounds and water quality measurements are shown in Table 6. The limits shown in the Table do not infer in every case that physiological or physical changes will not occur as the recommended limit is approached. In some instances levels higher than those recommended may be exceeded for a short duration without detrimental physiological or physical effects. Also water exceeding the proposed limits may be used intermittently with water well below the limits, thereby mitigating some of the adverse effects of the undesirable water. These data are intended for use in interpreting water analyses to determine some of the suitable uses for the water supply.

MEASUREMENT AND CONTROL

Several techniques have been developed in order to evaluate salinity buildup in fields. The principal method in widespread use today is the collection of a soil sample from the area under investigation, extracting the soil solution from a saturated paste under vacuum and then determining electrical conductivity of the extract. Other methods have been developed for in situ measurement of solute content in the soil solution.

In situ measurements of soil salinity were conducted by Oster and Ingvalson using the ceramic electrical conductivity cell developed by L.A. Richards. The cell consisted of a thin ceramic plate 1.5 millimeters thick and 8 millimeters in diameter in which platinum electrodes were embedded on both sides. While the accuracy of the measurement (estimated at plus or minus 0.5 mmhos per centimeter) was not especially good, the investigators did find that the sensors would measure changes in electrical conductivity resulting from irrigation and plant uptake of water. Enfield and Evans reported the use of a newly developed transducer constructed of commercially available porous glass. They found that conductivity measurements over a wide range of temperatures approximately 5 to 35° centigrade resulted in very little error in the conductivity measurements. They further found the transducer would operate with good repeatibility over the entire field moisture of 0 to 20 bars of moisture tension as an evaluation of soil salinity. The sensors once placed in a soil remain there and periodic readings may be taken by the use of an appropriate meter.

Another in place measurement technique of measuring soil salinity was developed by Rhoades and Ingvalson. The method consists of measurement of resistance between an array of electrodes that are placed in the immediate surface of the soil at the site of investigation. They pointed out that it is critical for this type of technique to calibrate for soil types and water content. That is, calibration should be made with a soil type and some reference to irrigation such that it is feasible to make the resistance measurement at a time when the water content is approximately the same with relation to that for the calibration measurement. One possible technique of accomplishing this would be the use of tensiometers or gypsum blocks for soil moisture measurement. They found a very high correlation (greater than 0.9) between the electrical conductivity as calculated from the resistance measurements at standard conditions and the electrical conductivity as determined on the saturation paste extract. While these in situ measurement techniques provide rapid determination of the salinity in soils, the cost of equipment prohibits their use for field investigations for all but a few growers and/or experimental investigators.

The method of obtaining soil samples, making a saturation extract, and determining the conductivity of the extract is time consuming and laborious. Nevertheless it provides a widespread opportunity for soil salinity investigation for the greatest number of growers and experimenters. Ghaith and Mikhail sampled 58 different soils with a variety of soil textures and soil salt content to evaluate the effectiveness of electrical conductivity in the saturated paste extract versus actual determinations of the soluble salts present. They found

Table 5 Classification of irrigation water according to residual sodium carbonate content 1/ 2/

Classification	Residual Sodium Carbonate milliequivalents/litre
Not suitable for irrigation	Greater than 2.5
Marginal	1.25 - 2.50
Probably safe	Less than 1.25

1/ Adapted from Eaton

2/ Residual sodium carbonate = (meq $CO_3^{=}$ + meq HCO_3) minus (meq Ca^{++} + meq Mg^{++})

Table 6 - Recommended limits for various water quality criteria

Source		Type of usage		
		Domestic	Stock	Irrigation
Electrical Conductivity(x10 3 mhos/cm)		0.7 1/	7.1 5/	- - 7/
Total Soluble Salts	ppm	500 1/	5000 5/	- 7/
Calcium	ppm	200 2/	1000	See SAR
Magnesium	ppm	150	500	See SAR
Sodium	ppm	200	2000	See SAR
Chloride	ppm	250	1500	*8
Sulfate	ppm	250	1000	*9
Carbonate	ppm	20	*	See RSC
Bicarbonate	ppm	150	*	See RSC
Fluoride	ppm	0.8-1.7 3/	1-10 6/	10
Nitrate	ppm	45	100	*10
Manganese	ppm	0.05 4/	*	*
Iron	ppm	0.3 4a/	*	*
Boron	ppm	30	*	4 11/
Lithium	ppm	5	*	2 11a/
Hardness	g/gal	10	**	**
Sodium absorption ratio (SAR)		**	**	13
Residual sodium carbonate (RSC) meq/1		**	**	2.5
pH		*	*	5-9 11b/

* No established limit or the limit is higher than that found in normal water supplies.

** Not applicable

1/ The 1962 U.S. Public Health Service(USPHS) Drinking Water Standards suggest the salt concentration of good, potable water not exceed 500 ppm. Higher concentrations may be consumed without harmful physiological effects. Each water exceeding 1000 ppm TSS should be judged on the basis of local situation, availability of alternative supplies, and reaction of the local population. Many communities use water containing 2000-4000 ppm TSS when no better water is available. Such waters are not considered very potable and may have a laxative effect on new users. Water containing more than 4000 ppm TSS are considered unfit for human consumption.

2/ The USPHS Drinking Water Standards of 1962 do not contain any limits for calcium; World Health Organization International Standard of 1958 indicate 75 ppm is permissible and above 200 ppm is excessive, probably based on hardness of the water.

3/ Permissible concentrations vary with the mean maximum daily air temperature. The lowest limit applies at 79.3-90.5° F. and the highest limit at 50.0-53.7° F.

4/ 4a/ Limits are based on aesthetics rather than any physiological effects.

5/ An interim threshold limit of 5000 ppm depends primarily upon animal species; however, diet, age, condition, season and climate also influence the safe upper limit. Some animals may use waters containing as much as 10 000 upon or more without deleterious effects.

6/ The permissible limit varies depending upon animal species and mean annual maximum daily air temperatures, see 3.

7/ As salinity increases water management becomes extremely important. Salt tolerance of the plant is of primary importance in evaluating salinity effects. Although some plants are considered salt tolerant their production is increased at lower salinity levels. Other factors such as soil texture, drainage, type of salts present, and quantity of water available for leaching influence the effect of irrigation with water containing salts.

8/ Certain plant species have been shown to be sensitive to chlorides e.g., Lemon, alfalfa, fruit trees, and potatoes. Less than 100 ppm is not considered harmful.

9/ Concentrations exceeding 1000 ppm may cause deterioration of concrete ditches.

10./ Nitrates present in irrigation water may influence a grower's nitrogen fertilization programme especially for plants whose maturity or quality is considerably influenced by excessive nitrogen.

11/ 11a/ 11b/ The permissible limit varies depending upon the tolerance of various plant species.

a highly significant correlation of 0.937 between the conductivity in the saturation extract and the total salts found present by actual determination. This study is further indication, along with other studies by several investigators, that this technique is extremely valuable in evaluating salinity levels of soils. Within certain limits, the salinity or alkalinity of soil may be controlled through the effective management of soils and irrigation water.

Soils should be managed in a manner which is conducive to the maintenance of a relatively high infiltration rate. Such things as minimum tillage to prevent compaction(and therefore of infiltration), land levelling to provide for uniform distribution of water, the flooding of the entire surface where flood type irrigation is practised to prevent accumulation of salts at high points in the field, seedbed preparation and bed shape are important factors in considering salt accumulations.

The acumulation in salts on the surface of beds has been demonstrated by Rauschkolb. A study of the distribution of salts in beds before and after a germination irrigation with well water containing a 2500 ppm total soluble salts showed that prior to the irrigation the salts were uniformly distributed in the bed. After the germination irrigation, salts accumulated on the surface resulting in a concentration of approximately 5300 ppm over all treatments. At the 1.5, 3 and 4.5 inch depths in the beds the average concentration was 1500 ppm of total soluble salts. The deposition of salts at the surface resulted from capillary movement of the soil solution to the surface of the bed and evaporation of water from the surface resulting in deposition of salts.

In seedbed preparation and bed shape, one can take advantage of the knowledge that salts tend to accumulate in high points of the field, or the high point of the bed and place the seed in such a manner as to avoid the concentration of salts near the seed at germination and during early plant growth. Placement of the seed in the bottom of an irrigation furrow or corrugation where the least concentration of salt occurs also assists germination and seedling growth.

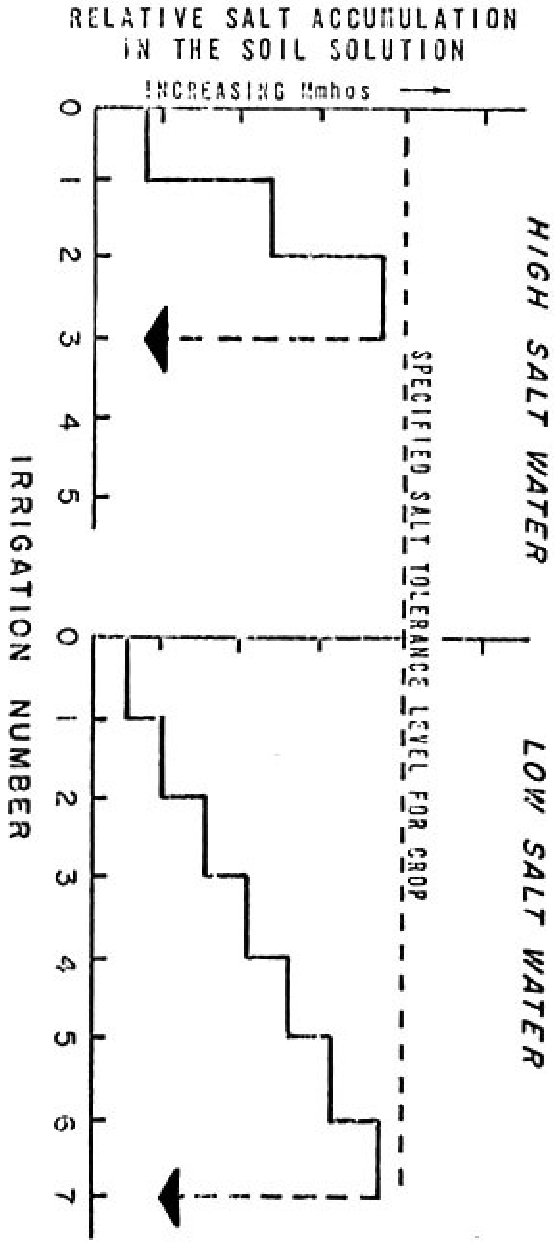
Sprinkler irrigation is very effective in moving salts through the soil profile and preventing harmful accumulation of salts. Nielsen et al have shown that frequent light irrigations can oftentimes be used to prevent harmful accumulation of salts in a soil profile.

Sub-irrigation and drip irrigation are two practices which are receiving widespread attention at the present time, especially in countries where there are limited supplies of water available for irrigation. Undoubtedly these techniques provide a water saving. However, it must be recognized that when this type of irrigation is practised, depending on the water quality, sooner or later these soils will have to be leached of their salt accumulations, since almost by definition these methods do not provide for a leaching requirement. The water saving is attributable to the more efficient technique of irrigating during the season. However, water will have to be supplied for leaching in sufficient quantities at the termination of the crop or some time during the life of the crop, depending on water quality and salt tolerance of the crop. By leaching the salts out of the profile in preparation for the next crop, (rather than accomplishing leaching with each irrigation and submitting to the inefficiencies of surface irrigation), one can apply the leaching irrigation at a time when there is less demand on the water supply and more labour available to handle the large volumes of water necessary to achieve leaching.

In some areas where water supplies permit, it is also possible to alternate between a relatively high salt water and a water with relatively low salts. The author's experience in irrigating alkali soils with water of relatively high conductivity ($EC \times 10^3 = 3.5$ to 4.5) has been that 2 to 3 irrigations may be applied with water containing relatively high salt before salinity built up to the point where it would begin interfering with the production of a cotton crop. Then water with a lower salt content ($EC \times 10^3 = 1$ to 1.5) would be used in the next 2 to 3 irrigations until the infiltrations would noticeably decrease as a result of leaching out the salts and dispersion of the soils containing a high exchangeable sodium percentage. Then the alternate relatively high salt content water would again be used. Yields obtained on a variety of crops ranging from moderately salt tolerant to tolerant were comparable to those obtained in areas where salinity buildup during the season was not a factor.

As has been alluded to many times, the leaching requirement is an important concept in control of soil salinity. Leaching requirement may be defined as the fraction of irrigation water that

Figure 1. The relationship between salt content of the irrigation water and salt buildup in soils.[1/]



1/ Taken from Fuller

must be leached through the root zone to control soil salinity at any specified level. The leaching requirement as defined may be expressed in the following simplified manner:

$$LR = \frac{D_{dw}}{D_{iw}} = \frac{EC_{iw}}{EC_{dw}}$$

Simply stated it is the ratio of the equivalent depth of drainage water (D_{dw}) to the depth of irrigation water (D_{iw}) and may be expressed as a fraction or a percent. The EC_{iw} and EC_{dw} represent the electrical conductivity of the irrigation water and drainage water, respectively. For field crops where a value EC_{dw}= 8 mmhos/cm can be tolerated and for irrigation waters with conductivities of 1,2 and 3 mmhos cm respectively, the leaching requirements would be 13, 25 and 38 percent respectively (Handbook 60). In general, the poorer quality the irrigation water, the more frequently the soils need to be leached to keep the salts washed out of the active root zone. See Figure 1 on relative accumulation of salts in soil solution.

When calculating the amount of water to apply to accomplish leaching one should also consider the irrigation efficiency factor. For example, if a normal irrigation would be 4 inches, as previously calculated the leaching requirement for a water with conductivity of 2 mmhos per cm would require 25 percent more water, therefore, you would need to apply 5 inches. If one assumes a 50 percent irrigation efficiency, this amount would have to be applied in addition to the 5 inches, therefore, you would have to apply a total amount of 7.5 inches to accomplish the 4 inches irrigation with 25 percent leaching at a 50 percent irrigation efficiency.

One of the essentials of leaching is to have a deep well drained soil or make some provision for removal of salts by the use of drainage tile or pumps. As a minimum the drainage system must be adequate to remove from the soil the equivalent depth of water that would pass through the root zone in order to maintain a favourable salt concentration in the soil.

In the reclamation of alkali soils, chemical amendments are used which provide for the replacement of adsorbed sodium on the exchange complex of the soil. The choice of amendments will depend on the solubility of the amendment, the lime content of the soil, the pH of a soil and economic considerations. Because of their low cost and availability, gypsum and sulfur are the most commonly used materials. Where sulfur is used, the soil must have a sufficiently high content of limestone to provide for a formation of calcium sulfate as the sulfur is oxidized in the soil. In addition, soil temperatures and other variables afffecting soil microbial activity will influence the rate of sulfur oxidation to sulfate. The sulfate reacts with the calcium carbonate to form calcium sulfate and carbonic acid. The calcium sulfate then will perform in the same manner as the gypsum (calcium sulfate) when that material is used.

The reclamation of alkali soils, in addition to the application of an appropriate amendment in adequate amounts, requires large quantities of water leaching through the profile in order to accomplish the dissolution of the cation bearing material and provide for replacement of sodium on the exchange site and simultaneous movement of sodium below the root zone. Consequently, the same need for drainage in the reclamation of alkali soils is necessary as in the reclamation of saline soils. Usually the alkali soils have very low permeability and leaching may be slow, perhaps requiring several days or weeks to apply the required amount of water in order to distribute the calcium through the profile and remove the sodium. Because of the complexity of effects results from saline and/or alkali soils, and because soil management factors profoundly influence the degree of salt accumulation, the plants response to a given irrigation water, as pointed out by Bernstein, cannot be predicted without taking into account the probable effects of conditions under which the water will be used on the resultant level of soil salinity or alkalicity.

II. ORGANIC WASTES

EXTENT

When man was less numerous on the face of the earth, there was little concern about the effects of man's activities on the environment. However, as our population increased, man being a social animal, develope high population density centres. Along with this congregation of man, industries have had to develop and expand, and in developing they chose an area close to the work force. Raw materials were necessary for the industry and food was necessary for the population. This brought about a high production level and concentration of some types of agricultural production in order to meet these demands. Now the consequences of these aggregate activities are the production of all kinds of wastes that are not only odorous, infectious, or degrade the environment, but are also objectionable from the esthetic point of view. The end result has been that this waste is being collected in huge quantities. It has been estimated by Hershaft that domestic wastes are produced in the United States at the rate of about 190 million tons per year (see Table 7). On the basis of a population of 200 million people, this figures out to be slightly over five pounds of solid waste produced per day per person. Abelson estimated the production of solid waste to be approximately eight pounds per day per person. At that use rate, it would take approximately one acre per year for a population of 10 thousand people to dispose of this material in a sanitary land fill .... assuming a 10 foot thick layer of waste is deposited.

SOURCE AND INTENSITY

It also is recognized that population in all parts of the world will not use their environment at the same rate. It has been estimated by Miller that the annual per capita consumption of paper in the United States amounts to approximately 525 pounds. Most other countries use less.

There is another aspect of domestic waste which the world at large has in common, and that is human excrement. Estimates by Wadleigh and Byerly indicate that human waste in the United States is approximately equivalent to the production of animal waste, which also varies in estimates from about 1-1/2 to 2 billion[1/] tons per year. This is equal to a daily deposit of 2 to 2-3/4 pounds per person per day of solid and liquid waste. In some countries this material is looked upon as desirable from the standpoint of fertilizer and is used for that purpose. In many of the same countries, cost of handling and distributing this material from a high population density centre would prohibit its use in this manner. Consequently, around the world the material is passed into the environment with treatment consisting of none at all to sophisticated tertiary treatment.

In relation to domestic waste, a certain portion of the total solid waste production can be directly attributed to population density since the waste generated in metropolitan areas must be assigned on a per capita basis. In Table 8 (taken from a report on the status of solid waste management in California) the quantity of waste produced is listed by different categories. One can readily see that as population density increases, the amount of waste generated increases. The report states that residential wastes were found to be very consistent and did not appear to fluctuate significantly with the size of the community. Sewage residue as shown in the table refers to a material remaining at the sewage treatment plant after treatment; sewage sludge. This does not refer to the amount of raw sewage produced per person.

Agricultural waste also suffers to a large extent from population density of animals. As long as animals were pastured, manure management was not a problem. However, by confining animals either for purposes of protection against the weather or intensified production, the management of their solid waste does become a problem. Table 9 lists the estimated production of various types of livestock which may be produced on a confinement basis. There is no attempt in this paper to determine the whole amounts of material produced, but rather to indicate the production per animal because intensity of manure production will depend upon the manner and quantity of each animal produced in respective countries. In California, slightly over 17.5 million tons of manure is estimated to have been produced in confinement by various animals, (Garrett et al).

Another aspect of agricultural waste production is that of residues from various crops. The figures given in Table 10 are based on the fresh weight of residue produced per crop. The contribution of the lumber industry is shown in Table 11. There would be some obvious weight losses due to the loss of water if these values were expressed on a dry weight basis.

1/ Billion American usage = thousand million

Table 7 - Classification of United States solid waste 1/

Category	Description	Composition %		Production Rate ($X 10^6$ tons/yr)
Refuse; garbage	animal & vegetable kitchen waste		15	
Rubbish & ashes	dry household, commercial and industrial, and combustion residue	paper	28	
		yard	14	
		metal & glass	10	170
		other	10	
Municipal waste	street sweepings, construction		23	
Scrap metal	autos, major appliances & machinery			20
Mining	overburden gangue			1500
Agriculture	animal carcasses, manure crop residues, logging debris			2000

1/ Taken from Hershaft .

Table 8 - Domestic waste production by category and population density 2/

Category	Waste Generation Factor
Residential waste	2.5 pounds/capita/day
Commercial waste:	
less than 1000	1.5 pounds/capita/day
1001 - 10,000	2.0 pounds/capita/day
10,001 - 100 000	2.5 pounds/capita/day
greater than 100 000	3.5 pounds/capita/day
Demolition waste:	
1000 - 10 000	100 pounds/capita/year
10 001 - 100 000	250 pounds/capita/year
greater than 100 000	500 pounds/capita/year
Special waste:	
Street refuse 3/	120 pounds/capita/year
Sewage residue	54 pounds/capita/year

2/ Adapted from Status of Solid Waste Management

3/ Only applied to incorporated cities or large metropolitan areas.

Table 9 – Estimated production of solid and liquid waste by livestock as produced [1]

Animal	Waste production/animal/day
	pounds
Cattle:	
Beef (feedlot)	39
Dairy	51
Horses	40
Swine	9.5
Sheep	4.0
Fowl:	
Chicken(fryers)	0.025
Chicken (hens)	0.25
Other	0.4 – 0.8

1/ Adapted from Status of Solid Waste Management and Waste in Relation to Agriculture and Forestry

Table 10 – Waste production from various classes of plants [2] [3]

Plant	Residue production factor
Fruit and nut crops:	
Class 1. grapes, peaches, nectarines	2.5 tons/acre
Class 2. apples, figs, pears	2.25 tons/acre
Class 3. apricots, plums, quince	2.0 tons/acre
Class 4. almonds, avocados, olives miscellaneous	1.5 tons/acre
Class 5. cherries, citrus, dates, prunes walnuts	1.0 tons/acre
Field and row crops:	
Class 1. field corn(maize), sweet corn	4.5 tons/acre
Class 2. broccoli, cauliflower, lettuce	4.0 tons/acre
Class 3. brussel sprouts, cabbage, cantaloupe, melons, rice, sugar beets, tomatoes	3.0 tons/acre
Class 4. beans, carrots, celery, cotton cucumbers, garlic, peanuts, peppers potatoes, onions, other miscellaneous vegetables	2.0 tons/acre
Class 5. asparagus, barley, oats, safflower sorghum, wheat	1.5 tons/acre

2/ Adapted from Status of Solid Waste Management in California

3/ Classes are based on approximately equal production of fresh weight assuming average production in California.

Table 11 - Organic solid waste production from the lumber industry 1/ 2/

Forest plants	Residue production factor
Logging debris	1 ton/1000 board feet
Sawmill(bark, sawdust, etc.)	1.25 tons/1000 board feet

1/ Adapted from Status of Solid Waste Management

2/ Waste Production is based on yields obtained in California

Principal concern with plant residues from the pollution point of view is their contribution to land degradation through the inoculation and perpetuation of diseases or insects in soils and their contribution of hydrocarbons and particulate matter to the atmosphere upon burning. This atmospheric contribution may be of concern from the health of plant and animal point of view, however, it is of little consequence from the standpoint of land degradation. Where the land degradation may be involved is through the loss of nutrients by volatilization from burning and/or loss of the benefit which may have been derived from the incorporation of the residue in the soil. In this regard it has been pointed out by Garrett, et al in their report that in California as much as 98 percent of the solid waste from succulent crops is disposed of by soil incorporation. Of the tree and vine crops and the field and row crops, the latter accounts for about 70 percent of the total hydrocarbon production in California; indicating that a significantly larger area of field and row crops residues are burned.

Industrial organic wastes are derived from canneries, animal processors, sugar refineries, pulp and paper mills, and the petroleum industries. These organic wastes constitute the same hazard as attributable to domestic and agricultural wastes plus the extra hazard of containing toxic substances. When these materials are disposed of in lagoons they create odorous and esthetically unpleasant conditions. Considerable concern about these types of waste is their contribution to contamination of water supplies.

MEASUREMENT AND CONTROL

Effluents are usually discussed in terms of the biological oxygen demand for the waste. The biological oxygen demand (B.O.D.) indicates the amount of oxygen required for the complete oxidation of the organic matter present in a sample of water. It is expressed by the amount of oxygen the water will absorb when it is incubated for a five-day period at 68° F. Water samples absorbing less than one ppm of oxygen in five days are considered very pure. Samples absorbing three ppm in five days suggest reasonably clean water and water absorbing five ppm of oxygen or more is considered of doubtful purity. The BOD for processing effluent may range from less than one to greater than 50 thousand. As previously pointed out, many of these different sources of organic wastes are disposed of in a manner that cannot be considered as directly degrading from the land point of view, with the possible exception of transmittal of infectious disease into an area previously uninfested.

It seems unlikely that hydrocarbon production or particulate matter produced from burning of either plant or industrial organic residues would create much of a hazard with regard to land. However, with the current environmental trend, burning or dumping of this effluent into waterways will cease to be methods of disposal of these materials. In that event, it becomes necessary to look to the land as a means of recycling these residues.

Other methods of disposal of organic matter need to be evaluated with regard to some of the consequences, either good or bad, from the incorporation of this material. In considering effects one should also look at costs of disposal since this is one of the major influences in the disposal of this material. Cost is probably the overriding reason why procedures have not been developed that will effectively handle the tremendous quantities of organic substances coming from domestic sewage, garbage, food processing industries, lumbering operations, crop residues, and animals. There are a number of other factors to consider when assessing the desirability of incorporating this material in land.

