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Environmentally Dangerous Products (**)

Introduction

The theme of this symposium "Towards a second green revolution: from chemical to new biological techniques in agriculture in the tropics" opens up an opportunity for this paper to briefly address the broad aspects of chemical substances particularly those that are described as "environmentally dangerous chemical substances" emphasizing specific points and issues which arise for environmental and human health in the use of agrochemicals as nations and international bodies intensify efforts to increase agricultural production to meet rising demands for food and fibre. Within these efforts, there are opportunities to integrate with chemical pesticide application other control methods that are now at our disposal in order to minimize environmental risks. A special dimension of this paper is the review of some of the promising lines in the new science of biotechnology with a view to singling out those with potential impacts for sustainable food production and environmental management. The closing remarks examine the current role of the international community, particularly the United Nations system, in designing programmes addressing some of the environmental challenges posed by chemical pesticide pollution.

1. Chemical Substances

A literature review enables a rough estimate of the various kinds of chemicals currently circulated into nature as a result of technological advances to be placed at approximately five million, about 70,000 of which are marketed, either in com-

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mercially viable quantities, or in intermediate waste products or laboratory chemicals that do not directly reach the public. Many of these products are ingredients in mixtures, solutions, powders and other products. The organic chemicals sector produces several products: primary organic chemicals in large-scale continuous process plants, converts primary chemicals by chemical reaction into secondary or intermediate materials downstream into a huge array of final products such as pharmaceuticals, fine chemicals, pesticides, plastics, elastomers or synthetic detergents.

With the increase in the production and use of chemical compounds, man could become more and more exposed to varying degrees of toxicity and other deleterious effects which several of these products exhibit. Considerable research is still necessary in order to elucidate the different pathways and fates of toxic chemicals in the environment, the routes of chemicals in the food chain, and the health hazards resulting from these chemicals. In the case of many chemicals, it is still not known how far man is at risk from exposure to very low concentrations over a lifetime. We know from the experience of people who have been exposed to specific components at work. We know, too, that over longer periods some can cause cancer, delayed nervous damage, malformations in unborn children, and mutagenic changes that could produce disability and disease in future generations. Many other chemicals are likely to have similar effects, but because these take time to show and their causes are hard to pinpoint, we do not yet precisely know which substances are the dangerous ones, or which are more dangerous than the others. Moreover, once the chemicals are in the environment, they spread in a very complex way and may be converted into other substances which have different effects, thus compounding our ability to identify the specific sources of contamination and prescribe elimination or control measures.

A most worrisome feature of the problem is how to handle the enormous amount of the hazardous waste generated by the chemical industry. Bad disposal can make a relatively harmless substance troublesome, if not dangerous, while if a hazardous waste is properly treated, it will probably be safer than many others that are not officially classified as potential dangers. Land is increasingly used as a hazardous waste disposal medium. Key to the proper use of land for this purpose is an adequate understanding of the assimilative capacity of the soil. Equally important are the environmental criteria or limits that should be used to assure that land is not abused when it is used for waste management. There are varying opinions on the advisability of using land for waste disposal. Some feel that any introduction of material from an anthropogenic source into a natural system will cause an irreversible change from the natural condition which can be permanently dangerous. Before one chooses which argument to favour, information is required on the degradation, immobilization, transformation, diffusion, bioaccumulation, transport and fate of constituents in the wastes and residues which need to be managed. Then, of course, there are the special problems posed by transboundary pollutant exchanges, the most intractable arising from those that are easily pushed into the air and carried by the winds. Sulphur and nitrogen oxides, carbon dioxide

and similar chemicals raise global issues of acid rain, ozone layer depletion and climatic change, for which solutions can only be generated if there is better international cooperation and understanding.

We can classify a number of chemicals as dangerous in a global sense on various grounds. In one sense, being airborne, their environmental effects are transfrontier and widespread. Oxides of nitrogen and sulphur dioxide and their derivatives and similar toxic gases can be viewed in this sense. A second category of globally dangerous substances are pollutant loads of industrial wastewaters such as heavy metals of mercury and lead, whose effects are widely distributed with similar consequences. The effects of many other well-known pollutants are, however, restricted and area specific. The toxic effects of chemical pesticides, fertilizers, and fluorides fall in this category.

What do we understand as environmentally dangerous substances?

A simple operational definition should include all substances which enter the environment as the product or the by-product of human activities, that appear to pose, directly or indirectly, a real and urgent threat to man and the environment, and whose elimination from the environment at the moment in time, can only be accomplished in technological as well as management/