Increasingly, as people become more aware of their environment, and the fact that conditions can change for the better regardless of their individual economic status, it will become more important for these materials to be disposed of in a manner that will not destroy the esthetics of the area nor create undesirable odours. Stephens used an analytical method which showed promise as a practical means for the field study of odours. He was also able to show the odour threshold concentrations of some strong odorants. Table 12 shows the threshold concentrations of various compounds as detected by Stephens and others. These compounds were detected in promixity of feedlots and may be characteristic of them alone. Some of the by-products of microbial decomposition of organic material can be detected at extremely low concentrations.

While it is true that soil incorporation of organic material has a tendency to reduce the production of these odorous compounds, there is the classic example of gas production in rice paddies causing plant damage. It occurs in sufficient magnitude to be of economic importance in rice production.

Another indirect and minor effect of site and smell attributable to disposal of these residues in the soil and around population centres results from their non-compatibility with the urban public. There are many cases where irate home owners have brought such pressure to bear through litigation and harrassment that land disposal sites or areas of accumulation of organic waste have been forced to move to low population density areas.

Organic matter depends upon soil microorganisms for its decomposition. Figure 2 shows the relative activity of three important soil variables. These variables are important factors to consider when trying to ascertain the rate of decomposition of the organic waste, assuming adequate nutrients are there for the decomposition of the material. The rate of decomposition is an important factor to consider, especially if soil is the media for disposing of these materials. If the rate of decomposition were not rapid, these materials would accumulate. For the most part, when all three of these major factors are at their optimum the rate of decomposition can be fairly rapid. Most materials decompose in soils within a few weeks to two years time.

One very good exception is in sanitary land-fill where paper has been found intact in completed land fills 15 to 25 years later (Sorg and Hickman). In the same report it was stated that approximately 90 percent of settling that is going to occur does so within five years. In a Los Angeles land fill 90 to 110 feet deep, it had settled 2-1/2 to 5.5 feet in three years. In sanitary land fills, production of gases (methane, carbon dioxide, nitrogen, hydrogen and hydrogen sulfide) usually reach their peak rate of evolution after two years and then taper off. Methane is a concern because of its explosion hazard.

The aerobic decomposition of organic wastes is generally considered more desirable because of the undesirable gases and odour associated with the anaerobic decomposition of these materials. It is well known that when a large amount of easily decomposable high-carbon organic matter is present in the soil, the microorganisms will utilize this material. In order to decompose this material, microorganisms will have to appropriate the nitrogen contained in the soil, thus limiting or entirely preventing the accumulation nitrate. This is one of the reasons a depression of yield is observed in crops planted shortly after a high-carbon content material is incorporated in the soil.

Table 12 - Odourthreshold concentrations of some strong odorants[1]

Odorant	Concentration (ppm by volume)		
	Ref 3[1]	Ref 2[2]	Ref 1[3]
Trimethylamine	0.0006	0.00021	
Dimethylamine	0.089	0.047	
Monomethylamine		0.021	
Propylamine	0.009		
Ammonia	3.9	46.8	
Pyridine		0.021	
Hydrogensulfide	0.048	0.0047	0.0045
Ethyl mercoptan		0.0010	0.0004
T-butyl mercoptan			0.00009
Acetic acid		1.0	
Butyric acid		0.001	
Formaldehyde		1.0	

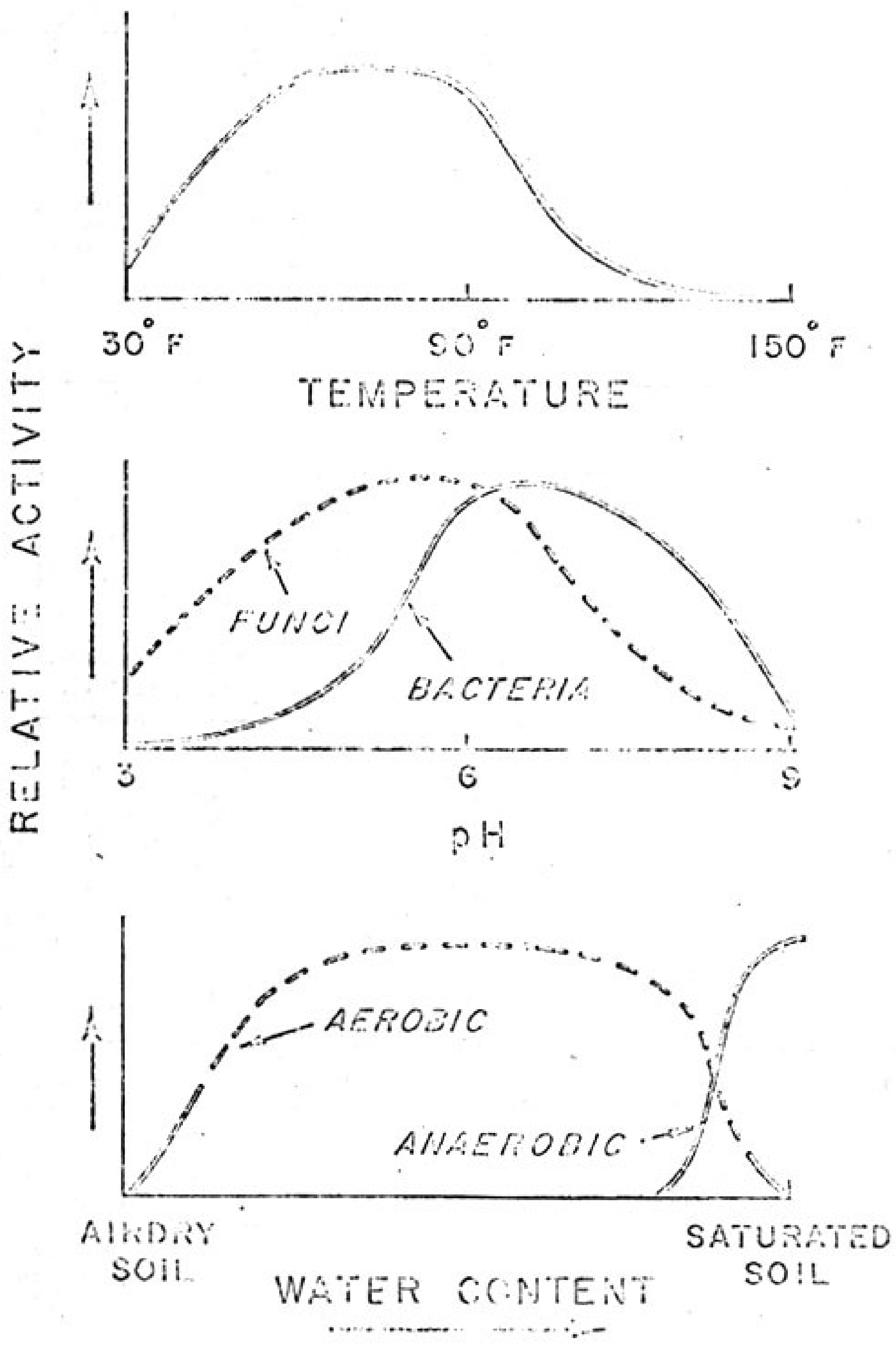
1. Taken from Stephens
2. Wilby, F.V., Air Pollution Control Assoc. Jour, 19(2): 96, 1969
3. Leonardos et al (ibid) 19(2):91, 1969.

Table 13 Nitrification of mixtures of carbonaceous materials and sulfate ammonia[4]

Carbon source	Carbon content	C-N ratio of mixture	Added nitrogen converted to nitrate	
	——percent——		——percent——	
			20 days	60 days
Lignin	57.2	20:1	86	86
Cornstarch	39.0	20:1	49	54
Dextrose	35.8	20:1	49	50
Cottonseed oil	76.5	20:1	39	49
Cellulose	42.0	5:1	77	77
Cellulose	42.0	10:1	65	66
Cellulose	42.0	20:1	41	49
Cellulose	42.0	40:1	-2	21
Cellulose	42.0	80:1	-19	-18
No carbon added	——	——	91	85

4/ Adapted from Rubens and Bear

Figure 2. The influence of certain soil variables on microbial activity.



As the decomposition process continues, nitrogen will tend to concentrate. Table 13 (Rubens and Bear) very dramatically illustrate the effect of carbon-nitrogen ratio on nitrogen release. One can readily see from these data that soil incorporation of residues with different carbon-nitrogen ratios can have a marked effect on crop yield through its influence on the nitrogen availability in soils for plants through the direct competition of micro-organisms for the soil nitrogen. This deficiency can be easily overcome, if one exists, by the addition of inorganic fertilizers. The nitrogen content of the material should only be of consequence when one is not considering applying nitrogen to enhance the decomposition of a material with a high carbon-nitrogen ration.

Various estimates of cost of processing and hauling of organic waste to the location where it would be used range from $15 to $50 per ton of material. Cost will depend upon the size and sophistication of the plant processing the material. Processing materials costing from $20 to $70 per ton can hardly be an economical means for farmers to improve soil chemical and physical conditions.

The influence of animal manures on plant growth may be more than can be attributed to the simple addition of nutrients alone. In a six year study on cotton, Tucker et al compared the addition of manure at the annual rate of 10 tons per acre with cotton receiving nitrogen alone with no manure. The first three years the yields were greater with nitrogen plus manure than they were with nitrogen alone. The fourth year, Verticillium wilt began to build up in manured plots and the yield advantage in favour of the manure plots was lessened. In subsequent years, a Verticillium wilt tolerant Pima variety of cotton was planted. The manure advantage maintained itself for the next three year period.

When considering the nutrient level of manure, one has to recognize there are tremendous variations in quality of the initial product. This was shown in a study conducted by Stewart when he used a laboratory model to study soil moisture conditions on ammonia volatilization and nitrate accumulation under cattle feedlots. When urine from cattle was added every two days to an initially wet soil, less than 25 percent of the nitrogen was lost as ammonia and approximately 65 percent of the nitrogen in the urine was transformed to the nitrate form. However, when urine was added to a dry soil every four days, essentially all the water evaporated and 90 percent of the nitrogen was lost as ammonia. This variation in quality of manure is shown in Table 14.

Steer and poultry manure were used as sources of phosphorus for alfalfa production in a five-year study. Chicken manure from four different sources was applied on two separate occasions. Yields were not statistically different between the manured plots and the plots receiving treble superphosphate. In another study, dairy manure was compared with treble superphosphate. Again the four-year total production was not significantly different between the manured plots and the plots receiving the commercial phosphorus.

Some effects of incorporation of cattle manure on chemical properties of soils were studied by Pratt. Organic carbon content for the soils was 0.44, 0.91, 1.12 and 1.32 percent, respectively for manure application rates of 0, 6, 12 and 18 tons per acre per year. These treatments were applied from the period 1939 to 1955. Associated with the increase in organic carbon was an increase in the cation exchange capacity of the surface six-inch depth. Large amounts of phosphorus and potassium were added to the soil; in each case most of these elements stayed in the surface foot of soil. Similar results have been obtained by Broadbent concerning the decomposition of organic residues in soils. He found the larger the addition of plant residue, the lower the percentage loss of added material. Small, frequent additions will do little to change the level of soil organic matter, however, regular additions of resonably resistant materials such as farm manure in susbstantial amounts may increase the organic matter level.

Incorporation of plant residues can have a substantial effect on plant nutrient status in the soils. In a study conducted by Abbot and Tucker where residues of sorghums, small grains and cottons were either incorporated or removed, it was found that incorporation of the residues over the three year period of the study resulted in a yield advantage on the soil with a low phosphorus level. There was no apparent effect of incorporation of the plant residues on the soil with the relatively higher phosphorus level.

Table 14 - Approximate composition of manures on a dry weight basis.[1/]

Type	Nutrient		
	N	P_2O_5	K_2O
	- - - - - - - - -	percent	- - - - - - - - - - - - - -
Dairy, steer & feedlot:			
Low	0.53	0.24	1.08
High	3.55	1.75	5.01
Average[2/]	2.03	1.06	3.06
Poultry:			
Low	1.70	0.75	0.90
High	5.14	5.56	3.76
Average[3/]	3.48	2.85	2.18

1/ Adapted from Solid Waste Disposal and Management Research Task Group, University of California

2/ Average of 35 samples in the Los Angeles area

3/ Average of 40 samples in the Los Angeles area

In two studies, Williams and Doneen investigated the effect of green manures and crop residues on the improvement of infiltration rates of irrigated soil. They found that incorporation of whole crop residue (tops and roots) is one of the most effective ways of improving the infiltration rate of the soil. Plants used in the study were barley, corn, cotton, cow peas, Sesbania, Sudan grass, cereal rye, soft chess, annual rye grass and mustard.

In a study by Laws, several different farming systems were evaluated over a 12-year period. It was found that only systems with the annual average return of more than 3600 pounds of residue per acre maintained the organic matter content of the soil at a constant level. Larger quantities of residue returned were required to increase the organic matter content a significant amount. Significant increases were only obtained in systems producing more than 5100 pounds of above-ground residue per acre annually.

In a study of farmyard manure and grass residues on soil structure, Williams and Cook found that continuous grass was more effective than annual dressing of farmyard manure in making more soils more permeable through formation of more water stable aggregates.

Some of the adverse effects on soils resulting from disposal of organic wastes on the land are as follows: Application of 5 and 10 tons per acre of garbage compost containing one percent nitrogen was used to grow corn in five experiments on nitrogen deficient soil (Terman and Mays). They found this material caused immobilization of soil and fertilizer nitrogen, resulting in a nitrogen deficiency in the crop. Small yield increases were obtained for Bermuda grass and sorghum forage in field plots with a less nitrogen deficient soil where compost applications were made up to 82 tons per acre. However, in no case did yield equal that obtained with 160 pounds of nitrogen per acre. Positive yield benefits from compost were not profitable but do show the potential of agricultural land for accepting large amounts of compost without yield reductions.

The occurrence of nitrate and soluble salts in soils and its movement into the groundwater in relation to cattle feedlots was studied by Adriano, Pratt and Bishop. Soil and water samples were collected at various locations in the Sutter Basin and in the dairy production area of the Chino Basin in California. Nitrate-nitrogen levels range from 14 to 210 ppm in groundwaters. Evidence for substantial movement of nitrate into the water table was obtained. The pollution hazard from surface runoff of phosphorus was greatest from the corral areas intermediate from the permanent pasture areas, and least for irrigated fields. However, the downward movement of phosphorus under the corrals was not greater than under the field sites.

Beatty et al compared the nitrate and ammonium nitrogen levels to a 20-foot depth between a virgin forest soil, cultivated soil, and soil under a cattle feedlot. The lowest concentration, 56 ppm nitrate-nitrogen was obtained under the virgin soil, 407 ppm nitrate-nitrogen was found under the feedlot. In the virgin soil the ammonium nitrogen level was 21 ppm and 2203 ppm under the barnyard feedlot. Because of the highly permeable soils and the tremendous load of nitrogen available in these soils, there is a definite hazard of groundwater contamination of nitrates from these types of organic wastes.

Another concern with regard to dairy and feedlot manures is the salt content of these materials. Unleached, fresh manures may contain as high as 10 percent total soluble salts. When these manures are added to soils in the rates usually recommended for an adequate supply of nutrients, 1000 to 2000 pounds of total soluble salts may be added to the soil. That amount of salts in addition to those already present in soils may be sufficient to create salt toxicity problems for the plant being grown.

In order then to prevent the addition of salts from manures from becoming a problem in plant growth the soils have to be leached to remove the soluble salts from the root zone of the plant. These salts are subject to further leaching into the groundwater supplies, creating the possibility of degrading the quality of the groundwater.

There is little concern about the movement of disease organisms into groundwaters, especially where there is good drainage, since one of the classic methods of purifying water from the standpoint of bacterial content has been to filter the water through the soil. One of the problems associated with all sorts of organic wastes are their susceptibility to runoff and contamination of our water supplies. According to Wadleigh, during the 15 year period, 1946 to 1960, there were only 16 human deaths in the United States attributable to waterborne agents; 8 from typhoid fever, 4 from chemical poisoning, and 4 from infections other than typhoid. Wadleigh points out the excellent record in protecting human health is most likely due to the high level of activity in preventing and controlling animal deseases as well as the intense vigilance in monitoring drinking water supplies.

Other sources of undesirable side effects are those of phytotoxic substances, either through the exudation of phytotoxins and antibiotics by soil microorganisms in the decomposition of the material or by the addition of phytotoxic substances in the material itself. Various studies have shown that phytotoxic substances could be extracted with water and various organic solvents from a number of crop residues used for mulching purposes. Several fungi and other organisms have been found to have the capability of producing phytotoxic substances. One other interesting aspect of these studies was that when rates equivalent of 4 to 10 tons per acre of wheat straw were ground and mixed into the surface one-half inch of soil simulating the stubble mulching, this created the most phytotoxic effect on wheat seedling development. When the same rate of wheat straw was mixed in six inches of soil simulating the effect of ploughing, the influence of phytotoxic substances on plant growth was not evident. It was also found that when wheat straw had decomposed for a period of times it showed less phytotoxicity than fresh wheat straw.

The addition of phytotoxic substances inherent in the plant are characteristic of sawdust and bark of some tree species. Resins, phenols, and terpenes contained in the fresh sawmill by products of these trees have an inhibitory effect on plant growth. Aging or partial decomposition of the sawdust can prevent the toxicity from occurring. Most of the investigations have been in the use of these lumber by-products as soil conditioners for ornamental and horticultural type crops. The studies have shown that bark and sawdust from some lumber species of trees have greater toxicities than others, while some have none at all. There are also varying degrees of plant susceptibility to the phytotoxic effects.

As pointed out in the disease section, organic wastes may be helpful or a hindrance with regard to disease and insects. If the infectious organism is not a good competitor in the soil environment, the additions of organic matter can reduce its number and hence decrease the disease potential. Organic matter especially in the form of plant residues may also provide a means of overwintering and transmission of the organism. In California, it has been estimated by McNelly that yield losses in tree crops from disease and insects totalled slightly over 58 million dollars in 1968.

Another adverse effect is the perpetuation of weeds through the use of animal manures, green manure crops, or incorporation of plant residue. According to Harvey, the percent of viable weed seeds passed by animals shows cattle 9.6 percent, hogs 8.8 percent, horses 8.7 percent, sheep 6.4 percent and chickens 0.2 percent. Cow manure composted in piles showed a 22 percent germination of morning glory seed after two months of composting. However, there was only one percent germination after three months. Morning glory seed survived chicken manure composting regardless of treatment. A mixture of cattle and horse manures were composted with 52 different weed species present. None germinated after one month.

What can be done about alleviating the undesirable effects of accumulations of organic wastes in our environment? In the literature there have been two predominant themes which have occurred in relation to the disposal of organic wastes. These are the costs of handling or disposing of the material and the seeming unwillingness to sacrifice very much in the way of convenience or to pay the cost of the necessary disposal, either by increased costs of consumer goods or increased taxes.

Costs of disposal of organic wastes vary widely. In the United States last year the Bureau of Solid Waste Management in the Department of Health, Education and Welfare estimated it cost 4.5 billion[1/] dollars to collect and dispose of the previous year's waste which amounted to almost 4.3 billion tons, including industrial, agricultural and domestic wastes of all types.

An economic review can be conducted more readily in the area of disposal of agricultural organic wastes. The most intimate association of agriculture with the disposal of organic waste has resulted in the necessity of developing cost information for various mechanisms of disposal. Agriculturists have long recognized that disposal is part of production costs and have attempted to develop efficient means of disposing of these materials. In a cost analysis study of various alternative methods for dairy and manure disposal, Berge found that the annual cost per animal for a 50-cow dairy ranged from $29 to $49 for different systems of handling the material. Fairbanks estimated that the cost of treatment of dairy waste to the same degree as city sewage would raise the retail price of milk about four cents per quart.

There are various methods of treatment of our organic wastes which have been investigated and are currently being re-investigated in order to determine if modifications may produce more efficient ways of disposing of these wastes. Currently known methods of disposal of domestic refuse include land filling. This method has the advantage of being relatively inexpensive and applicable to the wide variety of terrain. Some of the disadvantages are rising land costs, increasing urban pressure requiring more stringent controls for the use of the land for higher value purposes. Open dumps are usually the most prevalent type of disposal. The current environmental emphases render this as a very undesirable technique.

Incineration, which is the process of burning solid or semisolid combustible wastes is another method of treating organic wastes. The principal advantages of incineration are less land required and the facility may be stalled in a centralized location reducing collection and hauling costs. Some of the disadvantages of this method consist of the high capital outlay and cost of operation. There is also the problem of loading the atmosphere with contaminants and the fact that it is not a complete disposal method. The residues from the system must be disposed of as well.

Another technique is composting. Like incineration it cannot be considered an ultimate disposal method in as much as the material is treated so that it can be disposed of by other means. It has the advantage of conserving resource material. It too may be conducted in a centralized location reducing hauling distances, and it may provide a useful end product. The disadvantages of the system are the high capital and operational costs including the segregating of non organic refuse. Another major problem is finding the markets for the end product.

Recycling is another means of reducing the total amount of material to be disposed. The obvious disadvantages of this are the costs of sorting through the refuse and segregating the material into a number of like materials. Currently about 20 percent of the paper consumption in the

1/ Billion American usage = thousand million

United States is being supplied by the use of recycled paper.

Pyrolysis is another technique which has been under investigation. This is a process of destructive distillation carried out in an atmosphere almost completely devoid of oxygen. Similar to incineration and composting, pyrolysis cannot be considered an ultimate disposal method.

Various studies are in progress to determine methods for handling some of the plant residues which are not presently being incorporated into the soil. One of the more interestingkinds of disposal techniques has been the preparation of cellulosic wastes for animal feeding. Several investigators: Kohler, Guggolz, Waiss, Graham, Garrett, and Klopfenstein have been investigating this possibility of utilizing cellulosic wastes for animal feeds. Klopfenstein found that 4 percent sodium hydroxide seemed to be a practical level of treatment for corncobs. Steers fed this ensiled material were able to gain 1.6 pounds per day. Lambs fed treated wheat straw supplemented with soybean meal and urea were able to gain 35 and 18 pounds per day. Garrett found that pelleting or cubing the straw containing rations improved the animal intake. He also found that sodium hydroxide treatments increased the total digestibility from 38 to 59 percent. Rice straw can be treated to have a reasonable value in feeding of animals. An economic study by Parsons showed that if rice straw could be cubed and sold for $25 per ton the increased value per acre to the grower would be $60 for four tons of rice straw. The study assumed a possible demand for the product.

In countries where the availability of feed for animals is somewhat limited, the utilization of these cellulosic crop residues as feeds for ruminant type animals may provide an additional source of income from production of plant residue or through the increased number of animals which could be fed. The problem then arises in developing a technique for on farm treatment of these cellulosic plant residues for utilization by animals.

With regard to domestic sewage effluent, there is a time honored practice in many countries of utilizing this material for its fertilizer value. One of the problems associated with its use in that manner is the possible contamination of food crops with human or animal pathogenic organisms. In some areas, use of sewage is prevented by regulations by the public health agencies. Regulations on the use of sewage for irrigation crops are usually a general law under the public health act. The law will state specifically that effluents of septic tanks, other settling tanks, partially disinfected effluents, sprinkling filters, activated sludge plants, similar sewages shall not be used to water any growing vegetables, low growing fruits, fruit that is in contact with the ground, vineyards or orchard crops during seasons in which fruit lies on the ground. Such sewages, effluents, sludge, or screenings are not permitted in ditches or pipes which may be used to irrigate the aforementioned crops. It may also state the effluents can be used on certain specified field crops. Most countries, if not all, have similar laws. One of the obvious benefits deriving from these regulations is the low rate of human and animal mortality from the utilization of contaminated plants or water. This has already been pointed out by Wadleigh.

Various techniques of handling animal manures produced from confinement animal production are being investigated. Those which have been most successful involve the biological degradation of these materials. Aerated composting and lagoons are receiving renewed attention. The aeration in lagoons is achieved by floating an aerator on the surface, thus creating an aerobic layer of water on the surface. The municipal type of sewage treatment plant is under investigation as a possible means of disposing of animal manures. A secondary type treatment plant would cost about $250 to $1000 per cow to build and perhaps $60 to $100 per year per animal to operate(Fairbank).

Another technique which is currently being investigated for disposal of dairy waste is the use of wash water to transport suspended solid material to the field and to use this for irrigation of field crops. Investigations are currently under way to evaluate this system and to determine the effect of different loadings of material on crop production, soil characteristics, and the quality of the groundwater (Rauschkolb, Ayers and Kite, unpublished data).

In many areas where commercial fertilizers are not available, animal organic wastes are held in high regard and still provide a beneficial effect. These areas do not constitute a problem as far as organic waste disposal is concerned. Where the problem arises is in countries which have access to plant nutrients through relatively inexpensive commercial fertilizer. This makes the utilization of organic waste for plant nutrients too costly.

There have been several instances cited to indicate that soil can withstand very large loads of organic waste without resulting in adverse affects upon crops providing the soil is managed in such a manner as to account for the presence of this organic waste. It would seem likely that land is or will have to become the primary manner of disposal of organic wastes. In order to do this there are several critical matters requiring attention.

What is now needed is to develop information regarding the characteristics of these materials to ascertain some of the long-term usage effects on soils. The primary concern has been the effects on the fertility of the soil. Although some investigations have looked perfunctorily at the physical characteristics of the soil resulting from the incorporation of these materials, there is still very little evidence on the long-term changes of soil structure and the benefits if any derived from this change. Perhaps one of the reasons for this has been the lack of uniformly acceptable and reproducible techniques for evaluating soil structure. Even assuming an improvement of soil structure from the incorporation of these organic materials, there have been few investigations that have attempted to assess an economic value to this improvement. One of the problems has been that soil improvement is generally so slow and of such subtle nature that changes on the short-term have not been discernible. Even though its economic value, resulting from spreading it on the land, is not commensurate with the advantages it may provide, the use of this technique is possible. However, for the very reason stated, economic incentives will have to be provided for those willing to utilize organic wastes in this manner.

III. RADIOACTIVITY

EXTENT

In any discussion about radioactivity and its effects, it is difficult to be factual and objective without conjuring up in people's mind a sort of insidious death, genetic aberrations causing congenital birth defects and malformation, and unexplained adverse effects on the environment which affect all of our lives. For those same reasons it is necessary to more fully understand the occurrence, transmission, and reactions of radioactivity in our environment. People have been weaned on the mass hysteria which developed after the nuclear explosion toward the end of WW II and the threat of nuclear war which prevailed for a number of years after the close of WW II. However, reason among men has prevailed, which in itself is comforting, and several nations entered into an agreement whereby atmospheric testing of nuclear weapons was banned. Unfortunately, other nations, also with nuclear weapons capabilities, have not entered into such an agreement. Consequently, atmospheric explosions of nuclear weapons continue to be a source of radioactive contamination. Other sources of radioactive contaminants are wastes from mining and refineries of uranium and thorium, power plant nuclear reactors and medical and research laboratory wastes. Since soils naturally contain radioactive materials, it is necessary to become familiar with their contribution to the radiation level of the environment so one can accurately determine the contribution from other sources.

SOURCE AND INTENSITY

Some of the radioactive elements in nature are discussed to assess their contribution to the natural radioactivity of soil. According to Talibudeen, Carbon-14 has a mean specific activity in equilibrium biosphere of 16.1 disintegrations per minute per gram of carbon as a very weak beta emission. Potassium-40 has a specific activity of 28.3 disintegrations per second per gram of potassium as beta emissions and 3.6 disintegrations per second per gram of potassium as gamma emissions. Rubidium-87 has a maximum beta emission energy similar to that for Carbon-14. Thorium-232 is the parent member of the thorium family which has a disintegration rate of 4100 disintegrations per second per gram of uranium. The total alpha radioactivity of the uranium family at 1 ppm uranium is 285 micro-microcuries ($\mu\mu c$) per hundred grams of soil, and for the thorium family at 1 ppm thorium, the level was 77 $\mu\mu c$ per hundred grams of soil. In a study using Montpilliar coarse sandy loam located in the San Joaquin Valley in California, Hanson found uranium concentrations varied from 1.9 to 2.6 ppm and thorium concentrations from 9 to 11 ppm in the soil profile. The isotopic activities of the soil horizons ranged from 1.5 to 2.9 disintegrations per minute per gram. Hanson indicated he was able to calculate the radioactivity per unit of area and depth from the study. This type of information is of use when assaying background radioactivities. Another interesting finding of the study was uranium is leached more rapidly through the soil profile than is thorium.

The physical chemical composition of radio elements in soils is complicated by the added feature of radio elements being transformed continuously into new elements. In the gaseous phase there is radon and carbon dioxide. In a study examining the appearance of radon in soil atmosphere, Delwiche <u>et al</u> concluded a major portion of airborne radioactivity of natural origin is due to radonisotopes having their origin in uranium and thorium found in soils and rock. Some of the naturally occurring radionuclides also occur as solutes in the soil solution. The degree depends on solubility of the mineral. All of the naturally occurring radioactive elements are found in soil. Probably the most important radioelement contributing to the activity of the biosphere is potassium and the second is carbon (Hansen <u>et al</u>). In Table 15 are given the sources and estimates of background irradiation received by man.

The manner by which radioactive materials are disseminated becomes important from the standpoint of evaluating distribution and intensity of land degradation. Meteorological dispersal of radioactive aerosols is one method of transmission. These aerosols may result from an atmospheric nuclear explosion and release their fissionable products into the air or from radioactive release, either accidental or uncontrolled, or from wastes. The importance of atmospheric redistribution as a mechanism for the radioactive contamination of soil was shown by Schleien <u>et al</u>. In monthly composite sampling of the air one meter above the ground near Winchester, Massachusetts, they were able to detect the influx of radioactivity from all but one of the Chinese atmospheric detonations during the sampling period. In 1968, they found approximately 60 percent of the detectable radioactivity originated after 1963. The samples were collected and analysed as suggested by the United

Table 15 - Dose rates due to external and internal irradiation from natural sources in "Normal" areas.[1] (In parentheses, estimates given in the 1962 report)

Source of irradiation	Dose Rates (mrad/y)		
	Gonads	Haversian canal	Bone marrow
External irradiation			
Cosmic rays			
Ionizing component	28 (28)	28 (28)	28 (28)
Neutrons	0.7 (2.5)	0.7 (2.5)	0.7 (2.5)
Terrestrial radiation (including air)	50 (50)	50 (50)	50 (50)
Internal irradiation			
K^{40}	20 (20)	15 (15)	15 (15)
Rb^{87}	0.3	0.3	0.3
C^{14}	0.7 (0.7)	1.6 (1.6)	1.6 (1.6)
Ra^{226}	— (0.05)	0.6 (0.54)	0.03 (0.06)
Ra^{228}	— (0.08)	0.7 (0.86)	0.03 (0.1)
Po^{210}	0.3 (0.03)	2.1 (0.36)	0.3 (0.04)
Rn^{222} (dissolved in tissues)	0.3 (0.3)	0.3 (0.03)	0.3 (0.3)
Total[2]	100 (102)	99 (99)	96 (98)
Percentage from alpha particles and neutrons	1.3 (3)	4.4 (2.8)	1.4 (3)

1/ Taken from the United Nations Report on Effects of Atomic Radiations

2/ Totals were rounded off to two significant figures

States Department of Health, Education and Welfare radioactive material assay procedure for environmental sampling (1967).

Several factors are to be considered when evaluating wind pickup of radioactive particles from the ground surface and their ultimate redistribution causing land pollution. Such soil factors as particle size, area covered by nonerrodible particles, vegetative cover, cohesiveness of surface particles, density and shape of the individual particles, coupled with meteorological factors such as wind speed , gustiness near the ground, temperature, humidity, and the occurrence of precipitation all influence the wind pickup of radioactive particles (Healy and Fuquay).

Menzel indicates that most fission products and naturally radioactive elements in the air are carried on solid particles. In higly contaminated zones close to a nuclear explosion the particles may be relatively large, one micron to several hundred microns in diameter, whereas world wide fall out of radioactivity are associated with smaller particles usually from 0.1 to 1 micron in diameter. A rule of thumb which has been developed to estimate the decay rate of a mixture of isotopes resulting from a nuclear explosion states that "for every sevenfold increase in time following the explosion, there will be a tenfold decrease in radiation activity".

Indications are that rainfall is one of the principal means by which the smaller radioactive particles are deposited on the surface of the earth. In Florida, approximately 90 percent of this Strontium-90 content of the crops resulted from intercepted rainfall (Menzel). He also found that particles greater than 10 microns are likely to settle by gravity before a rainfall occurs. In the arid regions where total rainfall is very low, the Strontium-90 deposited by rain was estimated to be roughly equal to that deposited by dry mechanisms. In the absence of rainfall, large particles are deposited by a gravity impaction in eddy turbulence. Studies by Woodwell and other investigators have shown the highest accumulations of radioactive fallout in the world occur between the latitudes 30 degrees north and 60 degrees north. Peak concentrations of 120 millicuries of Strontium-90 per square mile were found in samples at latitudes corresponding to Canada and Central Europe. The remaining latitudes showed concentrations of Strontium-90 at less than 80 millicuries per square mile with approximately two-thirds of those below 40 millicuries per square mile. After these radioactive materials are deposited from the air there is some wind and water movement after it reaches the soil.

From data obtained in erosion test plots, Heald found 99 percent of the fallout Strontium-90 remained on the soil where it fell, however, the Strontium-90 that ran off was concentrated 10 times in the sediment. Therefore, it seems likely that in areas subjected to sediment accumulations, radioactivity could be found in higher concentrations than in the surrounding areas. Other sources of radioactivity need to be evaluated as well.

To evaluate the extent of a possible hazard from the content of uranium, thorium, and radium in the world phosphate rock deposits, a survey of phosphate rock samples from all major phosphate producing areas in the world was conducted (Menzel). Out of a total of 316 individual phosphate rock samples, the median content of radium, uranium, and thorium was 18 manograms/kg, 59 milligrams/kg, and 8 milligrams/kg, respectively. Menzel concluded that phosphate fertilizer applications probably have not or will not result in an appreciable radiation hazard since the addition of high rates of phosphate may only equal the amounts of uranium and radium occurring naturally in the low layer, however, the addition of thorium would be less than the amount occurring naturally.

There seems little doubt that the electrical power consumption in the world will increase. At the same time, there is some doubt that fossil fuels will be capable of providing the energy needed to generate this power. Furthermore, it seems only realistic to recognize that fossil fuels are not a limitless supply of energy, nor is there likely to be much more development of hydroelectric power. Consequently, the door has been opened for the entry of nuclear reactor power plants.

It is projected that by the year 2000 in the United States approximately one-half of the power generated will come from nuclear power plants. Shaw and Whitman estimate that by 1975, 25 nations will have commercial nuclear power plants. The reason for concern about nuclear power plants is from the standpoint of accidental and waste release of radioactive materials into the surrounding environment. In the United States the Atomic Energy Commission requires a minimum of one year of background radiation survey data before the nuclear power plant can become operational. The surveys are conducted at the expense of the requesting company with periodic checks on sampling techniques and accuracy by the Atomic Energy Commission. These surveys of background radiation are very critical since they provide the benchmark data fon evaluating the effects of a nuclear reactor plant on the surrounding environment.

What happens in soils once they have been exposed to contamination by radioactive material? In this regard the reactions of naturally occurring and artificially produced radionuclides will be discussed.

MEASUREMENT AND CONTROL

Investigations have indicated that in soils the cation exchange capacity of the soil has a marked effect on movement of radioactive nuclides through the soil. Leaching soils with mixed fission product solutions resulted in 80 to 85 percent adsorption of the total radioactivity in the first few centimeters of soil (National Academy of Sciences Publication 1092). The fixation of these fission products have been studied by several investigators. One such study by Evans and Dekker shows that Cesium-137 was fixed against extraction by neutral one normal ammonium acetate. Fuller and L'Annunziata found the presence of various algae and fungi could incude some slight movement of Strontium-89 through the soil profile with water leaching. Most of the radioactivity was found in the first 2.5 centimeters layer of the soil where it was applied.

Since the principal reaction of the radioactive cation is similar to those of other cations in soils, they would be subject to the same influences of clay content, organic matter content, and pH effect. Where they may differ is in the degree or extent to which they participate in such reactions. In this regard, it has been found that several cations have a tendency to reduce the adsorption of strontium and cesium. The order of replacement on soil materials is usually lithium < sodium < potassium < ammonium < rubidium < cesium < hydrogen < magnesium < calcium < strontium (National Academy of Sciences Publication 1092). The type of anion present has also been found to have an influence on the availability of strontium for plant growth. When strontium was added to soils as the sulfate, oxylate, hydroxide, fluoride, carbonate or phosphate it was one tenth as available to plants as strontium added to the soil as either the chloride or nitrate. Massive doses of phosphate have reduced strontium uptake 50 percent on alkaline soils but give no such reduction on acid soil. Plutonium seems to be so tightly held by soil that little is taken up by plants so it may be considered of slight concern to man. Unless incorporated throughout the soil by mechanical manipulation of the soil, the best evidence indicates that these radioactive materials will be adsorbed at or very near the surface. Since very few if any plant roots feed at the surface, there seems little likelihood these materials will be taken up by plants, especially in arid regions where soil surfaces dry rather rapidly. In the more humid regions the possibility does exist for roots to explore the soil near the surface for its nutrient supply. However, when considering the rather small concentration of radioactive materials near the surface, in relation to the more uniform distribution of the essential plant nutrients throughout the soil profile and the magnitude of the non-radioactive materials, it also seems reasonable to assume that plants would not absorb great amounts of radioactive material.

Over the long term soils are manipulated, and these radioactive materials are distributed more uniformly in the soil profile, increasing the probability of adsorption. Yet at the same time the soil is tilled, the contamination in many cases is diluted to the point where it is no longer discernible from background radiation. Concern with radioactive materials in soils is not with their effect on soil <u>per se</u>, but their entry into crops and ultimately their entry into the food chain of man. The principal method of entry into the food chain is when fallout lodges directly on plants that are eaten by man or animals (Alexander, Menzel and Reitemeier).

Auerbach and Crossley found that soil applied radiocesium and radiostrontium had higher concentrations in the leaves and flowers of corn than in the other plant parts sampled. However, in sampling the natural vegetation it appeared that flowers of these plants had the lowest concentration. There were some plant species differences in this regard. This might be expected since it is well characterized that plants have different abilities to absorb and accumulate various elements.

Several isotope investigations have shown greater accumulation of strontium in the above ground parts, whereas radioisotopes of yttrium, cerium and zirconium are retained mainly in the roots. The data also indicated that the radioactive elements concentrated mainly in the vegetative portion of the plant with smaller quantities accumulating in the seeds. Studies by Gulyakin and Yudintseva found that strontium and cesium radioisotopes were more readily taken up by plants than other fission products. They have also demonstrated the close relationship between the uptake of radiostrontium and radiocesium to calcium and potassium, respectively. They indicated that in soils where the absorption properties of the soils are intensified, the accumulation of these radioactive materials in farm crops may sharply decrease.

Evidence of the influence of fertility on the uptake and radioactive strontium and its distribution in plants is viewed with mixed concern. A study by Andersen found that heavy applications of phosphorus decreased the concentration as well as the total uptake of Strontium-90 in oats. On the other hand, nitrogen applications increased the total uptake of Strontium-90. However, the distribution of the isotope in grain and straw was differently affected. Concentration of Strontium-90 in the grain decreased with increasing nitrogen supply until the maximum yield was obtained.

There is also information regarding the influence of soil pH on the uptake of Strontium-90. In general, the uptake was greater from acid soils, intermediate from slightly acid soils, and least on soils that have been limed (Haghiri and Sayre). The same study indicated the accumulation of radiostrontium varied for different plants. After five weeks growth the uptake was in this order: buckwheat > soybeans > alfalfa > Sudan grass, which was approximately equal to corn. Sudia and Linck demonstrated greater absorption of radioactive materials occurred at the lower pH values 2.5 and 4.5 and significantly lower amounts were absorbed at the higher pH values of 7 and 8.2. An interesting corollary of this study was the translocation of radioactive strontium from the site of foliar application. Less than 2 percent of the radiostrontium was transported from the applied leaf.

Investigating the availability of exchangeable and non-exchangeable Strontium-90 to plants, Roberts and Menzel found that cow peas were capable of extracting 8 to 18 percent of the exchangeable strontium, depending on the uptake of exchangeable calcium. They also found that non-exchangeable strontium made little or no contribution to the total uptake.

Through the accumulation of radioactive wastes in soils and their resultant uptake by plants, radiation enters into the realm of internal radiation in animal and man. Table 16 shows the amount of radioactivity calculated to be in one acre of a green crop by Hansen, Vidal and Stout.

Table 16 Radioactivity in one acre of green crop plant in curies per isotope. 1/ 2/

Nuclide	Radioactivity in curies
K^{40}	$76\,500 \times 10^{-9}$
Rb^{87}	$19\,900 \times 10^{-9}$
C^{14}	$13\,500 \times 10^{-9}$
Ra^{226}	400×10^{-9}
U^{238}	157×10^{-9}
H^{3}	156×10^{-9}

1/ The total activity (calculated) for the entire above ground portion of the crop on one acre is 0.11 millicurie

2/ Adapted from Hansen, Vidal and Stout.

It is not within the scope of this paper to discuss the effects of radiation dosages on animal and human health. As pointed out previously, there are several methods by which radiation may become an internal problem. Also, the concern of ingesting radioactive material is not necessarily that of a large amount of radioactivity ingested at one time, but rather the accumulation of small amounts through handling, ingestion or inhalation. By ionization, dissociation of compounds in the body, and denaturization of protein, the effects of radioactivity may be immediately exhibited. Or, the expression of the effects may be delayed for a considerable period of time depending upon the intensity and chronic nature of the radiation.

Methods of ameliorating the effects of radioactive contamination of the soil have been the subject of much investigation over the past several years. There are few practical solutions for decontaminating soils with relatively large amounts of radioactivity that might be associated with comparatively large releases from a nuclear explosion or an accidental fission product release. The term "practical" is used in the sense that as long as other large areas of soil are available for utilization in the growth of plants, decontamination procedures must fall within the realm of economically feasible reclamation.

Procedures of soil decontamination which have been investigated are continuous cropping, removal of sod or the surface 2 to 4 inches, deep ploughing, leaching and the use of fertilizers and soil amendments (Hills). While some of these practices may not be feasible from the standpoint of a large contamination, it may be reasonable to use certain of these techniques in the decontamination of small amounts of radioactivity, which are significant increases above the natural background radiation.

The use of chelating agents has been investigated as a possible mechanism for leaching radioactive materials below the root zone of plants where they could accumulate and harmlessly decay. Chelating agents such as ethylenediamine tetracidic acid (EDTA), ethylene diamene di-o-hydroxy phenylacidic acid (EDDHA) and diethylene triamine (DTPA) were compared with deionized water as to their ability to move several fision products, Strontium-89, Yttrium-91, Ruthenium-106, Cesium-137, and Cerium-134 in different kinds of soils (Nishita and Essington). Irrespective of soil type, the order of magnitude of fissionable products movement by water was in the following order: CS-137 = Y-91 = CE-134 < SR-89 ≪ Ruthenium-106. Among the chelating agents, EDDHA was generally least effective while the relative effectiveness of DTPA and EDTA varied with the soil and the radionuclides. These investigators concluded that the application of synthetic chelating agents for leaching of mixed fissionable products is of limited value. However, investigations by Fuller and L'Annunziata would indicate that the chelating agent DTPA in conjunction with algal or fungal activity in soil may provide a very important mechanism for moving Strontium-90 through the soil profile. Fertilization coupled with use of manure or organic waste incorporation in the soil, seems to be another technique which may reduce the accumulation of strontium and cesium in crops (Guylyakin and Yudintseva). The use of gypsum to encourage the replacement of the radioactive cation with calcium on the exchange complex causing the radioactive cation to be leached deeper in the root zone may be another technique which is available to reduce relatively low amounts of radioactive material in the soil.

Deep ploughing could be another practical technique. There are two aspects of deep ploughing which may be applicable. One is the actual burial of the contaminated soil to a depth of 2 to 3 feet, in which case shallow rooted plants could be grown. The other alternative is thoroughly mixing the contaminated soil in the 2 to 3 foot soil profile, thereby diluting and decreasing the probability of the radioactive element being taken up by plants.

It appears that four radionuclides are of importance in the consideration of the radioactive contamination of foods from soils. These are Strontium-89, Strontium-90, Iodine-131, and Cesium-137 (Federal Radiation Council). However, as pointed out by Reitemeyer et al, the half life of Iodine-131 is 8 days, which is too short, a time for it to be considered with respect to soil contamination.

Lieberman discusses the waste management problem in the nuclear energy industry and indicates that there are three basic considerations in the disposal of nuclear wastes. First, the establishment of appropriate standards. Second, the specific nature of radioactive waste under consideration. Third, the physical, chemical, and biological characteristics of the environment in which the waste is to be handled. As pointed out, essentially the proper waste management is in identifying and quantitatively describing items 2 and 3 and their combined behaviour so as to insure conformance with the standards established. The standards should be composed of the best available biological and medical knowledge and need to be of universal application. There are certain limitations however. Standards sometimes lack complete knowledge. They must therefore be subject to modification as better knowledge is gained. The general attitude toward radioactive waste management has been "concentrate and contain" or "dilute and disperse". The "dilute and disperse" technique has generally been imposed upon low concentration radioactive wastes and the "concentrate and contain" is generally associated with the disposal of highly radioactive wastes. With regard to waste containing low concentrations of radioactivity, the general practice has been to disperse these in the environment in such a manner as to not contribute to the background radiation level in any significant amounts. According to Lieberman, there are two cardinal principles in establishing performance criteria for waste dispersal operations from nuclear installations. They are (i): the minimum practicable amount of radioactivity should be dispersed into the environment commensurate with specific environmental standards to protect public health and safety; and (ii): a continuing periodic mandatory verification of performance criteria. Further investigation may be necessary to characterize wastes from nuclear power plants, and their long term contribution to our external and internal radiation exposure.

One can only hope and assume that reasoning of reasonable men will prevail and the danger of nuclear war is only an unpleasant memory of the past. And further, that reason will prevail in such nations that are practising nuclear atmospheric testing so this source no longer becomes an environmental concern.

Upper air direction and speed are important indicators of where the fallout will be deposited. The same indicators are of value in estimating the distribution of radioactive waste dispersal through atmospheric venting of nuclear power plants. Of considerable interest would be the radiation decrease rate following an accidental release of nuclear power plants which produce different kinds and amounts of fissionable products.

IV. INFECTIOUS ORGANISM

EXTENT

Infectious diseases from the standpoint of land degradation may be considered on the basis of the introduction of an infectious agent into an uninfected area. In that sense it becomes necessary to assess a relatively high degree of importance to the mode of transmission of these diseases. Realizing their presence in soils is of great economic importance, regardless of mode of infestation, they assume higher priority.

When one considers the number of years that plants and animals have existed, one can assume that large numbers of microorganisms causing various diseases must have been introduced into soils. That being the case, what has become of these infectious organisms, especially the ones that cause diseases in man and animals, for example, typhoid fever, dysentery, cholera, diphtheria, tuberculosis, mastitis, abortion in cattle, and numerous other diseases?

SOURCE AND INTENSITY: ANIMAL PATHOGENS

The results of soil investigations for presence of agents causing infectious diseases have established that many organisms pathogenic to man and animals do not remain alive in the soil very long. However some pathogens are able to survive in the soil for considerable periods. The infectious agents of anthrax, the clostridial diseases (including tetanus), coccidioidomycosis and ascariasis, for example, are found in soils after several years. There are also numerous plant dieseases that are able to remain viable in the soil for considerable periods of time.

The lack of persistence of many pathogenic organisms in soils is probably due to such factors as unfavourable environment, lack of substrate, destruction by predatory organisms and antibiotic or antagonistic effects from the indigenous soil population of microorganisms. However, it is not within the scope of this paper to discuss all types of organisms that can survive in soils and are pathogenic in nature to plants, man and animals.

MEASUREMENT AND CONTROL

In the transmission of human and animal pathogens, aerial transport of the organism as a free organism or attached to organic or soil particles is one of the principal methods of transmission of the disease. Investigations into the survival of organisms as aerosols have revealed that relative humidity is one of the controlling factors in survival rate. It is, however, very interesting to note that organisms vary in their ability to survive at different levels of relative humidity. Investigations by Stewart and Wright, using streptococcal L forms showed that survival was greater at comparatively low and high relative humidities, while the intermediate relative humidity was the most lethal. In another investigation using Escherichia coli B, Cox found the best survival in air occurred at the relative humidity range of 40 to 10 percent. At relative humidities greater than 40 the survival rate was greatly reduced.

In evaluating the effect of various aerosols on the survival rate of airborne u.c. Rhizobium melilote, Won and Ross found that survival rate of this organism was maximum at high relative humidities, and the survival rate was reduced significantly at lower relative humidities. They also found that certain other aerosols and environmental factors influenced the rate of survival. It seems that the organism was capable of surviving in the air at relatively high concentrations of NO_2, SO_2, or formaldehyde, and while the survival rate was reduced by ultraviolet irradiation the effect was accentuated at low relative humidities.

The survival of various microorganisms in water has also been found to vary considerably with degree of contamination of the water. The organism Eberthella tyophosa survived in sterilized water for 15 to 25 days as opposed to 4 to 7 days in fresh water. It died off even more rapidly, 1 to 4 days, in raw river or canal water, and in this instance the degree of the survival of the organism in water was found to be inversely related to the degree of contamination. Saprophytic bacteria were directly responsible for the destruction of the pathogens (Waksman). When Pseudomonas aeruginosa on the other hand is present in drinking water, it may not be accompanied by other bacteria. When water was inoculated with Escherichia coli and Pseudomonas aeruginosa only the latter organism survived. However, Waksman found the two organisms can coexist in sterilized water. In sterilized tap water inoculated with Brucella melitensis the organism was able to survive for 42 days as opposed to 7 days in unsterilized tap water, further indicating the microbial compliment of the media is extremely important in evaluating the rate of survival of a pathogen.

Soil survival of various organisms also is quite variable. For example Mycobacterium tuberculosis was found alive and viable in cow feces on pasture land after 5 months during the winter, but were undetectable after 2 months in the summer. In other studies where Mycobacterium tuberculosis was added to nonsterile soils, it was slowly destroyed until it was reduced to about 1/6 of its original count at a one-month period (Waksman).

A fungus disease of man and animals, coccidioidomycosis, resulting from inhalation of spores of Coccidioides immitis is a soil borne disease endemic to the arid area of the southwestern United States. Epidemics of coccidioidomycosis sometimes associated with severe dust storms are regarded as examples of true aerial transmission. It also appears that the soil serves as a point source of infection and the most common means of transmission involves physical perturbation of soil upon the natural site of soil inhabitation of the organism (Kahrs). The hookworm disease caused by Ancylostoma duodenale and Necator americanus is primarily due to soil pollution (Waksman). The larvae were found to survive for as long as 6 months in soil protected by vegetation, and the larvae were found largely in the capillary film of moisture surrounding the soil particles.

SOURCE AND INTENSITY: PLANT PATHOGENS

There is widespread distribution of many different types of soil organisms which can infect plants through their intimate association with plants in soils. These organisms have adapted over a wide range of soil environments and are able to persist for long periods of time, especially in the presence of host plants.

Seedling diseases may be caused by many organisms. Two organisms associated with this type of plant disease are naturally found in soils and have worldwide distribution. They are Pythium species and Rhizoctonia species. Davidson estimated that seedling diseases have caused slightly over one percent losses in cotton in 1966 in Arizona. By using the estimate of losses due to seedling disease, very often the only consideration is the reduced stand and effect of stunting on the ultimate production. However, as it is pointed out by Garber, the seedling disease organisms are capable of rotting seeds or killing seedling plants often to the point where it becomes necessary for cotton growers to replant their fields. The complete loss of stand and cost of replanting are economic losses which are not generally considered when estimating yield losses due to inadequate stands.

Another type of widespread soil inhabiting plant pathogens are the wilt organisms. These organisms, Fusarium oxysporum, and the Verticillium albo-atrum are worldwide in distribution and the Verticillium albo-atrum especially has a wide host range (Hall). Severe crop losses have been attributed to this soil microorganism in strawberries (Wilhelm). In order to combat this disease, soil fumigants are used extensively and repeatedly in the California strawberry industry to prevent losses due to the Verticillium wilt. In Arizona, estimated yield losses due to Verticillium in 1966 were about 5 1/2 percent of the total production. In California, in 1963 Schnathorst reported a two percent loss to the cotton crop due to the Verticillium species and Thielaviopsis species complex.

Various root rotting organisms are also known to exist in many areas of the world and also have a wider range of hosts. For example, Phymatotricum omnivorum was reported by Davidson to have caused approximately 8/10 of one percent of a crop loss in cotton in 1966. Another organism, Macrophominia phaseoli, invades roots of numerous higher plants at relatively cool and warm climates. The fungus created serious problems with cotton production in Pakistan as reported by Ghaffar and Erwin, especially under water stress conditions. This organism has also been the cause of serious losses of corn and sorghum in the midwestern United States (Ashworth).

Other plant infecting organisms intimately associated with soils are nematodes. These organisms have a rather wide distribution as indicated by investigations conducted by several individuals and also have a rather wide host range. The Southern Cooperative Series Bulletin No. 74 indicated there were 68 different species or genera of plant parasitic nematodes in the South and these were associated with at least 52 plant families. They indicated that the number of plant species known to be attacked by the rootknot nematode throughout the world exceeds 2000. Outstanding cases of injury by these organisms have been known to occur in the southern United States on such important crops as tobacco, cotton, peanuts, sugar cane, forage legumes, and many vegetables including melon, beans, peas and tomatoes. In Australia, Meagher found damaging infestation of nematodes in grapes. In Egypt, Elmiligy attempted to establish a nematode infection index on cowpeas. The vertical distribution of root knot nematode was studied in Rhodesia by Ferris. These various studies serve to indicate the worldwide distribution and economic importance of nematodes.

Nematodes of the genera Meloidogyne and Pratylenchus seem to be rather common. Their persistence in soil seems to be related to soil texture. On soils with 50 percent or more sand, O'Bannon and Reynolds found the nematode population increased very rapidly. In a loamy soil, Elmiligy found a high rate of crop damage despite a low infection index; the soils which he studied had a sand content between 61 and 75 percent.

Annual losses due to nematode infestations can be quite severe. It was estimated by Reynolds that during the period 1951 to 1965, there was an estimated yield reduction equivalent to the full production of approximately 10 thousand acres per year from nematode infestations. In fields which are known to have infestations, soil treatments have provided rather dramatic increases.

MEASUREMENT AND CONTROL

Cotton production was increased 2 1/2 times (Nigh and Tate). In Australia, Meagher found approximately 85 percent of the grape areas treated gave good yield increases due to treatment.

There are four generally accepted methods for controlling indigenous soil pathogenic organisms. These are by the use of biocides, cultural practices, biological controls and immunization by selection for tolerance.

Soil fumigation and fungicides have been used by several investigators as a means of controlling infectious organisms in prevention of losses: Nigh, Wilhelm, Reynolds, Meagher, Ashworth, see Table 17. One of the expected but undesirable side effects from fumigating the soil is the adverse effect on what might be considered desirable soil organisms. For example, Chandra and Bollen were able to demonstrate changes in the microbial population in a soil. They were able to completely suppress nitrification for 30 days. However, by the end of 60 days, nitrification had recovered sufficiently to become approximately 1/2 the rate shown by the controls. In another investigation, with a different array of soil fumigants, Koike was able to demonstrate the same kind of effect on nitrification rates. All the materials used markedly inhibited nitrification for a period of 4 to 8 weeks.

Cultural practices have markedly different effects on the control of indigenous soil organisms. Garber indicates that black-eyed beans have been incorporated as green manure crop in soils to promote the incidence of seedlings diseases for their experiments. Blank and Tucker demonstrated the effect of cropping sequence and nitrogen fertilization on Verticillium buildup in soils. They found the incidence and intensity of wilt was greatest in cropping systems where cotton occurred most frequently. The infestation was intensified by the addition of manure and/or high rates of nitrogen fertilization. Rotation with other crops was helpful in retarding the buildup of wilt. Grains and sorghums were more effective than alfalfa.

Established nematode populations of M. incognita acrita were very rapidly reduced when pure stands of Pangolegrass remained in the plot. Coastal Bermuda grass was also effective in maintaining the nematode populations at low levels. Clean fallow and clean fallow plus flooding was effective in controlling nematodes, but neither methods was superior to the Pangolegrass (Winchester and Hayslip). They found that wild crabgrass, Common Bermuda grass, and water sedges, while showing no symptoms of galling upon casual examination, appear to be excellent hosts and maintain the root knot nematode at high population levels.

The use of organic matter incorporation for the control of Phymototricum Omnivorum root rot of cotton in Arizona was demonstrated by Dr. E.B. Streets. Investigations into the mechanism of action showed the development of saprophytic organisms which were able to reduce the inoculum level of the infectious organism. Other examples of this method of biological control of several soil borne diseases are available. For example, the inoculation of soil with the saprophytic fungus, Trichiderma, was found to prevent infection of citrus seedlings by the pathogenic Rhizoctonia (Waksman). Although this technique is not widely-used because of lack of better knowledge of soil microbial antagonisms, there are certain instances where it has been demonstrated as an effective method for regulating high inoculum levels of infectious dieseases.

Table 17 - A list of fungicides and soil fumigants commonly used in the United States

Common Name	Chemical Name
fungicides:	
Captan	N-[(trichloromethyl)thio]-4 cyclohexene - 1, 2-dicarboxamide
Ferbam	Ferric dimethyl dithiocarbarmate
Nabam	Disodium ethylene bis-dithiocarbomate
PCNB	Pentachloronitrobenzene
1/	Hydroxymercurichlorophenol 2/
1/	Phenylmercuric acetate 2/
Terrazole	3-trichloromethyl 1-5-ethoxy 1, 2, 4 thiadiazole
fumigants:	
Chloropicrin	Nitrotrichloromethane
DBCP	Dibromochloropropane
DD	1, 3 dichloropropene
EDP	Ethylene dibromide
Methyl Bromide	- - -
Telone	1, 3 dichloropropene and 1, 2 dichloropropane

1/ Either no common name or the common name is the same as the chemical name.

2/ These are the only mercuric compounds now registered in the United States for commercial usage(1970)

Pathogenic viruses are of considerable interest in both the plant and animal kingdom and may be transmitted as aerosols.

In 1960, Sill et al reported the reactions of winter weeds to soil borne wheat mosaic virus in Kansas. They were investigating the susceptibility of various winter wheat varietal selections and crosses to the soil borne wheat mosaic virus.

Immunization of man and animals along with plant selections for tolerant or resistant varieties seem to hold the most promise for widespread prevention of infectious diseases. There are several classic examples from which to choose to point out the effectiveness of this sort of control. Immunization for smallpox and tetanus in man, and anthrax, tetanus and other clostridial infections in animals are examples from the animal world. Varietal selections in cotton for Verticillium wilt tolerance, and in alfalfa and grapes there is varietal selection for wheat mosaic virus resistance. The success of these selections or immunizations indicates that these are appropriate and proper methods for preventing land pollution by infectious organisms from becoming a more serious hazard.

V. AGRICULTURAL AND INDUSTRIAL CHEMICALS

A. DETERGENTS

EXTENT

Investigations of sources and their contribution to the eutrophication of our surface waters has revealed that phosphates from detergents constitute a major portion of the contribution of phosphorus to these waters. Miller found that when considering all the water sheds, which feed Lake Erie, it has been estimated that the total input of phosphorus from rural runoff was only 13%. The greatest inputs accrue from detergents: 46% of the total, and human excretia 20%. Wadleigh pointed out that in the United States metropolitan sewage effluents yield about 2 pounds of phosphorus per person annually. He also indicated that this phosphorus comes mainly as the result of approximately 5 billion pounds of detergents being used each year in the United States. In a survey of the Potomac River near Washington DC, he found that the Potomac Estuary's daily load of phosphorus contained 14% contributed by the river's watershed above Great Falls, the remainder of the phosphorus (approximately 85%) came from the Washington Metropolitan Area.

SOURCES AND INTENSITY

The phosphates usually contained in detergents are one of the three principal ingredients in detergents. The three categories of ingredients being the surfactant, the phosphate builder, and miscellaneous ingredients such as brighteners, perfumes, and inhibiters. The phosphate builder in detergents consists of a sodium tripolyphosphate complex which is the basic ingredient of the all purpose household detergent (Weaver). In Table 18 are listed some of the most widely used products in the United States by name, showing their ranking by the percent phosphorus content (Burgess).

Table 18 Phosphorus content of several household soaps and detergents 1/

Type of material	Product	Percentage phosphate
I. Automatic dishwashing detergents:	Cascade	54.5
	All	54.0
	Calgonite	49.4
	Finish (formula for):	
	hard water	43.8
	medium hardness	28.7
	soft water	17.9
II. Heavy duty detergents (dry):	Dash	58.2
	Tide	49.8
	Oxydol	46.6
	Ajax Laundry	44.6
	Dreft	41.9
	Rinso	39.5
	Duz (detergent)	38.5
	Concentrated All	37.9
	Cheer	36.3
	Fab	34.8
III. Heavy duty detergents (liquid)	Cold Water All	24.5
	Wisk	14.2
IV. Heavy duty soaps	Instant Fels Naphtha	11.9
	Duz	0
V. Light duty detergents:	Thrill (liquid)	11.9
	Trend (dry)	7.1
	Ivory (liquid)	1.0
	Dove (liquid)	0
	Joy (liquid)	0
	Swan (liquid)	0
	Trend (liquid)	0
VI. Pre-soak enzyme product:	Biz	73.9
	Axion	63.2

1/ Taken from AES University of California Bulletin, Consumer Economics in Review, May, 1970

Terkeltaub and other aquatic ecologists agree that the addition of phosphates to bodies of water increases the rate of eutrophication, except where other nutrients are in such short supply as to limit plant growth. One source of these unwanted supplies of phosphorus is the waste water containing detergents. This led to a ban of detergents containing more than 12 percent phosphates in the state of Indiana, as the first state in the United States taking such a step.

There is evidence also that in certain marine estuaries nitrates may be limiting the growth of aquatic flora. In such cases phosphate additions have less or no eutrophication effects. In still other cases, occuring much less frequently, other plant nutrients limit the development of aquatic flora.

MEASUREMENT AND CONTROL

Ryther and Dunstan in their investigations of eutrophication of marine environments indicated the nitrogen to phosphorus ratio in domestic wastes is slightly higher than 5 to 1. They further indicated that if half the phosphorus and sewage came from detergents, and if all the phosphorus from that source could be eliminated, the amount of nitrogen and phosphorus entering the coastal marine environment would still be in the atomic ratio of 10 to 1 and no reductions of algal growth or eutrophication would be expected. Their investigations would indicate that about twice the amount of phosphate as can be used by algae is normally present in coastal marine waters. This results from the very rapid utilization of nitrogen by algae and plankton and the more rapid regeneration of phosphorus than ammonia from decomposing organic matter.

Phosphorus has been a constituent of surface waters long before detergents were used or widespread phosphate fertilization was practiced. In evaluating the phosphorus concentration in natural drainage waters in 1921, Mc Hargue and Peter found that the phosphorus content in several streams and rivers in Ohio, Mississippi and Kentucky contained phosphate levels of a trace to 0.22 ppm, and there was a high correlation between the parent rock through which they ran or drained. In the Ohio and Mississippi Rivers, at Paducka and Baton Rouge respectively, the phosphorus concentration was 0.07 ppm. As was pointed out in the bulletin, the source of water came from mixed geological formation. The phosphorus concentration in the Mississippi River also reflects influence of the sediment load. While there is no verification of what the sediment load would have been in the year or two preceding 1921, it seems reasonable to assume that the sediment load would not have changed a great deal. The estimate of the amount of sediment discharged in the Mississippi currently is approximately 500 million tons of sediment per year.

As regards the use of waters with increased phosphate contents for irrigation purposes, it has been measured that the world consumption of detergents contains about 5.3 million metric tons of P_2O_5 per year, while the world consumption of P_2O_5 as fertilizers was 16.4 tons in 1968 of which more than half was used in the highly industrialized countries. This shows that for irrigation purposes the water quality is hardly diminished by detergent containing effluents.

There have been several investigations into the movement of phosphorus in the soils and this movement has been reasonably well characterized. In an experiment with nitrogen, phosphorus and potassium fertilizers from 1951 through 1959, Alben and Hammar found that on a loam soil fertilized with triple super phosphate and muriate of potash, the phosphorus penetrated to a depth of 18 inches, and potassium to 30 inches during the 10 year period of the study. Hannapel et al demonstrated essentially the same lack of movement of phosphorus through a sandy loam when inorganic phosphorus was the material applied to the soil, see Table 19. However, they were able to demonstrate that organic phosphates through the incorporation of residue containing organic phosphorus or through the incorporation of an energy source conducive to microbial activity in the soils that there is a considerable amount of movement through the soil profile in the organic phosphate form.

There are situations when phosphorus in the inorganic form will move through the soil profile. These represent essentially two extremes in soil texture: sandy and organic soils. Miller found that phosphorus moves in fairly large quantities through sandy soils and Larsen et al, with the use of radio autographs, also found that there was no movement of inorganic phosphorus in the mineral soil, whereas in an organic soil considerable movement was found to occur.

These and other numerous data are evidence of the fact that phosphorus is a relatively immobile nutrient in soils. This accounts for the statement that phosphorus does not move in soil, although as pointed out by Grant it is more accurate to say "phosphorus does move in the soil but the amount of phosphorus moving in the soil solution is very low compared to the total amount of phosphorus in the soil." Oftentimes among soil scientists the modifier "relative" is implicit in the discussion of phosphorus movement in relation to other essential plant nutrients. In the environmental context perhaps it is more meaningful to discuss phosphorus movement in the more accurate manner.

There seems to be little advantage to belabour the point that phosphorus is a very necessary plant nutrient and in many areas of the world has to be added to the soil in order to promote optimum growth and production of plants which is turn provides the absolutely necessary mineral nutrition of animals and man. It is difficult to conceive of the situation where additions of phosphorus to the soil would be construed as land degradation. The possible exceptions being the contaminants associated with phosphorus minerals or the inducing of the micronutrient deficiences through the use of excessive applications of fertilizer phosphorus.

Table 19 - Cumulative phosphorus displaced from Tucson sandy loam soil columns by deionized wat r.[1/]

Material added	Amount added	Cumulative P dispaced[2/]		
		Total P	Org. P	Inorg. P
	tons/acre	µg		
Control	---	153 a	79 a	74 bc
Barley residue[3/]	2	201 a	148 a	54 ab
Barley residue[3/]	10	740 b	662 b	78 bc
Bean residue[3/]	2	218 a	155 a	63 ab
Bean residue[3/]	10	887 c	789 b	98 cd
H_3PO_4	P ≈ to 10 T Bean residue	157 a	95 a	62 ab
K_2HPO_4	P ≈ to 10 T Bean residue	157 a	116 a	41 a
Sucrose + NH_4NO_3	C ≈ to 10 T Bean residue	1197 d	1077 c	120 d
Standard error		42.0	38.9	7.9

1/ Adapted from Hannapel, et al

2/ Data represent a total of 10 displacements through an 8 inch soil column. The same letter following any two values indicates that they belong to the same population at the 0.05 level according to the Duncan Multiple Range Test

3/ Residue from plants grown in P-32labelled nutrient solutions. P-32 in the inorganic form added to all other columns prior to incubation

V. AGRICULTURAL AND INDUSTRIAL CHEMICALS

B. PESTICIDES

EXTENT

By the very nature of the product a considerable amount of pesticides ultimately reaches the soil. The purpose of their use is very specific, that is to kill the target pest. Several countries have registration procedures which prevent the use of pesticides until scientific evidence is obtained to prove that it can be used safely and effectively when applied according to direction. It has appeared to the general public that these laws have not been adequate in the regulation of the pesticide impact on safety, health, and environmental considerations. The potential for contamination of the environment by pesticides, particularly the chlorinated hydrocarbons, has been under public and private debate since about 1961. Although the use of these materials has made a tremendous contribution to the welfare of man, there have been some instances where the products have been misused. It has not been until quite recently that widespread public concern has resulted in the banning of the use of pesticides of various sorts because of their proclaimed adverse effects on the environment. There are reasonable doubts raised as to the pesticides widespread adverse effects. Some of the evidence used to indict pesticides, especially DDT, is suspect in view of experimental evidence which is currently being developed and critical examination of the manner by which the indicting evidence was collected. In any regard, it does seem in peoples best interest to promote the judicious use of these materials.

SOURCE AND INTENSITY

Pesticide production in United States for 1969 was 1.133 billion[1/] pounds including all classes of pesticidal chemicals, which is about 50 to 75 percent of world production. Sales of these synthetic organic pesticides accounted for 928.66 million pounds in 1969, both foreign and domestic sales. The foreign sales accounted for greater than 44 percent of the materials sold. The United States usage was 526 million pounds in 1969, which included slightly over 7 million pounds of synthetic pesticides imported from other countries. The breakdown on all classes of pesticidal chemicals is about 16 percent as fungicides, 33 percent as herbicides, 51 percent as insecticides or fumigants, and rodenticides.

The principal concern over pesticides is related to the persistence of chlorinated hydrocarbons in the environment. Even though these materials are degraded in soil, they tend to degrade rather slowly and persist in soils for a period of a few months to several years. It is the ability to persist in a toxic form, either as the original chemical or as an equally toxic breakdown product, that creates concern about the effects of these materials in our environment. This seems to be rather ironic since the organo-phosphates which are more readily broken down in soils and are not considered persistent are by far the more toxic to animals and humans in their applied form.

The accumulation and persistence is viewed with alarm because of untold damage which might occur if these materials are allowed to accumulate in the environment. Several investigators have shown DDT residues, including its derivatives, in the fatty tissue of man and various organisms all over the world. There is a wide distribution of the chlorinated hydrocarbons in various organisms; the highest concentrations seem to be in carnivorous birds.

The relative importance of chlorinated hydrocarbons in worldwide crop production and estimated losses in the world due to insect damage on various crops are shown in Table 20. Pesticides are used throughout the world in varying amounts, and because of the persistence of some of these chemicals, even in places where pesticide applications are known not to have occured, residues in animal tissue are found. As a result there is a need to examine some of the effects on animals and plants which are considered nontarget organisms.

In Figure 3 there is shown the flow diagram for a regional system of pesticide movement in the environment. This is an important consideration since the concentration of any one particular segment of the environment may be low. These presumably insignificant amounts may accumulate into toxic levels in various organisms through magnification in the food chain, as pointed out by Woodwell.

The effects of these insecticides on the target organisms is the death of the organism. The effects on nontarget organisms are usually more subtle. There have been reported deaths of certain fish and birds with the entry of the so-called persistent pesticides into the environment. The California Department of Fish and Game has estimated the total number of fish and wildlife losses due to pesticide pollution are slightly less than 781 thousand known killed. This does not include those probably or possibly killed by the pesticides. This was for the period 1965 to 1969.

1/ Billion - American usage = thousand million

Table 20: World usage of insecticides for various crop groups and estimated losses due to insect damage. 1/

Crop Group	Insecticide usage 1966 tons x 10^3	Chloronated Hydrocarbons Percent in Total	Crop losses 1967 tons x 10^3
Cotton	60.4	38	1 098
Rice	12.0	59	107 324
All other cereals	7.6	85	37 991
Vegetables	6.8	46	20 865
Potatoes	2.8	61	14 825
Sugar beets	2.4	55	9 735
Sugar cane	2.1	74	199 330
Tobacco	2.0	67	443
Oil seeds	1.9	77	9 345

MEASUREMENT AND CONTROL

There are various current investigations to indicate organic matter content influences markedly the breakdown of chlorinated hydrocarbons in soils. Other studies on soil microorganisms, as affected by pesticides, have shown a variety of effects. Winely et al in a study of nitrite oxidation by nitrobacter agilis show that in a $NADH_2$-oxidase activity was totally inhibited in concentrations of 375 ppm DDT in cell free extracts. Another insecticide CIPC inhibited $NADH_2$-oxidase by 67 percent at 500 ppm. The concentration of these two materials is quite high and it is very unlikely that such concentrations will exist in the soil.

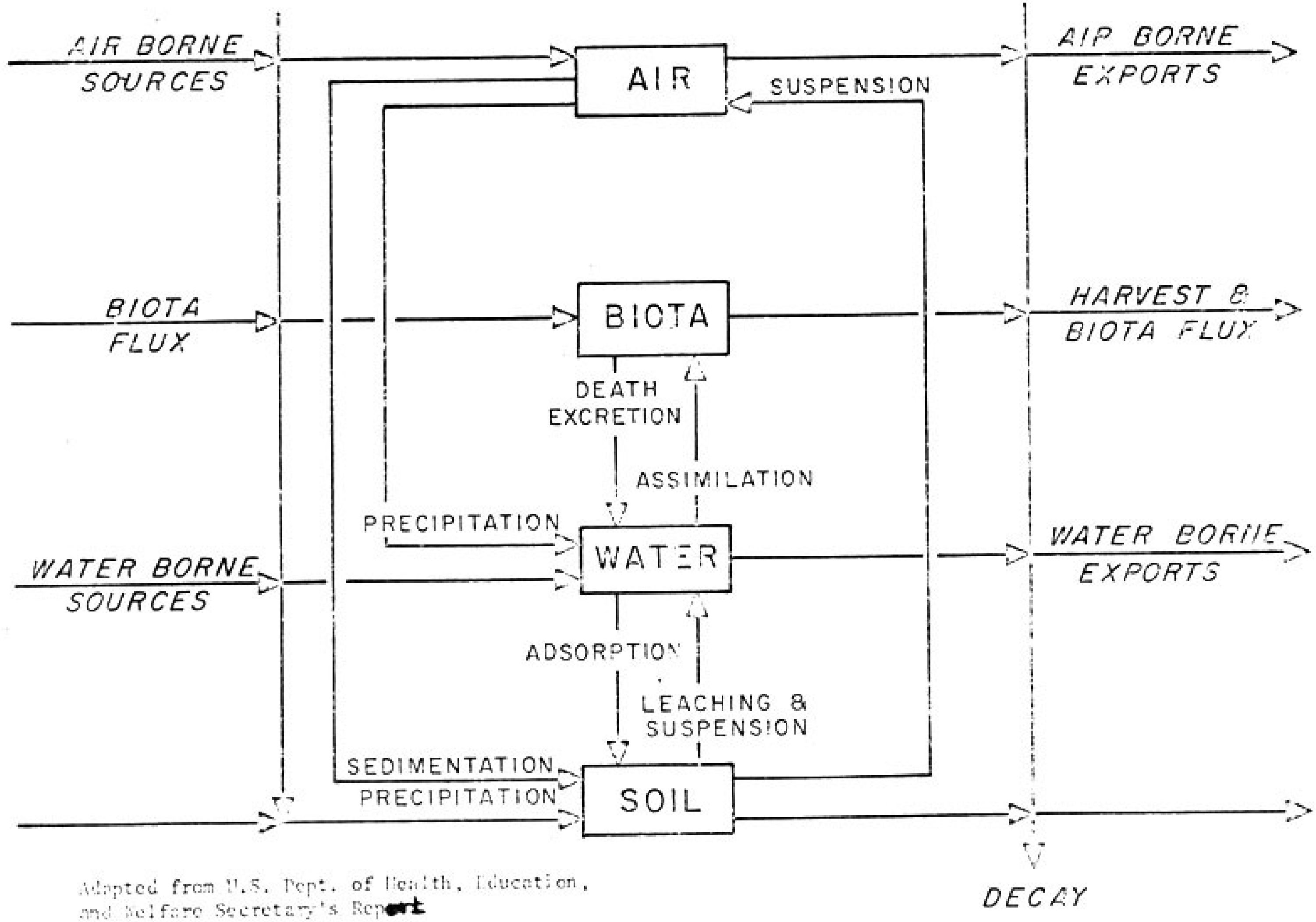
Changes in soil fauna population resulting in treatment with Aldrin and DDT were investigated by Edwards. Dosage rates applied to field plots varied from 4 to 60 kg of active material per hectare. They found that Aldrin did not affect predatory mites, nematodes, and earthworms, but killed other mites such as Collembola and root aphids to name a few. Also, DDT readily killed predatory mite increasing the numbers of Collembola which were relatively immune to the insecticide. Otherwise, DDT had less effect on most groups of soil animals than Aldrin. About 10 percent of the DDT applied disappeared annually. Aldrin dissipated faster, but about half of the amount that disappeared was converted to Dieldrin.

With regard to microbial activity in soils and their reactions to additions of pesticides to the soil and the unexplained microbial failure to metabolize or degrade, these added substances constitute according to Alexander, " the principle of microbial infallibility". According to his concepts, some microorganism exists in nature which can metabolize and destroy any organic compound. However, he points out that there are cases where certain organic compounds have not succumbed to biodegradation for millions of years. The recalcitrance of certain pesticides has been noted and unquestionably attributed to the appearance of these chemicals in unintended segments of our environment. Table 21 shows the persistence in years or months of several pesticides in soils. (Alexander).

There appears to be growing evidence, as already alluded to, that chlorinated hydrocarbon

1/ Adapted from U.S. Department of Health Education and Welfare Report to the Secretary, E.M. Mrak, Chairman, 1969.

Figure 3. Flow Diagram for a Regional System for Pesticide Movement in the Environment



Adapted from U.S. Dept. of Health, Education, and Welfare Secretary's Report
E. M. Mrak, Chairman.

persistence in soils may be dramatically influenced by the addition of organic matter to the soil.

Table 21: Selected data on the persistence of several pesticides in soils. 1/ 2/

Pesticide	Persistence
Insecticides:	
Toxaphene	6 years (?) 3/
Heptachlor	9 years (?)
Aldrin/dieldrin	9 years (?)
DDT	10 years (?)
HCH	11 years (?)
Chlordane	12 years (?)
Herbicides:	
2,4,5-T	6 months (?)
Diuron	16 months (?)
Simozine	17 months
Atrazine	17 months
2,3,6-TBA	18 months (?)
Fenac	18 months (?)
Tordon	19 months (?)
Monuron	36 months

Johnsen reported that sandy soils treated with cow manure and incubated for one and two months were essentially free of the parent compound DDT. After only one week, most of the DDT had been degraded by microorganisms in the enriched soil. In soils where manure had not been added, essentially 100 percent of the DDT was recovered in the same two-month period. Peterson et al, in studying the effects of various soil properties, concluded that the sorption of DDT by soil organic matter was the principal means of deactivation and that modest accumulation of DDT in soils high in organic matter may present little biological hazard. These men are not nearly so eager to conclude that the deactivation of DDT by soils high in organic matter is through the degradation of chlorinated hydrocarbon. However, they do seem to be in general agreement that the organic matter in the soil is the most important property governing the persistence of these compounds if persistence is based on the bioactivity of the compound rather than the presence of the compound.

The resistance of Diazinon in soils and its effect on soil microflora and uptake by plants was studied by Gunner et al. Diazinon is an organo-phosphate. They found that Diazinon applied at the three pounds per acre rate under nonsterile soil conditions persisted for as long as 180 days after application. Diazinon or its degradation products exerted a selective effect on soil microflora. After 180 days a large number of the genus streptomyces appeared as a climax population. Diazinon was adsorbed and rapidly translocated through the bean plant with no apparent adverse effect. They also indicated the biodegradation of Diazinon was conditioned by the presence of a readily decomposable carbon source.

Lange et al studied the effect of different cultural practices on phytotoxicity of herbicides and their persistence as evidenced by crop response. Phytotoxicity readings were taken on a variety of crops. Ratings are shown in Table 22 for various materials at different application rates and under different cultural conditions; ratings are averages of all crops for three replications. The post-emergence herbicides commonly applied to foliage and weeds showed essentially no residual effect on crops even at rates higher than potential load on soils resulting from 4 to 16 years of continuous application. The three herbicides are 2-4-D, Dowpon, and MSMA. Breakdown of herbicides was influenced by method of incorporation and amount of soil moisture, which are factors that can be altered by cultural practices.

1/ Adapted from Alexander.

2/ Results of various individual studies on different soils and different conditions.

3/ Pesticide still present at detectable levels at last sampling date; detection levels vary depending upon the pesticide.

Tables 23 and 24 show the effects of soil fumigation and applications of various chlorinated hydrocarbons to soils and their effects on soil microorganisms (Martin). The chlorinated hydrocarbons also have very low solubility in water and tend to be adsorbed on clay particles and organic matter. Accordingly, the substances are very resistant to downward leaching. Lindane has been shown to be one of the most readily leached pesticides; 54 to 88 percent of this chemical was removed from six different soils (USDA and Georgia Expt. Stn.) . Endrin was found to leach from three of the soils but did not leach in the other three soils. Dieldrin ranged from 1 to 65% of the material applied and leached from the six different soils. Aldrin was very resistant to leaching, only a trace was removed from five of the soils. In a two-year investigation evaluating the effect of DDT sprayed on the Yellow River drainage area at the rate of one pound per acre, recovery to normal total numbers of stream bottom invertebrates occured within a year in most streams, but species composition was altered. No mortality to fish was found although chemical analysis showed DDT in concentrations up to 0.03 ppm in several samples of the stream. In one case, a trace was found 55 miles downstream from the spray area. Vegetation samples contained up to 2.3 ppm of DDT, Concentrations as high as 14 ppm were found in fish samples taken from the stream. Two years after the initial spraying, DDT was still found in the stream (U.S. Department of Health, Education and Welfare, Mrak).

In general, each pesticide has a complex mode of action. In most cases the modes of actions of the pesticides against target organisms are only partially known. Even less is known about the actions in nontarget organisms. However, if the target patho-physiology of the chemical were known, its effect on nontarget organisms may be quite different due to the differences between species. For example, DDT, DDE, and DDD are thought to act on the nervous system of most insects. In some birds, DDD especially, influences their physiology of egg production (U.S., D.H.E.W., Mrak).

There are numerous other investigations of pesticide residues and the ecosystem. A great deal of information is available regarding the appearance of DDT and its breakdown products in several different kinds of animals, fish and birds as well as the larger game animals. Earthworms have been found to contain 4 to 194 ppm in varying body tissues. Dead and dying robins have had 50 to 70 ppm of residues in brain tissue. Irebes were found to contain as high as several hundred parts per million. Elk were found to have as much as 22ppm. This present knowledge demonstrates the existence of pesticide residues nearly everywhere, and the impact of these new components of the ecosystem has appeared as death, reproductive impairment, disruption of species, and balance and behavioural alteration, but the overall effects on the environment have not been determined and cannot be well foreseen. The development of effective short-lived pesticides which remain in the environment a matter of weeks or months rather than years is perhaps the solution to the magnification of pesticide effects on wildlife.

The effects of a coordinated hydrocarbon type of pesticide on humans has been more subtle, if indeed there has been any effect. In Table 25 are listed the acute LD_{50} values for rats of some widely used pesticides and other chemicals (Hayes). According to Burnside et al, in 1966, 1967, and 1968 the total DDT and metabolite intake for man in the United States was 0.0010, 0.0008, and 0.007mg per kg body weight, respectively. Assuming their figures are correct, and assuming DDT is all accumulated, they calculate the amount of DDT that would be ingested by a 154 pound man during a 70-year lifetime total was 1.25 grams of DDT. Further, they compared this amount with the fact that a single dose of five grams of DDT had been administered to humans in the successful treatment of barbituate poisoning.

No discussion of the effects of pesticides on the environment would be complete without some indication of the benefits which have been derived from the use of these materials. Burnside et al showed the influence of DDT on malaria cases in Ceylon. In 1950 there were more than two million cases of malaria; shortly after that the DDT mosquito control program was begun. In 1963 there were 17 cases of malaria reported. In 1965, DDT use stopped and there were 150 cases reported. The benefits derived from other insecticides and herbicides are not demonstrated so dramatically in terms of human suffering, although they have accounted for billions of dollars in savings from the standpoint of production and food cost.

One of the interesting aspects of pesticides in soils is the uptake by plants and entry into the animal diet from soils through plants. In this regard, the plant uptake and soil reactions are legitimate areas of investigation to understand where, how, and if controls must be applied. Clore et al investigated the residual effects of DDT, Chlordane, and Aldrin on various plants. Rates of application of materials varied from 15 pounds to 238 pounds for a one-time application at the initiation of the experiment. Yields of all plants except alfalfa were reduced. It should be pointed out the application rates were extremely high. The percent material remaining in the soil at the end

Table 22: A comparison of herbicide residue effects on crops under various cultural practices.[1]

Herbicide	Rate of Applic.	Sprinkler Irrigation Mechanical Incorporation			Sprinkler Irrigation No Incorporation			Furrow Irrigation Mechanical Incorporation		
	lbs/A	4[2]	8[3]	12[4]	4	8	12	Ratings[5] 4	8	12
Triflurilin	1	2.4	0.0	0.2	1.4	1.6	0.0	2.5	2.0	1.1
"	4	6.4	1.9	2.4	2.6	0.2	0.7	4.6	2.4	2.8
Nitralin	1	3.8	0.3	0.2	2.8	1.4	0.4	2.2	1.0	1.1
"	4	7.4	5.2	1.2	6.5	2.2	0.2	6.1	4.1	1.9
Prometryne	1	1.8	0.8	0.2	0.4	0.2	0.1	1.0	1.1	0.2
"	4	0.8	0.1	0.1	0.4	0.1	0.4	1.4	0.1	0.3
Diphenamid	4	1.5	1.5	0.0	1.2	0.4	1.0	1.9	0.3	0.5
"	16	0.7	0.8	0.1	2.3	0.1	0.1	2.0	1.2	0.6
Pyramin	4				4.5	1.5	1.0	5.7	4.4	1.5
"	16				8.2	3.5	0.3	8.1	7.2	2.5
DCPA	8	5.1	1.1	0.1	2.6	1.5	0.6	4.7	2.9	0.1
"	32	7.6	2.8	0.8	5.0	3.1	0.3	5.7	3.0	1.6
2,4-D	16				0.9	0.0	0.2			
"	64				1.4	0.1	0.2			
Dalapon	16				1.1	0.3	0.1			
"	64				1.4	0.0	0.0			
MSMA	16				1.2	0.6	0.6			
MSMA	64				1.6	0.3	0.2			
MSMA	256				3.1	0.4	0.2			

Table 23: Influence of soil fumigation on numbers of bacteria in Hanford sandy loam [6]

Treatment	Bacteria x 10^6 per gram of soil following treatment:			
	1 day	10 days	50 days	250 days
None	48	22	16	15
D-D at 400 lbs/A	18	85	31	17
Chloropicrin at 200 lbs/A	4	71	38	29
Carbondisulfide at 600 lbs/A	23	73	27	24

Table 22:

1/ Adapted from Lange et al
2/ Crops: barley, milo, lettuce, sugar beets, broccoli and tomatoes.
3/ Crops: barley, milo, cotton, and tomatoes.
4/ Crops: barley, canary grass, safflower, sugar beets, lettuce and carrots.
5/ Ratings zero (0) = no effect on crop plant; 5 = one half a stand or stunted; 10 = all plants dead or missing.

Table 23:

6/ Taken from Martin.

Table 24: Influence of five annual applications of insecticides to Ramona sandy loam on soil microorganisms. 1/

Insecticide	Bacteria $\times 10^6$/gram	Fungi $\times 10^3$/gram	CO_2 evolution 2/ mg/100 grams of soil
None	53	238	271
Aldrin	53	239	284
Dieldrin	42	254	285
Chlordane	48	264	262
DDT	48	248	256

Table 25: Acute Oral LD_{50} Values (Rats) of Some Widely Used Chemicals in the United States 3/ 4/

Pesticide	Acute Oral LD_{50} for Rats	Human Deaths - 1961
Insecticides		
Parathion	4	18
Toxaphene	80	2
Carbaryl	500	0
DDT	118	0
Endrin	7	1
Herbicides		
2,4-D ester	700	1
Atrazine	3080	0
Trifluralin	5400	0
Propanil	2270	0
Amiben	3500	0
Other		
Aspirin	365	182
Amitrole	15000	0
Lead arsenite	10	29
Strychnine	1	1

Table 24:

1/ Taken from Martin, differencesare not statistically significant.

2/ Incubation period of one month.

Table 26:

3/ Adapted from Hayes.

4/ Pesticides are representative of those widely used in 1969.

of 10 years ranged from 10 to 33 percent depending upon the rate of material added. The lower rates tended to show only low percentages of material.

Using radioactive carbon labeled DDT, Ware et al found that cuttings of alfalfa removed periodically at 89, 158, 226, and 295 days after planting in soils with 4 ppm of ring labelled Carbon-14 DDT did not have counting rates significantly higher than background and counting error. Soybeans and cotton grown in Lakeland sandy loam and Hagerstown silty clay loam soils treated with 0.5 ppm DDT, Dieldrin, Endrin, and Heptaclore containing Carbon-14 were investigated by Nash et al. No DDT or Heptaclore was detected in any of the soybean or cotton samples by gas chromatographic determinations. Small amounts of unidentified Heptaclore and DDT metabolites were detected by liquid scintillation counting of the plant extracts of both species.

There are currently several methods of control under investigation. The principal method is that of biological control, either by the use of pesticides, predators, pathogens, sex lure traps, or the use of sterile males. Each of these has had limited success for occasional insects. However, there has not been widespread general usage of these techniques. Another biological control technique which may have possibility is the development of the strains or varieties of plants which are tolerant to the insect/pest. For some insects, which overwinter in crop residues, suitable cultural practices may be developed which can reduce the population and limit the infestation potential so that other biological methods of control may be more effective. Another alternative is the development of pesticides which are more specific for the target organism plus have the advantage of being rapidly biodegradable in the environment.

The necessity of weed control results from the persistence of weed seeds in soils, see table 26. Concerning herbicide replacement, there is already a reasonably effective method, albeit expensive with regard to the advantage of weed control with herbicides, and that is the use of mechanical means for destruction of weeds. Another technique which is available is the use of flame. Although not usually persistent, occasionally soil carryover of herbicides is a factor in the production of crops sensitive to specific herbicides following a crop on which the herbicide was used.

It is interesting to note in the literature of the early 60's there occurred an increase in the number of publications regarding pesticide reactions and movement in soils and how this persistence and movement influenced other segments of the environment. There has been a tremendous amount of information gained since that time. With an equal effort in attempting to develop materials, as there is in determining what happens to them, the development of pesticides which meet the criteria of being effective, specific, and decomposable in relatively short periods of time should not be far away. Perhaps one of the criteria in developing a pesticide would be to ascertain if there are microorganisms in the environment which can degrade the product before it is released for usage.

Table 26 : Survival of weed seed in soil[1]

Weed	Germination percent following burial in soil for:			
	40 years	50 years	60 years	70 years
Tumbling pigweed	66			
Rough pigweed	2			
Black mustard	18	8		
Lambsquarters	4			
Plantain	10			
Dock	18	52	4	8
Mullein		62	68	72

[1] Taken from Harvey.

C. FERTILIZERS

EXTENT

The principal concern over fertilizers has been the entry of nitrogen into our surface and ground water supplies and the concern over its possible adverse effects on human health. There are numerous investigations on the nitrogen in our environment because of its importance in all aspects of plants, animal, and human existence. Because of its transitory nature and necessity for all biological activity, it is only reasonable to assume that nitrogen plays a very vital role in controlling the activity of biological systems.

The importance of nitrogen to our existence and its transformations in our environment through various biological and chemical reactions are depicted very well in the nitrogen cycle as proposed by Delwiche.

SOURCE AND INTENSITY

In Table 2 are given the estimated gains and losses of nitrogen from the atmosphere due to the incorporation and loss of nitrogen from biological systems on or in land and the ocean. Juvenile additions of nitrogen to the atmosphere and sediment losses of nitrogen are offsetting gains and losses of approximately equal magnitude. These are incosequential fluctuations in relation to the total amount of nitrogen present in sediments and crust of the earth. The nitrogen in those sources are essentially unavailable for cycling and are estimated by Delwiche to be 1.8×10^{16} metric tons.

The figures which Delwiche has developed indicate the fraction of nitrogen which is cycling, in relation to the amount of nitrogen available, to be 3.2×10^{-8} of the total. Localized concentrations of nitrogen occur from runoff or percolation through the soil and entry in the water ways and have occurred long before man became interested in adding nitrogen fertilizers to the soil.
However, in order to manage resources to obtain their fullest benefit and yet prevent the localized contamination it is necessary to become familiar with the types of reactions which nitrogen undergoes in soils.

Table 27: Balance for Nitrogen Cycling1/.

Source		Amount (metric tons x 10^6)
Gains:		
Biological fixation;		
Terrestrial		30
Legumes		14
Marine		10
Industrial fixation		30
Atmospheric fixation		7.6
Juvenile addition		0.2
	Total gain	91.8
Losses:		
Denitrification;		
Terrestrial		43
Marine		40
Sediment		.2
	Total loss	83.2

1/ Adapted from Delwiche.

Native soil organic matter may contain from 4 to 8 percent nitrogen and if one assumes a mean value of six percent, then for every one percent organic matter in a foot of soil there is approximately 2400 pounds nitrogen. The organic nitrogen is only slowly available and does not provide the supply of nitrogen which is normally required for the rapid growth and development of plants. Consequently, there is a need for the addition of fertilizer nitrogen. It has long been known that applications of fertilizer and nitrogen are not totally recovered by the plant. The movement of N^{15} nitrogen applied in fertilizers through lysimeters in which plants were grown was studied by Willaford and Tucker. They were able to account for 61 to 80 percent of the applied fertilizer nitrogen in the form of plant residue from a barley and grain sorghum crop and from soil extracts and leachates. These figures agree with other investigations of nitrogen fertilizer recovery. This nitrogen was applied at one time at the beginning of the experiment. They concluded that the unaccounted portions of nitrogen would include those quantities lost by volatilization, denitrification, nitrogen in plant roots, adsorbed on the clay complex, nitrogen converted to organic form by a soil bacteria and remaining in solution in a soil column. More investigations of this sort are needed to determine what portion of the nitrogen applied is involved in each of the fractions of the soil nitrogen mentioned. It also seems of interest that approximately 85 to 90 percent of the soil nitrogen exists in the organic form (Delwiche; Stanford et al).

The use of nitrogen as fertilizer in relation to total requirement was depicted by Stanford et al. They showed that in 1930, 1947, and 1969 the use of fertilizer nitrogen amounted to 0.3, 0.7, and 6.8 millions of tons respectively in the United States. For those same years, harvested crops removed 4.6, 6.5, 9.5 millions of tons respectively of nitrogen. The additional nitrogen required for plant growth was supplied through nitrogen fixation and release from organic matter in soil. Also, in 1969 for the first time, the nitrogen gains were greater than the nitrogen losses if one assumes no loss due to denitrification of nitrates in the soil in the United States. If all the animal waste now produced in the United States were applied to the soil, this could account for approximately 10 million tons of nitrogen, although very slowly released. In studies by Reubens and Bear, they found that the rate of release of nitrogen from various animal and plant organic materials varied considerably. For cattle manure and chicken manure, the amount of nitrogen added which was converted to nitrate in 40 days was 7 and 30 percent, respectively. The slow rate of release coupled with the expense of animal manures in relation to inorganic nitrogen sources account for the principal reason why the use of animal manures is not more widespread, especially in countries with agriculture developed to the point where yields provide gross incomes adequate to allow for the production cost of nitrogen fertilizer. The merits of nitrogen fertilization hardly need to be defended.

Of all the essential plant nutrients, nitrogen is the element most universally limiting plant growth and development. To further point out the fact that nitrogen fertilizers are a necessary addition to our environment, Stout has calculated the farmsite nitrogen needed to support the food demands in the United States. He shows that amount of nitrogen to be 65.1 pounds per capita per year without any allowances for efficiency of nitrogen use or other losses. He finds that when the efficiency and losses are taken into account, the farmsite nitrogen needed to produce the vegetable protein fed to animals becomes 173 pounds of nitrogen per capita per year, or a total of slightly less than 18 million tons of elemental nitrogen per year for the United States. An additional 1.8 million tons of nitrogen would be required for plant protein, sugar, and fiber production. This is a total of slightly more than 19.5 million tons of nitrogen required per year. This figure is about 5 million tons greater than the figure cited by Stanford et al.

With nitrogen it is not the fact that it degrades the land, but rather that nitrogen in soils seems to be a sink from which nitrogen enters into our ground and surface waters, either indirectly through animal consumption and deposition, or directly through runoff and leaching. In order to ameliorate the problems associated with nitrogen in soils, it becomes necessary to evaluate some of the reactions and movement of nitrogen in soils with the goal in mind of being able to predict and prevent its unwanted entry into our water supplies.

MEASUREMENT AND CONTROL

There are five basic reactions which nitrogen undergoes in soils. It can: (1) be incorporated into organic matter through utilization by soil microorganisms: immobilization. It can be released from unusable organic forms into a usable inorganic form by soil microorganism: mineralization,

3) be transformed into inert gaseous forms by soil microorganism: denitrification, 4) be moved out of the root zone of plants by the downward movement of water: leached, or 5) can be utilized by crop: crop removal.

When crop or animal residues with relatively low nitrogen contents are incorporated into the soil the nitrogen needs of the organism for the decomposition of the residue are obtained from the soil. The effect of carbon-nitrogen ratio on nitrogen immobilization or mineralization has already been discussed.

Another soil reaction of considerable importance is denitrification. In a study by Meek et al, the effect of a relatively high water table on applied nitrogen was measured, Table 28. Nitrogen was applied at the rate of 280 kilograms per hectare; one-half in May and the remainder in June. The water table occurred between 107 and 152 centimeters. There was a sharp decrease in the nitrogen content of the soil solution between the 107 and 152 centimeter depth. The average nitrogen level over all locations in sampling times was 2.4 ppm above the water table and 0.6 ppm below the water table. There was also a corresponding shift in the reduction-oxidation (redox) potential from an average of 372 millivolts (mv) above the water table to 186 mv below the water table. Previous studies have indicated denitrification occurs at redox potentials below 300 mv.

Connell and Patrick found that denitrification can occur at a very rapid rate. Partial results of their study are shown in Figure 4. Within four days approximately 380 ppm nitrogen was transformed from nitrate to the gaseous form and volatilized from the soil.

TABLE 28: The Effect of Depth and Location on Nitrate Nitrogen Concentration of the Soil Solution During June, July, and August.1/

Sample Depth	Location 3E	3	4A	5A
cm	ppm NO_3-N			
15	1.8	2.7	3.8	1.4
31	1.8	2.8	3.8	1.2
46	1.2	3.0	2.1	1.1
76	2.2	3.2	2.2	1.2
107	2.4	—	4.3	2.4
152	0.6	0.9	0.7	0.5
244	0.4	1.0	1.1	0.5
305	1.6	0.3	0.2	0.7

There are three conditions that must be met simultaneously before denitrification can occur: first, the microorganism must be present; second, there must be an energy source, usually in the form of an organic carbon source; and third, an anaerobic condition must exist in the soil.

Leaching into the groundwaters or drainage water and subsequent entry into our surface waters is another possible way of nitrogen promoting eutrophication. An investigation of nitrogen distribution in soil profile under various cropping systems was conducted by Stout and Burau. Soil samples were taken at various depths and analyzed for nitrate content. The nitrate nitrogen values shown in Table 29 are data adapted from their study. Missing values in the table result from not having a sample at corresponding depths for all locations. The nitrogen content of the soil deep in the profile is less under irrigated strawberries, which are usually heavily fertilized, than in the profile of the soil uncropped for five years. Interestingly enough, this same concern with nitrogen leaching out of the soil profile and entry into drainage waters was a matter of concern almost 100 years ago. In a report by Miller in 1906 on a study that had been initiated in 1877, he showed the

1/ Adapted from Meek et al.

Figure 4. **Denitrification as a function of time**

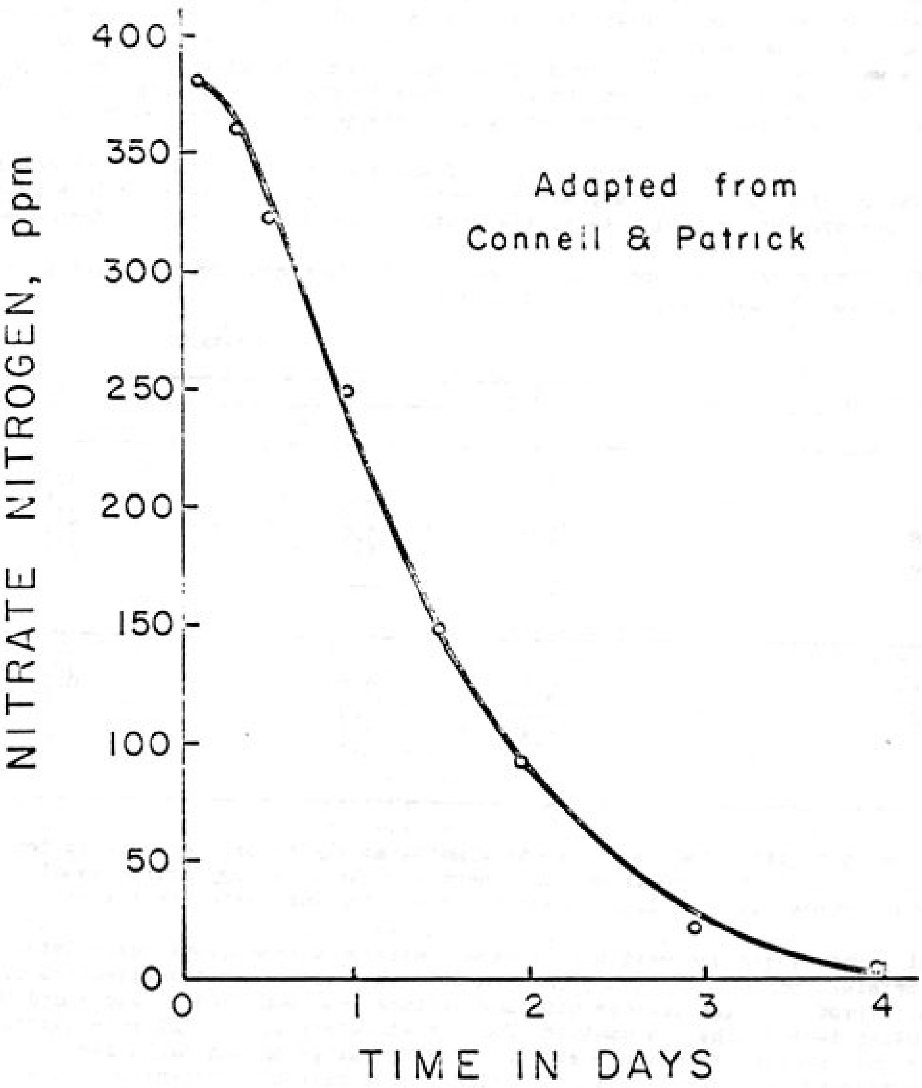


Table 29: A Profile of Nitrate Nitrogen in the Soil for Different Cropping Histories and Soil Textures.[1]

Sample Depth Feet	Irrigated Strawberries Soil Texture*[2]	Irrigated Strawberries NO_3-N ppm	Uncropped 5 years Soil Texture	Uncropped 5 years NO_3-N ppm	Irrigated Celery Soil Texture	Irrigated Celery NO_3-N ppm	Permanent Pasture Soil Texture	Permanent Pasture NO_3-N ppm
1			S	1.8	C	41	L	58
2			VFS	<1	C	31	L	2
3	S		VFS	<1	C	45	GL	<1
4	S	2.7	VFS	1.4	C	25	GSL	<1
6			FS	3.5			GSL	<1
8	S	3.6	FS	4.3				
10	S	2.0	FS	3.9	S	4		
12	S	2.0	FS		S	14		
14	S	2.0	S	4.3			GSL	<1
16	S	2.5	S	3.7				
18	S	1.4			SIC	16	GSCL	<1
20	S	<1	FS	7.9			GSCL	<1
22	S	1.4		11.8	C	16		
24	S	1.6	GS	4.8	C	15	GSL	<1

Table 30: Loss of nitrogen in the soils of the three gauges during a 35 years period.[3]

Depth of soil	Nitrogen: In soil and rain per acre — In soil 1870	In rain 35 yrs.	Total	In drainage per acre — 1870-1877 Est.	1877-1905 Deter.	Total	Remaining in soil 1905	Loss from soil	
Inches	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	lbs.	%
20 inches	6027	175	6202	231	926	1157	5045	982	16.3
40	10434	175	10609	204	816	1020	9589	845	8.1
60	14043	175	14218	223	892	1115	13103	940	6.7

Table 29

1/ Adapted from Stout and Burau

2/ Soil texture symbols are as follows:

S = sand	L = loam
FS = fine sand	GL = gravelly loam
GS = gravelly sand	GSCL = gravelly sandy clay loam
GSL = gravelly sandy loam	C = clay
FVS = very fine sand	SIC = silty clay

Table 30

3/ Taken from Miller

yearly measurement of nitrogen loss in pounds per acre for the 28 year period. Nitrogen losses varied from 15 to 60 pounds per acre as determined in the soil leachate. The large amount of variation in the amounts of nitrogen leached for any given year was related by Miller to the differences in rainfall. Table 30 shows the 35 year losses of nitrogen at various depths of soil. The real point to be made here is that the amount of nitrogen lost from leaching was from an unmanured and uncropped land.

The effect of nitrogen fertilization on nitrogen content of irrigation and drainage waters of the upper Rio Grande River was studied by Bower and Wilcox. Some of their data are reported in Table 31. Essentially, it shows no increase in the nitrate-nitrogen content of either the irrigation water or drainage water over the 30-year period the measurements were made. During the same 30 year period there was a 35 to 100-fold increase in the amount of nitrogen fertilizers applied to the irrigated areas under investigation.

In a lysimeter experiment conducted to determine the fate of nitrogen applied to soils several months prior to cropping, the fate of ammonium nitrogen labeles with N^{15} was followed over a 2-year period (Owens). About 65 percent of the nitrogen was accounted for at the termination of the study and the leaching losses were directly proportional to the amount of water moving through the profile.

The composition of the leachate from undisturbed lysimeters cropped with white clover and meadow fescue was investigated by Low and Armitage. No nitrogen fertilizers were applied and only initial dressings of phosphorus and potassium were applied. They discovered the grass received more nitrogen from the rain than it lost by leaching, whereas clover lost more than it received. Over 90 percent of the nitrogen leached through the soil profile was in the nitrate-nitrogen form. The amount of nitrogen leaching from the clover and grass covered lysimeters was 2.7 and 2.3 pounds, respectively. The rates of leaching of potassium and phosphorus from the grass and clover covered lysimeters were very similar, amounting to approximately 1.7 pounds and 0.8 pounds per acre per year, respectively.

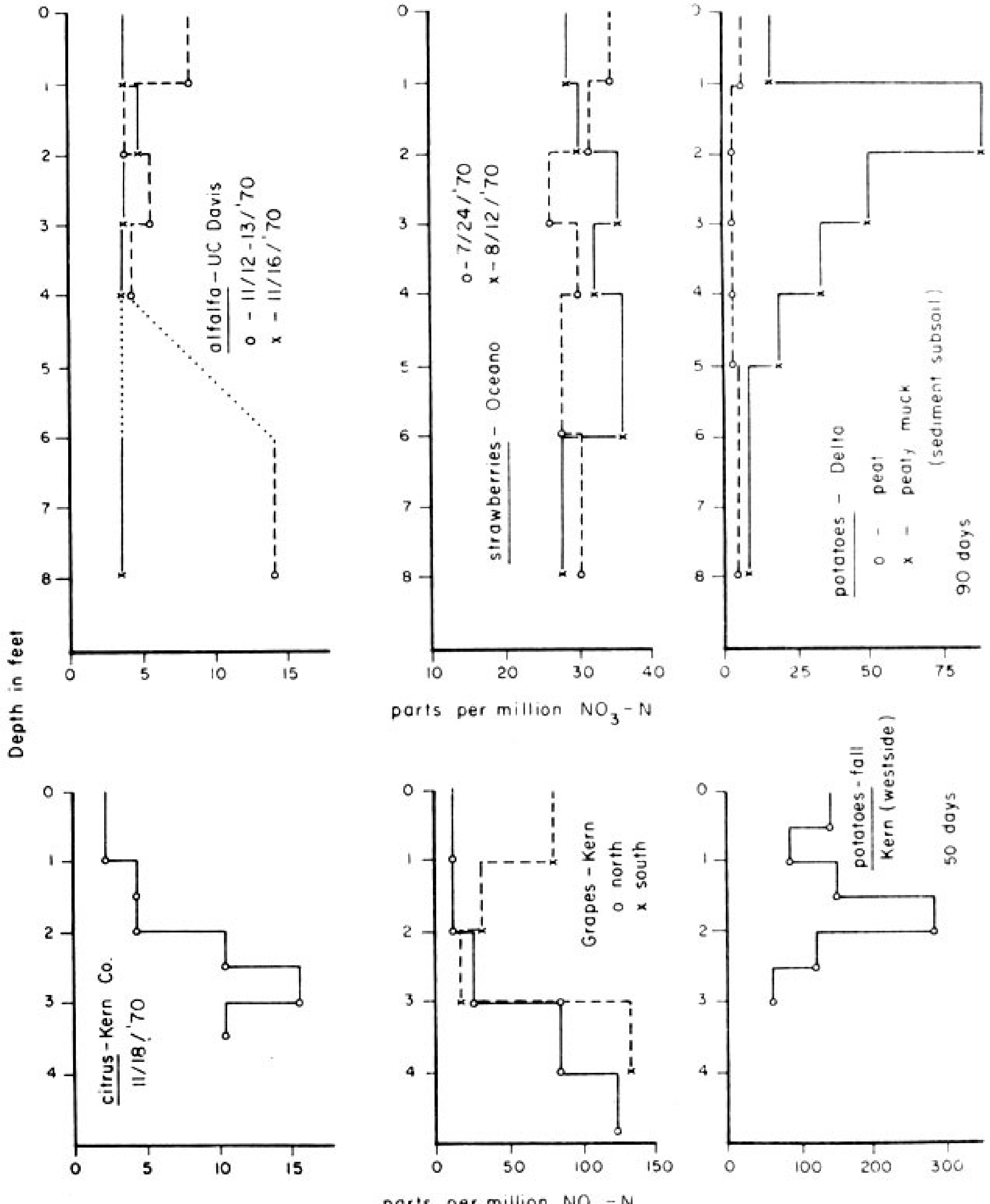
The concept of solute movement through the soil profile being dependent upon the amount and distribution of applied water, either through irrigation or rainfall, was the subject of investigation by Nielsen et al. Their studies revealed that chloride movement through the soil profile may be altered or controlled with the method of water application. They proposed a model for predicting the redistribution, drainage, or evaporation of water under natural field conditions which could be of value in predicting the redistribution of anions known to move with the water in the soil.

Ayers and Krauter investigated the use of soil suction probes (ceramic cups similar to those used for tensiometer measurements) placed at different depths in the soil, and followed by the soil solution being extracted under vacuum and analyzed for various solutes contained in the soil solution. Soil profiles were sampled under a variety of crops in an attempt to determine if this technique was suitable for studying leaching losses related to fertilizer rates and water management. Figure 5 shows the results of their preliminary investigation. Ayers has also developed a table showing the concentration of nitrate-nitrogen in drainage water when the soil profile is leached with different increments of water, Table 32.

The key to preventing pollution from nitrate-nitrogen is to retain the nitrogen in the root zone so plants can use it before it has an opportunity to become a pollutant. As shown in Table 33, plants can use large quantities of nitrogen, thus preventing nitrogen from becoming a hazard.

There is an additional concern about excessive nitrate-nitrogen present in soils, and that is the concern of accumulation of nitrates in grass or leguminous hay consumed by animals or humans. As pointed out by Summer et al, the literature regarding nitrate toxicity of forage is far from conclusive with regard to what levels are safe or toxic. Economic losses have been reported above 0.3 percent nitrate; however in other cases 2.0 or 2.5 percent nitrate resulted in no more mortality in livestock, loss of milk production or increased abortion rates. The critical nitrate level for plants to grow and develop deficiency varies with plant species. In most cases, if not all, it is lower than would be considered toxic concentrations in the forage for livestock. The problem with nitrates in forage is there must be adequate nitrogen for maximum growth and production but not excessive amounts.

Figure 5. Soil Suction Probe : Nitrate Profiles



1. Taken from Ayers and Krauter

Table 31: Nitrate nitrogen concentrations of irrigation and drainage waters for three irrigated areas of the upper Rio Grande.[1/]

Irrigated Area	Period	Average NO_3^-N Irrigation Water	Average NO_3^-N Drainage Water
		- - - ppm - - -	- - -ppm - - -
Rincon Valley	1934-43	0.15	2.31
	1944-54	0.11	2.84
	1954-63	0.12	1.61
Mesilla Valley	1934-43	0.29	0.17
	1944-53	0.30	0.09
	1954-63	0.24	Trace
El Paso Valley	1934-43	0.24	0.44
	1944-53	0.20	0.40
	1954-63	0.12	1.03

The appearance of nitrate in well water supplies tends to be associated with arid or semi-arid areas. In California, there are several areas where nitrate levels in drinking water supplies exceed the U.S. Public Health Service limit of 45 parts per million, yet there has been no report of infant deaths resulting from methemoglobanemia in California according the State Department of Health. In a report by Wadleigh, he indicated from 1947 to 1950, 139 cases of infant methemoglobanemia were reported in Minnesota alone. Out of the number of cases reported, there were 14 deaths. The nitrate source was from private well water supplies. Adults drinking the same water were not affected. Wadleigh points out there were no reports of methemoglobanemia in infants fed water from public water supplies in the United States, although levels of nitrate in some of the water supplies may be in excess of the 45 parts per million allowable limit set by the United States Public Health Service.

While standards have been set for nitrate levels in drinking water supplies, no such standards exist for nitrate levels of plant tissue which are consumed by humans. For that matter, there have never been reports of nitrate poisoning associated with ingestion of such foods. It seems unlikely this represents a serious problem, however data should be obtained to support the supposition. Because certain plant parts eaten as vegetables may accumulate nitrate to very high levels, they may present potential sources of toxicity to humans. The toxicity which develops is not from nitrate itself but its reduction product, nitrite. There have also been some attempts to relate high nitrate levels in plant tissue to the production of nitrosoamine which has been characterized as a carcinogenic agent. While such a possibility does exist, the role of nitrate, if any, in inducing the formation of a carcinogenic agent has yet to be determined.

Nitrate accumulations in blades and petioles of spinach were investigated by Barker et al with different rates of nitrogen fertilization. They found that due to the rapid conversion of urea and ammonium nitrogen in soils, the nitrogen carrier had no significant effect on the nitrate nitrogen concentration in spinach leaves. Generally, broadcast nitrogen resulted in relatively higher concentration of nitrate in the leaves than when the nitrogen was side dressed (applied in a band). They concluded that in order to minimize nitrate accumulations in spinach, nitrogen fertilizers should be applied periodically as required by the crop rather than a single application.

In another investigation along the same line with table beets, Peck et al found the same general types of results were obtained. Both studies found that late application of fertilizer resulted in very high accumulations of nitrate in the tissue. These studies and others show that the same timing of fertilizer applications that are necessary to improve production and create more efficent utilization of soil nitrogen also prevent its leaching into ground water or drainage into surface water supplies thus preventing unnecessary and unwanted nitrate accumulations in plant tissue.

Table 31:

1/ Adapted from Bower and Wilcox (1)

Table 32: Theoretical average nitrate nitrogen concentrations in drainage waters 1/

N available vs. drainage below root zone.

Inches Drainage Water	Pounds N available for leaching 2/					
	10	20	40	60	80	100
2	98	196	392	588	784	980
4	49	98	196	294	392	490
6	33	65	131	196	261	327
8	24	49	98	147	196	245
10	20	39	78	118	157	196
12	16	33	65	98	131	163
14	14	28	56	84	112	140
16	12	24	49	74	98	122
18	10.8	22	44	65	87	109
20	9.8	20	39	59	78	98
22	8.9	18	36	53	71	89
24	8.2	16	33	49	65	82
26	7.5	15	30	45	60	75
28	7.0	14	28	42	56	70
30	6.5	13	26	39	52	65
32	6.1	12	24	37	49	61
34	5.8	11.5	23	35	46	58
36	5.4	10.9	22	33	44	54
38	5.2	10.3	21	31	41	52
40	4.9	9.8	20	29	39	49
42	4.7	9.3	19	28	37	47
44	4.5	8.9	18	27	36	45
46	4.3	8.5	17	26	34	43
48	4.1	8.2	16	24	33	41

Table 33: Crop Utilization of Nitrogen 3/

CROP	YIELD	N CONTENT
Corn	6000 lbs.	160
Cotton	750 lbs.	105
Sugar Beets	20 tons	150
Wheat	2400 lbs.	70
Alfalfa	4.5 tons	170
Red Clover	2.0 tons	80
Potatoes	500 bu.	225
Tomatoes	20 tons	200
Apples	500 bu.	45
Peaches	600 bu.	95

Table 32: 1/. Adapted from R.S. Ayers (University of California-Davis unpublished, 1971)

2/. Calculated from formula: $C = \frac{19.6\ N}{D_W}$

C = Nitrate concentration in parts per million in drainage water.

19.6 = Constant from conversion N to NO_3 and inches of drainage water to pounds per acre inches of D_w.

N = Nitrogen available for leaching in pounds per acre.

D_w = Inches of applied water plus rainfall draining below recovery by roots.

Table 33: 3/ Adapted from American Potash Institute Plant-Food Utilization Chart.

V. AGRICULTURAL AND INDUSTRIAL CHEMICALS

D. HEAVY METALS

EXTENT

A considerable degree of worldwide concern has been developing regarding the effects of heavy metals on the environment. The concern comes from the fact that the magnification of very small amounts of other compounds has resulted in adverse effects on biosystems. The distribution of lead in the environment has resulted, in part, from its use as an anti-knock ingredient in gasoline. Other heavy metals are being used in the control of pathogens or pests and have accumulated to the degree that there is the possibility of being toxic. Another factor intimately involved with the current concern over the appearance of heavy metals in toxic amounts in the environment has been the development of analytical procedures which allow scientists to determine the presence of the materials in extremely small concentration. Not too many years ago it was difficult to determine concentrations of compounds or elements in the parts per million range. Now it is commonplace to see data reported for compounds and elements in the parts per billion range. The sophistication of analytical equipment has allowed detection of elements in our environment in minute concentrations. Nevertheless, magnification or accumulation may result in an undesirable effect.

SOURCE AN INTENSITY

There are four heavy metals with known toxicities to humans that are currently of concern. Practically any element when present in sufficiently large concentrations in the soils will become toxic. Only those elements normally present in plants and animals in extremely low concentrations which have been shown to have no known beneficial effect will be considered. The four principal metals of concern at the present are lead, mercury, cadmium, and arsenic. This automatically precludes such elements as zinc, which has been demonstrated to be an essential element, although it is well known that this element in high concentrations can become toxic. In normal diets the concentration of these sorts of elements would not become toxic. The principal concern will be with those elements which may be introduced into plants from soils or air and consequently enter into the diet. They have been demonstrated to have no essentiality and therefore may constitute a present danger.

The principal concern with lead is the long term exposure to low levels. Airborne lead occurs in association with particulate matter, flyash or as an aerosol itself. The combustion of fossil fuels in industry, emissions from motor vehicular combustion of gasoline, and smelters are the sources of lead. Industrialized countries use large tonnages of lead annually. In recent years, the United States alone has consumed an average of 1.1 million tons per year. Ault et al showed that lead in flyash from burning from coal was present in the same isotopic ratios as it was in the coal from which it came. The ratio of radiogenetic lead-206 to lead-204, which is not known to have been formed from any radioactive decayed process, constitutes a measure of the source of lead. Investigating the isotopic lead ratios from tree rings showed that as they sampled the more and more recent rings the ratio of lead-206 to lead-204 increased, indicating the lead in the more recent tree rings came from a different source of lead than that available to the plant in the early stages of development for growth. In soil studies the lead-206 to 204 ratio was different at the surface of the soil than it was in the 10 to 30" depth in the soil, once again indicating that the source of lead at the surface is of a different origin than the lead present in the remainder of the soil profile.

According to Page and Ganje, the lead consumed in the Los Angeles Basin amounted to approximately 2300 metric tons per year for an average value for 27 year period from 1940 to 1967, and all of this lead was assumed to have come from the use of leaded gasoline. In Table 34, taken from Page and Ganje, one can also see that the lead has a tendency to remain in the surface 2 to 3 centimeters of soil; and while it is not evident that as traffic density increases the lead concentration increases proportionately, it is apparent that as the traffic density reaches a certain level there is a greater tendency for lead to accumulate in the surface. Those areas where vehicle density is greater than 100 per square mile showed two to threefold increases in lead increase in the surface inch. They pointed out these amounts were considerably below levels which may cause toxicities to economic plants or cause abnormally excessive accumulations of lead in plants. In 1964, 100 thousand tons of lead were discharged in the United States atmosphere through the use of gasoline or motor vehicles.

Lazarus et al points out that, in addition to dry fallout, lead may become a contaminate of soils by entrapment in precipitation. In the course of their investigation they found that there was on the average during the 6 months sampling period of the last half of 1966, twice as much lead in the atmospheric precipitation as there was in the water supply. The values being 0.034 ppm and 0.017 ppm respectively. In either case these values were below the United States Public Health Service limit set for water, which is 0.05 ppm. The investigators concluded the difference in concentration between the precipitation and water supplies implied the existence of a process whereby lead was depleted after precipitation reaches the surface. Other investigators have shown that there was a tendency for lead to occur in suspended matter rather than in solution. One of the possible reasons for the discrepancy which occurred between precipitation and surface water concentrations is that sulfur dioxide may react with lead oxides in the atmosphere and maintain the lead as a relatively soluble sulfate, while in surface water oxides and the other unsoluble salts form and precipitate.

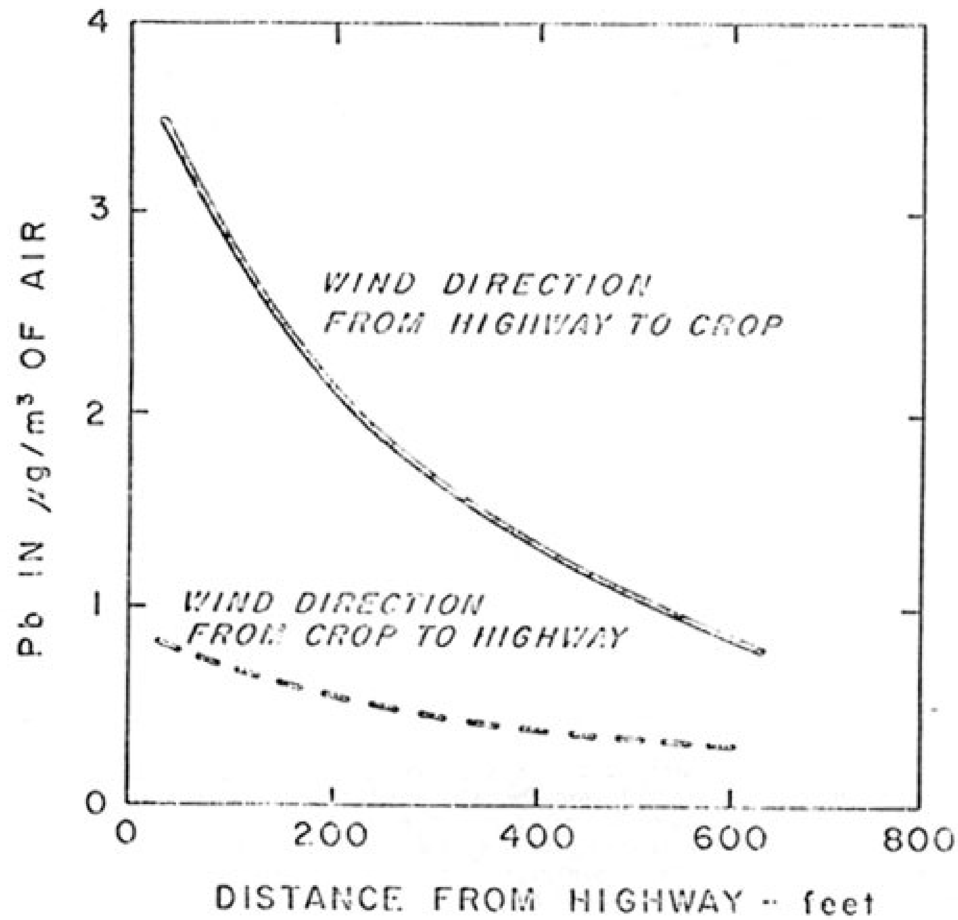
Table 34: Accumulations of lead in soils related to year sampled, depth and vehicle traffic intensity.1/

Location	Calculated density of motor vehicles per square mile 2/	Pre-1933 3/ 0-2.5cm of soil	1967 soil depths 0-2.5	2.5-15	15-30	30-45
			- - - Pb in parts per million 4/ - -			
La verne	735	17	52	19	12	16
Puente	1525	16	52	15	13	16
Whittier	2475	16	39	20	15	15
La Habra	1475	17	50	19	16	15
Tustin	1370	16	31	15	14	16
Riverside	580	17	38	18	16	20
San Bernardino	630	12	24	11	13	16
Hemet	25	19	21	15	13	15
Santa Paula	80	21	23	15	13	20
Meloland	50	26	25	18	14	15

Lagerwerff and Specht found that soil contamination of lead occured principally through the dry or wet precipitation form of aerosol lead. They also showed that lead concentration varied with distance from the vehicular traffic. Traffic related lead has been found as far as 250 meters from the roadside. They further found that concentration decreased with distance from traffic and decreased with depth from the highest concentration occuring at the 0 to 5cm depth, 8 meters from traffic for lead as well as other metals they had been sampling: cadmium, zinc, and nickel.

1/ Adapted from Page and Ganje.
2/ Based on 1967 population within a 10-mile radius of the sample and the average number of persons per motor vehicle in southern California.
3/ Sampling dates varied from 1919 to 1933 at different locations.
4/ Oven dry weight basis, 40° C. for 48 hours.

Figure 6. Changes in ambient air lead concentrations in relation to wind direction 1/



1/ Taken from Schuck and Locke

According to Klein and Goldberg the 1966 world production of mercury was estimated at 9200 metric tons, approximately one half of this is released into the environment. Presumably the way in which this is released into the environment is in the form of aerosol from various industrial sources and sediments. The source of mercury in sediments, in addition to what would be there in the natural state, would be principally from agricultural lands from the use of fungicides and bacteriocides. In the United States in 1969, slightly over 6 million pounds were used, both industrial and agricultural. Agricultural pesticides accounted for slightly more than 200 thousand pounds of Mercury. Other bacteriocide uses in paints and paper and pulp mills accounted for slightly greater than 780 thousand pounds of mercury in 1969. Total pesticide, bacteriocide, fungicide usage counted for just slightly greater than 16% of the total usage of mercury in the United States. Over the past 23 years this percentage of the total usage has varied from 13 to 21% in the United States. Kline and Goldberg found that in sediments the mercury content varied from approximately 80 to 90 ppb which was a normal concentration for saltic and granitic rock. Mercury concentrations in ocean bottom sediments collected near La Jolla and Palos Verdes, California, varied from 0.02 to 1ppm.

Cadmium has also been found in the environment and as a result of human activities. Cadmium concentrations in lubricating oil for automobiles vary from 0.20 to 0.26 ppm and varied in tires samples from 20 to 90 ppm (Lagerwerff and Specht). They were unable to detect cadmium in gasoline sampled from 12 different sources. In evaluating contamination of roadside soil with various heavy metals they found that cadmium, like lead, occurred at highest concentration at the 0 to 5 cm depth, 8 meters from traffic. Concentrations ranged for different locations from 0.90 to 1.82 ppm. In the same study they found that nickel was distributed the same as lead and cadmium, and the concentrations from nickel ranged from 4.7 to 7.4 depending on location.

MEASUREMENT AND CONTROL

In a study of the effects of lead levels in rabbits and guinea pigs, Smith et al found that there was an increase in the lead content in tissue and bone in animals which had been exposed to approximately 2.5 micrograms of lead per cubic meter of air for a period of nearly 4 years. The value of 2.5 micrograms per cubic meter was based upon the average air lead analysis for a 6 year period determined in a study conducted by the University of Michigan. The tissue and bones from animals subjected to the ambiant air, concentration of lead was compared with control animals which breathed only filtered air. The source of food and water was the same for both groups of animals. The total absorbed dose of lead for rabbits and guinea pigs was 73 and 83% respectively from food, 23 and 13% respectively from air and 4% for both animals from water. Tissue and bone analysis for both species, comparing the exposed animals with the control, show that the spleen and bone are the sites of highest concentration in these animals, and that the concentrations are 4 to 10 times greater than that found in other tissues of these animals. The concentrations varied from 0.11 to 3.2 ppm on a wet weight basis. Averaged lead content in bone ash varied from 5 to 110 ppm lead. Both the rabbits and guinea pigs showed increases of lead in the tissue and bone when exposed to a 2.5 micrograms of lead per cubic meter in the air. Studies of the health effects of lead on these animals failed to disclose differences between the control and exposed group. The only significant difference occurred in the case of the bone levels. The conclusion was that the lead intake via ingestion was much less efficiently absorbed than the inhaled lead, and the inhaled lead accounted for the reported difference in bone lead levels.

The importance of airborne particulate air in the contamination of plants and soils was investigated by Schuck and Locke; Figure 6 shows a distribution of lead in the air with distance from the highway. These curves are stylized curves summarizing a number of individual analyses at different periods during the day and on different days. Their combined findings from investigations of 5 different crops, cauliflower, tomatoes, cabbage, strawberries and valencia oranges, strongly suggest that the edible portions of the plant do not absorb automotive lead particulates. They exist rather as a topical dust coating of which at least 50% could be removed by simple washing with water. Their data agrees with other investigators showing the lead concentration was greater in soils at the surface than in the soil profile. They were not able to demonstrate any absorption of lead by these crops through the root system of the plants.

Mercury content in soils was the subject of investigation by Aomine et al. They showed concentration of 2.2 ppm mercury in paddy and orchard soils. The high concentration of 2.2 ppm was obtained in a soil sample taken close to a tree where the soil had been disinfected by a mercurial fungicide. The concentrations of mercury had a tendency to be near the surface on the finer textured soils. In soils having 50% sand or more, the mercury seemed to be more uniformly distributed throughout the soil profile. Depths of sampling range from 40 to 70cm in the sandier soil. It was believed that the reduction to mercury sulfide type of clay mineral and amount in organic matter content were the major soil variables influencing leachability of mercury and availability for plant absorption. In a subsequent investigation Aomine and Inoue in adsorption studies, using montmorillonite, alophane and kaolinite, found that montmorillonite had a very much greater adsorptive capacity for phenol mercury acetate than did either alophane or kaolinite. They concluded that of the two soil colloids, clay minerals and organic matter, the former is far more important for mercury retention in soils. Phenol mercuric acetate adsorbed on montmorillonite was only slightly removable by leaching with water. Allophane adsorbed less phenol mercuric acetate, and that which was adsorbed was more easily removed by leaching. Kaolinite absorbed very little.

Cadmium in soil may vary from .01 to 7 ppm and in plants the range is normally 0.2 to 0.8. Concentrations larger than this may be toxic in man. An average concentration for cadmium is .04 ppm. It has a tendency to accumulate in the kidneys. Although most food plants usually contain less than 0.5 cadmium, they may accumulate up to 3 ppm. before severe plant growth depression occurs, (Allaway). The levels in human diet which are required to produce detrimental effects are not known at the present time.

According to Allaway, arsenic concentrations in soils range from 0.1 to 40 ppm. and in plants from 0.1 to 5 ppm. The lowest oxidation state of arsenic ($As+3$) is the more toxic of the two oxidation states in which arsenic most commonly exists. In man the blood content of arsenic is normally 0.49 ppm.

In a study by Benson, showing the effect of residual arsenic from insecticide sprays on the survival of apple trees, it was found that at 100 ppm residual arsenic in the soil tree growth ceases. Benson found that field soils have high arsenic contents at the surface, which decreases with depth. On some fields, which have been subjected to continual applications of arsenic-containing insecticides, elevated levels were frequently found below 3 feet. Arsenic is believed to undergo reactions in soils similar to those undergone by phosphorus.

Johnson and Hiltbold found that about 90% of the soil arsenic content was associated with the clay fraction, much of which could be extracted by ammonium chloride which removes little if any phosphorus. Also, while most of the soil phosphorus was associated with iron minerals and organic matter, the arsenic was associated with the aluminum oxides in the soil. They found that arsenic contents of the crops differed with the plant species rates of application and source of arsenic in different materials. Cotton and soybeans were among the highest concentrations of arsenic while Crimson clover, oats and vetch have the lowest concentrations of those crops tested. Intermediate was sorghum and corn. Concentrations ranged from approximately 5 ppm. to 1.5 ppm. arsenic. Organic forms of arsenic were not found to be an appreciable part of the total soil arsenic. The arsenic was applied in the form of metharsenate, which is used commonly as herbicides. In the untreated plots the arsenic content at 0 to 30 inches varied with soil increments from 9 to 3 ppm. In the treated soil, with the same depth of sampling, the concentrations range from approximately 7 to 28 ppm. Yields of all the crops investigated were not affected by the arsenic treatments.

It does seem fortunate, as Alloway pointed out, that the plant subjected to excesses of these heavy metals either are stunted or cease to grow. Thus there is a built-in mechanism which helps to prevent plants from becoming a source of these toxic elements. However, in light of the new technology scientists are coming to understand that chronic exposure to low levels of these materials may be as detrimental to health as a one-time exposure to a toxic concentration. Investigations into the uptake and translocation of these materials and long-term use dietary levels are necessary in order to evaluate the environmental impact of accumations in the soil of these materials.

VI. INDUSTRIAL WASTES

EXTENT

Aside from the organic wastes, which may be distributed in the environment through the activities of industry, there are other by-products which hold some significance in relation to land degradation. Rosenfeld and Beath point out that increasing use of selenium in manufacturing processes presents an important industrial health hazard.

Another effluent of industrial activity is sulfur dioxide. Sulfur compounds in the atmosphere come from both the natural environment and air pollution emissions. The lifetime of hydrogen sulfide in the atmosphere ranges from about two hours in urban areas to about two days in remote unpolluted areas. Sulfur dioxide transformation to the sulfate ion occurs in a matter of days, perhaps about four (Robinson and Robbins). Other industrial stack effluents include fuorides and flyash. Minute traces of fluorides are found both in the air of rural communities and cities. Normal concentrations are usually less than 0.2 micrograms fluoride per cubic meter of air. It was estimated by the Edison Electric Institute that approximately 30 million tons of flyash were generated in 1969. About 17.4 million tons of this was recovered for eventual by-product reuse.

Other possible industrial or mining wastes consist of waste water from iron, zinc, coal, copper and aluminium mines and smelters. It was found that about 5890 miles of streams and approximately 15 thousand acres of impoundments in 20 states of the United States were del teriously affected by acid mine wastes.

SOURCE AND INTENSITY

Selenium is used in the manufacture of pigments, rubber, and photoelectric cells. Selenium bearing dust, fumes, or liquids may present definite hazards depending upon the protective devices used to dissipate these noxious materials. This selenium is generally associated with the selenium contents in native sulfur. According to Anderson et al, selenium contents of native sulfur supplied in the Western Hemisphere range from less than one ppm to as high as 8350 ppm.

In addition to the selenium content in sulfur supplies, selenium is generally found well dispersed in the earth's crust; and occurs in amounts rarely above the concentration of 100 ppm. Plants may take up varying amounts of selenium from the soils in which they grow. Normally those plants which have a high sulfur requirement also store a relatively large quantity of selenium. It may be distributed throughout the profile, accumulated at some depth in the profile, or accumulated near the surface.

Sources of hemispheric sulfur dioxide pollutants are shown in Table 36 taken from Robinson and Robbins. According to Argenbright and Preble, approximately 2.2 million metric tons of sulfur per year are emitted in sulfur gases generated in the operation of copper, zinc and lead smelters in the Western United States, indicating that approximately 23 percent of this is recovered.

Industries which heat and/or acidulate large amounts of fluorine containing ores include those devoted to aluminium reduction, steel manufacture, superphosphate and phosphoric acid production, and ceramic manufacture, including brick and clay tile. They contribute varying amounts of fluoride to the atmosphere (Brewer, Hodge and Smith). Plants are usually considered to be more sensitive to atmospheric fluoride exposures than man or animals. Consequently, as Hodge and Smith point out, the air quality standard to protect the vegetation would be far lower than that required to protect man. With regard to man there is the well known benefit of fluoride treatment of water to help prevent tooth decay.

Flyash is generally associated with those industries burning large amounts of coal, although coal used for heating homes may also be a limited source.

About 97 percent of the acid mine waste pollution reported for streams and 93 per cent of that reported for impoundments resulted from coal mining operations (Anon). The iron industry judiciously reuses water from its settling ponds; however in some plants where a heavy medium of finely divided ferrosilicon is involved a slight solubility of iron in the water effluent may result,

Table 35 - Hemispheric SO_2 pollutant emissions

Source	Total SO_2	Northern Hemisphere	Southern Hemisphere
	tons x 10^6		
Coal[a]	102	98	4
Petroleum[a]			
Comb. and Refin.	28.5	27.1	1.4
Smelting[b]			
Copper	12.9	8.6	4.3
Lead	1.5	1.2	0.3
Zinc	1.3	1.2	0.1
Total	146	136	10

a. United Nations Statistical Papers — World Energy Supplies 1963-1966, Series J, No. 11, Tables 2 and 9.

b. U.S. Bureau of Mines, Mineral Trade Notes Vol. 64, Nos. 9 and 12 (1967)

MEASUREMENT AND CONTROL

The reactions which selenium undergo is dependent upon the chemistry of the soil. The tendency is for the selenium toxicity to be greater in alkaline soils of semiarid and arid regions. Where selenium toxicity may be a problem, the application of sulfates decrease the uptake of selenium by plants (Anderson et al). It should also be pointed out that selenium provides some beneficial effects with regard to animal health. For ruminants fed high carbohydrate diet which results in a vitamin E deficiency, small doses of selenium can alleviate the effects of the deficiency. The rapid reaction rate plus the ready absorption of SO_2 by vegetation contributes to a rapid decrease in the concentration outside emission source areas.[2] In ambient atmosphere, most of the sulfur is present as sulfate. Thus, if any large-scale environmental effects are the result of sulfur emissions, they will probably result from adverse effects of sulfate particulate material. The effects would have to be within the dispersal area of the source which, according to Robinson and Robbins, could not be any further away than the material could be dispersed in four days at a given wind velocity.

Soil conditions, such as high moisture, low transpiration rate and high nitrogen content, may produce a rapidly growing plant which will tend to increase injury to plants caused by a given concentration of sulfur dioxide (Benedict). Sulfate in soils is of little consequence since soils generally contain large amounts. Those soils which do not contain sulfate, the addition of sulfur would help alleviate the deficiency. It would be possible to create an acid soil from very large quantities of sulfate being added to soils, but this could be easily and economically corrected by the addition of limestone.

Soil studies of fluoride uptake indicated that fluoride tends to accumulate in the roots; however, some is translocated to the leaves. Airborne fluorides usually result in high foliage and low root accumulations, and the gradient is reversed for fluorides that enter the plant via the roots. This may be one technique for investigating the source of fluoride contamination (Daines, et al). Plants vary in their capacity to absorb fluoride. In a study where corn and tomatoes were fumigated together a composite analysis of foliage showed that corn absorbed approximately 75 ppm fluoride by weight, whereas tomato leaf accumulated nearly 200 ppm. The corn foliage exhibited pronounced injury while no injury developed on the tomato leaves (Daines et al). Fluorine does not act like chlorine in soils. The solubility of calcium fluoride is 16 ppm in water, but it is doubtful if its maximum concentration would exceed 8 ppm, which is the concentration of fluorine in a saturated solution. Florida and Tennesseee phosphate rock supplies contain three to four percent fluorine. About three-fourths of this remains in fertilizers made from these sources which do not require the furnace treatment to produce elemental phosphorus.

In most European countries, flyash utilization is greater than that in the United States. In England, about 40 percent and in France and Germany about 50 to 70 percent of flyash is salvaged and utilised. One of the principal utilizations of the material now is as "pozzolan" (a material that by itself has no cementing property but when added to cement mixtures enhances the properties of the final concrete mix through a chemical reaction with cement ingredients) and as a raw material for building blocks and other masonry.

Flyash is of little consequence with regard to affecting soils. As a matter of fact, in England, the Central Electricity Generating Board has done considerable reasearch on the use of flyash for land reclamation and as a soil amendment.

Clarified waters from the iron mining industry can generally be discharged into public waters without detrimental effect. An example of such water showed less than the U.S. Public Health Service water quality standards for all of the heavy metals and all other criteria except hardness (Anon).

Wastes discharges from a zinc mill showed a total dissolved solids of 243 ppm with most of the conductivity resulting from calcium and bicarbonate. Again, resulting in a hard water which is not too suitable for domestic purposes but is more than adequate for agricultural purposes.

VII. SOIL EROSION

EXTENT

One must view sedimentation either by water or air with mixed emotions. Had it not been for erosion and sedimentation, many of the great agricultural areas of the world would not exist. On the other hand, present day erosion has a tendency to adversely modify the land surface. Wadleigh has estimated that nearly 4 billion tons of sediment are eroded into United States waterways each year. He assumed that at least 75 percent of the material was derived from agricultural and forested lands. Further assuming that if you have an average analysis of 0.1 percent nitrogen, 0.15 P_2O_5, and 0.5 percent K_2O, this means more than 50 million tons of primary nutrients were lost from agricultural and forested land each year through sediment effects delivery. On the other hand, there are areas which depend upon sediment delivery for supplying the fertility for the land. Periodic inundation during the year allows these areas to be used for growing crops with little fertilization. Further, there are soils which have been previously unsuitable for growing crops,which through the continual flooding and deposition of sediments,have developed a very recent alluvial soil of sufficient depth to become suitable for growing a variety of crops, including tree crops.

In Armenia, the impact of erosion, particularly in the mountain regions, has been estimated to account for 40 to 80 percent of annual harvest losses as well as removing approximately 12 million metric tons of productive soil. More than 90 thousand hectares of virgin forest has been felled and recent aforestation schemes have only replaced approximately 3000 hectares (Anon). In the Rocky Mountain area of the United States, Dortignac and Love found that erosion on forest and rangeland varied with vegetative cover, soil origin, and quantity of exposed or bare soil. They pointed out that except in local severe erosion areas, water erosion tends to receive generally less attention from farmers than does wind erosion. In Eastern Canada, Ripley estimated that of the 42.7 million acres of farmland, 71 percent of the land is in production of crops which are considered as good for soil erosion control. Crops intermediate for erosion control occupied slightly over 12 percent of the total farmland ,for a total of 5.2 million acres.

In the Mississippi drainage basin, the average annual loss of sediment per square mile is estimated at 390 tons (Walker and Wadleigh). They point out that variation throughout the basin is tremendous ,varying from 9 tons to 10,000 tons per square mile per year. According to Cheremisinov, about 50 million hectares of land in the Soviet Union are subject to water erosion of varying degrees.

SOURCE AND INTENSITY

In the USA, 10 to 11 million hectares are moderately to strongly eroded. Recent surveys by Glymph and Storey in the intermountain area of the western part of the United States indicate that 66 to 90 percent of the sediment production of many of the streams comes from streambank and streambed erosion. Other investigators estimate the sources of erosion to be about 73 percent from sheet erosion, 10 percent from gulley erosion, and 17 percent from other sources such as roadbanks, streambank and floodplain scour (Gottschalk). The relative importance of different sources of sediment vary with watersheds. This is apparent when you compare the estimates by Gottschalk and the estimates by Anderson and Wallace which indicate that 24 percent of the sediment is derived from forest lands, 22 percent from agricultural lands, and 54 percent from the main channel banks.

In many countries this mismanagement of range and virgin lands by overgrazing and shifting cultivation creates a condition of susceptibility to both wind and water erosion. On ranges ,the lack of adequate rainfall is usually the reason for limited regrowth and predisposes an area to overgrazing. These same areas are usually where infrequent but high intensity rainfall increases the amount of soil eroded. Very often plant species unsuitable or undesirable for grazing become established. Because of the necessity of destroying the unwanted plant species and the infrequent rainfall the process of re-establishing the area for grazing requires considerable time, effort, and money. Where overgrazing is not controlled there is an economic loss due to lower carrying capabilities of the area and cost of handling more sediment in waterways, estuaries and reservoirs.

Areas of shifting cultivation occur from marginal dryland to high rainfall conditions. In any case the results are the same; the destruction of native vegetative ground cover, a short period of utilization for production, abandonment and creation of a susceptibility to erosion until revegetation occurs. The amount of soil loss and the re-establishment of ground cover are subject to the vagaries of rainfall patterns and intensities.

Most of the erosion losses seem to be associated with surface runoff resulting from rainfall. However, over 90 million acre feet of water are delivered each year to the irrigated farms in the United States. According to Quackenbush, approximately 47 percent of this is beneficially used to produce crops. The remaining 53 percent runs off or is lost through percolation below the root zone. He shows the farm irrigation efficiency ranging from about 50 to 56 percent. This is for about 85 percent of the irrigated lands which are surface irrigated. Usually heavy irrigation erosion losses result from excessive water use, steep slopes, and long runs.

Wind erosion is another form of land degradation. The soils associated with water erosion are more or less the same soils associated with wind erosion. One important inclusion of soils susceptible to wind erosion would be the irrigated areas of the world. This is a tendency for soil erosion by wind to be aggravated by lack of vegetation and lack of water. These criteria make those dryland areas and many irrigated areas of farming very susceptible to wind erosion.

In the Great Plains of the United States during the early 1900's large areas were adversely affected as a result of wind erosion. The crop damage resulted in enormous economic losses for the area known as the "dust bowl". According to Yakubov, vivid descriptions of dust storms and so-called "black winters" occurred during the late 1800's in Southern Ukrane, indicating that wind has been a problem for agriculture for a considerable number of years.

MEASUREMENT AND CONTROL

As Chepil pointed out, those factors influencing wind erosion are depletion of vegetative cover, high temperatures resulting in dry soil surfaces, low rainfall, wind intensity, and soil texture. He arranged soils in the following increasing order to erodibility by wind: clay loam, silt loam, loam, silty clay, loamy sand, clay, and sandy clay loam; with the latter being the most susceptible. In addition to the loss of nutrients, which results from wind erosion (similar to water erosion), there is another problem of wind erosion and that is the abrasiveness of rapidly moving dust particles near the surface of the soil.

According to Yakubov, there is a definite pattern in the vertical particle size distribution of airborne soils. Content of sand usually decreases with height and the amount of fine particles increases correspondingly. The ratio of sand fractions with the sum of the silt and clay fractions gradually decreases and nearly evens out at the height of 0.8 to 1 meters. The largest number of soil particles, usually in the 0.1 to 0.5 diameter range, are transported at a height of approximately one meter from the soil surface under the direct pressure of turbulent air current. Particle sizes greater than 0.5 mm in diameter tend to move by rolling and fine particles less than 0.1 mm in diameter are suspended in a very thin layer of air near the ground. Most of the mass of wind transported soil is concentrated in the 0 to 30 cm layer above the soil surface.

These characteristics of windborne soil can be readily associated with the pruning effect of dust storms on small vegetative crops. Estimates of crop losses resulting from so-called "sand blasting" are not available to the author's knowledge. In some cases the results of "sand blasting" may be as extreme as complete loss of the crop. Other cases may result in stunting or stand loss. Any of these factors are capable of severely affecting crop yields.

Other contributors to the erosion of soil, not already discussed in relation to sources of sediment, are water repellent soils. Water repellent soil sometimes referred to as hydrophobic soils may produce a serious problem on steep slopes where they reduce infiltration of rainwater, thereby causing erosion. Debano found a high erosion rate after fire. The erosion was increased in part due to the water repellent layer of soil that formed during the fire. According to Holzbey, water repellence of soil is primarily a surface phenomena and is usually associated with organic matter littered surface. Usually, soils of 8 to 10 percent clay plus silt are those which are most susceptible to hydrophobia, according to Bond. Bond has also isolated several species of fungi which are able to produce the material that imparts the water repellent characteristics to the soil. The material coats the surface of the soil particles which, according to Bond, is probably the reason why sands are the soils most often exhibiting the hydrophobic characteristic. Soils which have particles with much greater surface area dilute the water repellent material to the point where it has little or no effect.

Krommes and Osborne in a survey of recently burned watersheds show that 60 percent of the area investigated had a water repellent or hard-to-wet soil layer. They found that in every case but one, when a surfactant was applied to improve the water penetration or infiltration rate the amount of erosion was significantly decreased. The average over-all locations and years showed about a 50 percent more soil loss from the untreated plots, which indicated a direct loss resulting from wildfire burns and the formation of hydrophobic soils.

It has been estimated that more than a billion cubic yards of sediment is deposited each year in the major reservoirs of the United States. In other parts of the world with great river basins, the amount of soil lost from these areas, if known, would be equally as large. The effects of losing this soils is not the loss alone, but is also the cost of removal from reservoirs, dredging of streams, not to mention the esthetics and the effects on wildlife.

A report by Glymph and Storey indicates that sediment and water adversely affects fish in a number of ways: by silting up spawning beds, reducing the penetration of light, lowering the productivity of the water so food for fish is less abundant, and reducing the visibility so that finding food is more difficult. They report that in England, suspended soils from China clay works, in concentrations of 1000 ppm, have markedly reduced the abundance of brown trout.

Another result of sediment in water is the cost of purification of municipal water facilities. Ninety four percent of various facilities dispensing surface waters in the United States apply some type of treatment to the water. Filtration for removal of sediment and other solids is almost a universal practice. In a study a few years ago, a cost savings of 10 percent per million gallons of water treated could be made by a 30 percent reduction in suspended solids in the streams. The savings would result primarily from lesser requirements for the alum needed for floculation and settlement of sediment.

Records of reservoir sediment deposition surveys available for 1069 reservoirs show the average of storage loss due to sediment deposited in artificial reservoirs each year. These reservoirs have an original capacity of approximately 500 million acre feet. The reservoirs will have been rendered essentially useless before their capacity for water storage has been replaced by sediment. The utility of old storage reservoirs will be seriously impaired by the time they are half full of sediment (Glymph and Storey).

It has already been pointed out that sediments are carriers of pesticides and radioactivity in addition to removing some of the primary nutrients necessary for crop development.

Another problem associated with surface runoff is the loss of organic matter through erosion. Studies of organic matter content of sediments have shown that organic matter removal by erosion occurs at nearly five times the level found in the original soil (Mannering and Bertrand). This organic matter contains relatively high amounts of nitrogen and phosphorus. Studies showed that soil erosion removed higher proportions of silt and clay but less sand than was found in the original soil. The summarization of a considerable amount of information indicated that nitrogen in runoff which included water plus sediments was 2.7 times that contained in the original soil. A similar summary of concentrations of available phosphorus in sediment showed it to be 3.4 times that contained in the original soil. Reported losses of potassium in sediments show up to 19.3 times the content of the original soil. Losses of other elements have not been investigated in enough detail to estimate losses in sediments.

The phosphorus content in sediments is of primary concern since it is often associated with eutrophication of the surface water. Williams et al evaluated the adsorption and desorption capacity of lake sediments and found that noncalcareous lake sediments generally adsorbed and retained more inorganic phosphorus than calcareous lake sediments. Sediments which adsorbed the most phosphorus tended to release the least phosphorus during a subsequent desorption. In all levels of phosphorus added there seemed to be little relationship between the amount of phosphorus added to the solution and the amount adsorbed, indicating that there is a maximum level at which the sediments become loaded with as much phosphorus as they can adsorb; therefore, the remainder is left in solution to undergo other reactions: precipitation as in soluble iron, aluminium, and calcium phosphates, depending upon the pH of the solution. In any case, they found no consistent relationship between lake eutrophication and phosphorus retention capacity, and concluded that the state of eutrophication could not be explained solely on the basis of the capacity of sediments to retain phosphorus.

There have been several people who have investigated techniques for preventing or controlling surface runoff, and thereby limiting the amount of sediment which is lost. Braude in the U.S.S.R. found that forest plantings on slopes were of value in protecting against wind and wind erosion, and slopes were protected against water erosion by 5 to 7 rows of trees, wind velocity decreased on an average of 48 to 50 percent, and runoff was reduced by 25 to 50 percent. A report by Eren indicates the protective role of forests in the reduction of runoff and erosion. With a 50 mm/hr rainfall the runoff for forest covers of 75, 37 and 10 percent was 2,14 and 73 percent respectively. The soil eroded from the three levels of forest cover was 0.05, 0.5 and 5.55 tons per acre, respectively.

Runoff and soil loss is intimately related to soil physical properties. However, it seems unlikely that the soil variables which were important in the Bertrand et al estimation of soil loss from runoff can be manipulated per se for controlling the losses. One factor conspicuously missing from their list of variable studies is the amount of aggregation resulting from decomposition of organic matter.

Several investigators have shown that organic matter mixed intimately with the soil is effective in reducing the perturbation resulting from intense rainfall, thereby reducing the amount of soil loss through erosion. Hayes estimated in fields planted with corn using a "slot method," whereby only a small portion of the total surface of the field is distrubed and with 6 000 pounds per acre of corn residue on the soil surface, the water induced erosion was reduced 90 percent from that in fields conventionally planted to corn. He found that more than 6 000 pounds of plant residue (corn) did not greatly increase the effectiveness of the mulch in controlling water erosion; but that small grain and soybean residues were about twice as effective as corn residue, and sod residue was approximately equally as effective.

Mannering and Meyer compared three separate methods of handling corn stalk for their effectiveness in preventing soil losses from water erosion: 1) the corn stalks standing, 2) corn stalks were shredded and 3) shredded and disced once. They found that the shredding alone was the most effective in reducing the soil loss due to water runoff. Therefore it was concluded that there was a lower soil content in the runoff. Soil losses from the shredded plus discing plots were intermediate between the unshredded and shredded alone.

Smith and Henderson found that over a six-year period the average soil loss from four years of corn after two years of grass and clover was 47 percent of the loss from six years of continuous corn. In an experiment at Ottawa, Ripley found that 264 tons per acre of soil were lost in a 12-year period when corn was planted up and down the slope, whereas only 41 tons were lost during the same period when corn was planted on a contour or across the slope. Under the same set of conditions, alfalfa continuously grown only lost 0.1 tons of soil.

Studies by the Soil Conservation Service of the U.S. Department of Agriculture have shown the effect of soil losses from surface runoff on rangeland which had various degrees of grazing. On areas which have good palatable grasses and good density, soil loss per year is less than 1 000 pounds per acre. On range where there is a mixture of weeds and grasses with medium density, soil loss is slightly less than 5 000 pounds per acre. On the area where annual weeds make up most of the vegetation, and there is a low density, soil losses average 15 000 pounds per acre per year. On prairie land with good sod, no loss of soil was measured after a 2¼ inch rainfall on a 10 percent slope. On overgrazed grassland there was a 160 pound loss of soil per acre while on bare soil there was a 6800 pound loss of soil per acre from the same 2-¼ inch rainfall.

VIII. SPECIFIC HEALTH PROBLEMS RELATED TO LAND DEGRADATION 1/

1. Soil Pollution by Biological Disease Agents

Biological agents which can pollute the soil and lead to disease in man can be classified in three groups:

(a) pathogenic micro-organisms excreted by man and transmitted to man by direct contact with contaminated soil or by the consumption of food grown in contaminated soil (man-soil-man contact);

(b) pathogenic micro-organisms transmitted to man by direct contact with soil contaminated by wastes of infected animals (animal-soil-man contact); and

(c) pathogenic micro-organisms found naturally in soil (soil-man contact).

Man-soil-man contact

Enteric bacteria and protozoa can contaminate soil as a result of insanitary excreta disposal practices or as a result of soil fertilization by night soil, sewage sludge or by direct irrigation of agricultural crops with sewage. Soil and crops can become contaminated with the bacterial agents of cholera, salmonellosis, bacillary dysentary (shigellosis) and typhoid and paratyphoid fever, or with the protozoan agent of amebiasis. However, these diseases are most often water-borne, transmitted by direct person-to-person contact or by the contamination of food. Flies which breed in, or come in contact with, faeces-contaminated soil can serve as mechanical carriers of the disease organisms, although epidemiological evidence suggests that flies do not generally play an important role in the transmission of this group of diseases.

Parasitic worms or helminths adversely affect the health of human populations all over the world. Helminths transmitted by polluted soil can be grouped into two categories:

(a) contagious or faecal-borne; eggs or larvae are passed from the faeces to the soil and infect persons in immediate contact with the contaminated soil.

(b) soil-transmitted or geo-helminths; larvae or eggs become infective after a period of incubation in the soil.

1/ This section was contributed by WHO.

In many areas of the world the most prevalent and dangerous are helminths of the soil transmitted group. A WHO Expert Committee on Soil Transmitted Helminths states that from the standpoint of their prevalence and the severity of the diseases caused by them, the most important soil-transmitted helminths are Ascaris lumbricoides, Trichuris trichiura, Necator americanus and Ancylostoma duodenale, the last two being the causative agents of hookworm. The same committee felt that the direct relationship between anaemia and hookworm infection and to a lesser extent other helminthic infections, though for many years obscure, has now been generally accepted. Helminthic infections may cause losses of iron, protein, or other essential constitutents of the red-blood cells; they may also induce a failure to absorb these substances, and may damage the liver and have other pathological effects. Malnutrition may be induced or aggravated by helminthic infections, for worms may not only produce secretions known to interfere with protein digestion, but may themselves compete with their hosts and absorb essential nutrients; and, by causing bleeding, they may bring about further important losses which increase nutritional demands.

Early attempts to control hookworm infection were initiated in mines in Europe and considerable success was achieved. The provision of sanitary facilities and the treatment of infected persons reduced the prevalence of hookworm infection and disease to a point where it is now negligible in Europe except for certain parts of Portugal and among agricultural workers in Italy. However, in most places where the environment is favourable to hookworms there has been little change in prevalence. The prevention of soil-transmitted helminth infections is largely a matter of the sanitary disposal of faeces, and in all control programmes this must be given high priority. Even in economically advanced countries sanitary sewage disposal is far from adequate. The chemical treatment of night soil and sewage is technically feasible; however, the chemicals are expensive and their application is often impractical. It is difficult to kill eggs and larvae in the soil because the eggs may be washed down into it by rain, or the larvae may migrate downward so they are protected by three centimeters of soil or more. For this reason many of the chemicals that kill eggs when applied under laboratory conditions are ineffective when applied to the soil.

The contents of latrines, septic tanks, sewage systems or effluents of sewage treatment plants, are frequently used for the fertilization of crops. In water-short areas the reclamation of waste water for irrigation often provides a valuable source for additional water supply, but unless certain precautions are taken such practices can be dangerous to the public health. Hookworm and ascaris as well as other helminths may survive for a relatively long period in the soil and contaminate vegetable crops which are consumed uncooked. In addition, pathogenic enteric bacteria and protozoan parasites such as Entamoeba histolytica may contaminate the soil and crops by such practices. For practical purposes it cannot be assumed that even a well operated biological sewage treatment plant can consistently remove more than 90% of the pathogenic organisms present in the sewage, unless heavy chlorination is applied. Simple processes, such as the primary sedimentation, may remove only 30-40% of the micro-organisms.

Animal-soil-man contact

There are a number of zoonoses for which the soil plays a major role in transmitting the infective agent from animal to man. A recent WHO/FAO Expert Committee has extensively reported on this problem. Leptospirosis, anthrax and Q-fever are transmitted in this way.

Leptospirosis now constitutes a major problem in all parts of the world. The spread of leptospires is related to specific environmental conditions, particularly those which bring animal carriers, water, mud and man together. Susceptible animals and man entering such environments are exposed to the agent and may develop infection varying from an inapparent response to an acute fulminating fatal disease.

The number of reported cases of anthrax in humans is relatively low compared with other zoonoses, but this disease is still of importance both as a human disease and because of its economic impact on animal husbandry. The spore form of the Bacillus anthracis is very resistant to chemical and environmental influences and can survive for years in certain soils as well as in animal products such as hides, hair and wool. Heavy contamination of the soil exists in many areas of the world, particularly in Asia, Southern Europe and Africa; other countries have large or small "anthrax districts" but in general anthrax problems are less serious in the western hemisphere than in other parts of the world.

Q-fever is caused by Rickettsia (Coxiella) burneti and is recognized as an important public health problem. A WHO-assisted survey of the distribution of Q-fever in 32 countries and other published reports have shown infection in over 50 countries on five continents, and only in a few countries has investigation failed to reveal the existence of the disease. Rickettsia are present in milk and in soil and may survive for long periods.

Soil-man contact

During the last few years increasing evidence has accumulated that fungi potentially pathogenic for man can be isolated from the environment. An example is Aspergillus fumigatus which is the etiological agent of one type of aspergillosis which appears to be more common in warmer and humid areas. Geotrichosis is another disease associated with the organism Geotrichum candidum, also frequently isolated in soils.

Tetanus is an acute disease of man induced by the toxin of the tetanus bacillus which grows anaerobically. The infectious agent Clostridium tetani is excreted by infected animals, especially horses. The immediate sources of infection are soil, dust, or animal and human faeces.

Botulism is a highly fatal poisoning caused by bacterial toxins produced by Clostridium botulinum. The reservoirs of the organisms are soil and the intestinal tract of animals. The toxin is formed by the anaerobic growth of spores in food which is the immediate source of poisoning.

Coccidioidomycosis is also associated with soil pollution and ranks high among the infectious occupational diseases of workers in endemic areas; it has been reported only in arid and semi-arid areas of the south-west of the United States, Mexico, Central America and South America. The highly infectious spores of Coccidiodes immitis are found in the first few inches of soil and in larger numbers in the vicinity of rodent burrows. In the heat of early summer, wind disturbs the surface dust and lifts the spores into the air.

2. Soil Pollution by Chemical Agents

In the last 25 years the use of chemical pesticides and herbicides applied to the soil and to plants has increased enormously. In many countries agriculture has become dependent on the use of such chemicals to maintain the high levels of production required. Some recent studies reviewing the problems of pollution by pesticides pointed out that the residuals of these chemicals which appear in food for human consumption may present a health hazard to man, although there is today little evidence that soil pollution per se has played a significant role. Many of these chemicals do not accumulate in the soil and within a matter of months or in a year or two, are destroyed by soil bacteria, but certain chlorinated hydrocarbons and chlorinated phenoxy compounds persist in the soil. They can be held tightly by the clay and humus fractions of the soil which prevent the attack by micro-organisms. Among the insecticides, DDT and dieldrin have been shown to be resistant to biological degradation in the soil. Whereas the weed killer 2,4-D is rapidly destroyed by soil micro-organisms, the closely related 2, 4, 5-T remains intact for longer periods. It is well known that persistant pesticides, if not fixed by the soil, are subject to possible biological concentration through the food chain. One example is that of heptachlor epoxide which can be absorbed and concentrated from the soil by earthworms either by contact or through the digestive system. Birds feed on the worms and may concentrate the pesticide still further. While the possibility of biological concentration of pesticides from the soil remains a potential problem, it is felt that most pesticides reaching the soil become unavailable or non-toxic and do not enter the food chain of animals or man.

Soil pollution by artificial fertilizers such as ammonium nitrate may result in contamination of groundwater aquifers by nitrates and nitrites. The consumption of water with high nitrate concentration may result in infant methaemoglobinaemia. This disease was first recognized clinically in 1945. Since then several thousand cases including a number of fatal poisonings have been reported in various countries of the world. For example, the number of cases recorded in Czechoslovakia approaches 1000 and during the period from 1948-1960, 314 cases were recorded of which 8% were lethal. The mean nitrate content in water consumed by affected children ranged from 18 mg/l to 247 mg/l. About three-quarters of the sick infants consumed water containing nitrates in concentrations above 100 mg/l.

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A more important and generalized potential hazard may be connected with nitrites, as they are the essential precursors in the synthesis of nitrosamines. Many of the known nitrosamines are carcinogenic in a wide range of organs in various species at very low concentrations. Nitrosamines are formed chemically by the interaction of nitrites or oxides of nitrogen and secondary amines at low pH values. Such reactions may occur in vitro in the gastric juice of various species but also in vivo in the stomach of rodents. The proposed replacement of phosphate detergent builders by nitrogen compounds such as the nitrilotriacetic acid may result in the increase in the content of nitrates in the water and soil.

3. Radioactive Materials

Radioactive materials can reach the soil and accumulate there, either from atmospheric fallout or by the disposal of liquid or solid radioactive wastes from atomic industrial or research establishments. The three most important radionuclides with long half lives produced by nuclear fission are carbon-14 with a half life of 5600 years, radio strontium (Sr-90) with a half life of 28 years and caesium-137 with a half life of 30 years. Carton-14 is normally present in the soil and it appears unlikely that changes in the C-14 content of the soil will be reflected in the composition of plants, because plants get the bulk of their carbon from the atmosphere; nor should there be any adverse effect on soil fauna which feed largely on these plants. Radioactive strontium concentrations in the soil are generally a function of the amount of precipitation, since this element is brought to the soil primarily by rain. Within the soil the deposited Sr-90 is held firmly by electrostatic forces in the upper few inches. If the soil is eroded, the deposited radionuclides will be carried away with the silt and clay. Radioactive cesium is held even more tightly by the soil than strontium, so much so that it is virtually unavailable to plants and most likely presents little hazard. The levels of radiation from fission products deposited in the soil by fallout in the United States of America are of about the same order of magnitude or one order lower than natural radiation from the soil. Many authorities feel that there is very limited evidence to date to prove that this increase in radiation could affect soil fauna and their predators, but increased radioactive fallout could in time result in soil contamination reaching levels sufficient to cause concern.

The disposal of radioactive wastes from atomic energy installations can cause levels of soil pollution in certain local areas to reach concentrations which may present health problems unless carefully controlled and monitored.

4. Soil Pollution by Solid Wastes

There is no doubt that solid waste disposal, in addition to agricultural chemicals, presents the most important source of soil pollution and land degradation. Solid wastes include domestic refuse and other discarded solid materials, such as those from commercial, industrial and agricultural operations. Domestic refuse includes paper, cardboard, metals, glass, food, ashes, plastics, wood and other material. Commerical refuse includes the wastes from markets, shops, restaurants and offices. Industrial refuse comprises a wide variety of wastes ranging from completely inert materials such as calcium carbonate to highly toxic compounds. The growth and diversity of industrial operations together with rapid technological development have resulted in a substantial increase both in volume and the complexity of solid wastes. Solid wastes are produced also in large quantities by mining. Agricultural wastes derive from the production and processing of food and other crops and from raising and slaughtering of livestock. Special handling is required for potentially dangerous wastes such as those from hospitals and from the use of radioactive materials.

The amount of solid wastes produced per person per year is increasing. Prior to about 1945 the production of solid wastes was assumed to be 350-400 kgs. per person per year. Improved standards of living and the building boom, the increase in the consumption of consumer goods and the use of synthetics have all contributed to an increase in the amount of urban wastes, so that the present average in industrialized countries is probably at least 700 kgs. per person per year. The annual increase is between 1-2%. These data do not adequately reflect the additional solid wastes produced by agriculture and large industrial operations, not do they take into account the solid pollutants increasingly being separated from gaseous and liquid wastes by improved treatment processes.

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Land disposal of urban and agricultural solid wastes can be carried out in a sanitary manner so as to minimize pollution. The controlled burial of such wastes in a sanitary landfill, when carefully planned and executed, can prevent pollution and lead to the ultimate reclamation of waste land areas. However, problems of groundwater pollution or nuisance can result from improper fill. The conversion of solid wastes, particularly those possessing a high organic matter content, to compost can ensure in some areas of the world a satisfactory method of preventing land pollution as well as the return of organic matter to the soil. The views differ as to the use of the land as ultimate repository of solid wastes. Some authorities hold that landfilling results in relinquishing valuable land and limits future development; others think that some of our land resources must be given over to the solution of waste management problems, and that with the transfer of solid wastes to another sphere, such as to the air by incineration or to the water environment, may in the final analysis lead to more severe pollution problems.

5. Inter-relationships between Air, Water and Land Pollution

Atmospheric pollutants such as organic or inorganic dust, pollens, fungal spores, and others are returned to the soil by precipitation and natural dustfall. There are some instances where such fallout from industrial air pollution can cause serious land devastation, for e.g. around factories producing artificial nitrogen fertilizers.

The principle mechanisms of water to land movement of pollutants include the deposition of silt, clay and other soil materials and organic residues by surface waters, including flood overflows; deposition of minerals in specific locations by groundwaters; deposition of salts from intrusion or flooding by saline waters; accumulation of salts as a result of inadequate leaching during irrigation; and accumulation of residues from spray irrigation with domestic or industrial wastes.

Conversely, some methods of solid waste management, for example, incineration, can lead to serious local air pollution problems.

Selected WHO papers and documents on land pollution:

A review of the public health aspects of soil pollution, H.I. Shuval (1970) WHO/W.POLL/70.5

Soil Transmitted Helminths, Report of a WHO Expert Committee (1964), Wld Hlth Org. techn. Rep. Ser. 277

Joint WHO/FAO Expert Committee on Zoonoses (1959) Wld Hlth Org. techn. Rep. Ser. 169 (Second Report)

World Health Organization, Expert Committee on Environmental Change and Resulting Impacts on Health. (Geneva, 1964) Wld. Hlth Org. tech. Rep. Ser. 292

World Health Organization, Expert Committee on Environmental Aspects of Metropolitan Planning and Development (1968), Wld Hlth Org. techn. Rep. Ser. 297

World Health Organization, Report of a Scientific Group on Treatment and Disposal of Wastes (1967) Wld Hlth Org. techn. Rep. Ser. 367

IX LAND SUBSIDENCE [1/]

Land subsidence caused by extraction of water, gas or oil and by underground mining is rapidly becoming a major environmental problem.

Still restricted to a relatively small number of areas, mostly urban areas in the vicinity of important oil or gas fields or important aquifers, the rate, magnitude and extent of land subsidence and its economic consequences have recently brought into the limelight this important problem.

Land subsidence related to man's activities became of economic importance long ago. As early as in 1924, after repeated precise levelling, abnormal subsidence of benchmarks was discovered in the Koto delta area, Tokyo. But it was only in 1952 that it was ascertained that the major part of the subsidence was caused by ground-water withdrawals which by then had reached 190.000 m3/day.

Land subsidence due to the withdrawal of fluids has become relatively common in the United States since 1940. Other areas of major land subsidence caused by ground-water withdrawal are Osaka, Nagoya, Tokyo and Niigata in Japan; London, England; Mexico City, Mexico, Po Delta and Venice area, Italy and several areas in Texas, Arizona, Nevada and California in the United States. At present, the areas showing greatest extent and maximum subsidence are located in California. It can be anticipated however that because of the increase in industrialization in selected areas and the consequent increase in the use of ground-water and oil the problems of subsidence will become more and more important and widespread.

As in other fields, studies and research on land subsidence are done mostly at national level. The causes of land subsidence have been circumscribed, theories have been developed (consolidation theory and aquifer-system compaction) that satisfactorily explain the phenomena concerned and enable its evaluation both in the laboratory and in the field. Prediction of land subsidence is now possible and thus remedial measures can be taken in many cases. These consist mostly of injecting fluids to reestablish as much as possible the original pressures. The experience gained in the Long-Beach, California area has been in this respect of great assistance for the development of repressurisation methods.

International action has been rather limited. The Co-ordinating Council of the IHD at its first session in 1965 recognized the importance of the problem. As a result UNESCO and the IASH organized in 1969 in Tokyo a Symposium on Land Subsidence in which about 70 papers concerning all phases of the problem were discussed. The symposium recommended that further international action be undertaken particularly by providing a machinery for continuing international exchange of information on land subsidence and by holding future symposia perhaps every 5 or 6 years.

Considering the results of investigations up to the present the following appear to be the areas where continuing, additional research or action should be undertaken: evaluation of subsidence both in the laboratory and in the field, prediction of land subsidence, and remedial measures for reducing or reversing land subsidence.

As a result of the Tokyo symposium, the following research may be of special interest:

1. Effect of multi-cyclic loading of clays and sands within the same stress range, as compared to the usual loading technique in time-consolidation tests.

2. Research in development of field methods for determining approximate gross compressibility of an aquifer system from aquifer pumping tests, in both the elastic and plastic-plus-elastic ranges.

3. Research in improved methods for measuring compaction or expansion of aquifer systems under changing stress; development of frictionless methods to measure changes in aquifer systems (laser, etc.).

1/ This section was contributed by UNESCO

4. Additional research on the relation between liquid limit and the compression index. Studies of possibility of using liquid limit tests (obtained from drilling samples) to furnish approximate compression characteristics of aquitards.

5. Improved methods for determining preconsolidation loads of compressible beds (aquitards) at substantial depth.

6. Improved geophysical methods for logging density, porosity, close-up and other physical properties in boreholes in unconsolidated deposits.

7. Further development of numerical and electrical simulation methods for predicting compaction in heterogeneous compressible deposits.

8. Research on the importance of secondary consolidation in the ultimate compaction of fine-grained sediments.

9. Research on the importance and influence of other internal or external stresses on aquifer systems, such as electrochemical stresses, the influence of physico-chemical factors, and the effect of bonded or adsorbed water.

10. Additional research on the relation between liquid limit and the compression index.

11. Research on compressibility and elasticity of sands, including the effect of shape, size, sorting mica content, and multi-cycle loading.

12. Development of economic methods of determining pore pressures in fine-grained clayey beds "in situ".

13. Development of improved methods of obtaining "undisturbed" cores.

14. Research on vertical and horizontal strain in the vicinity of a pumped well combined with measurements in observation wells, to explore whether direct determinations of the hydrotopic or mechanical properties of the aquifer system can be derived from such data.

International action in this respect should consist mainly in cataloguing information on, and organizing and coordinating the diffusion of information about research methods and their results. The organization of seminars on selected research topics should also be undertaken.

Areas of subsidence which by their economic or cultural importance are of great interest could be used as "International cooperation problem areas". The results obtained in Venice for which UNESCO has been in the past two years providing experts could be used as an example for future action.

Another area where exchange of information is of great importance is in the methods for reducing and reversing land subsidence. Detailed information on methods and techniques should be diffused for the use of countries having less experience.

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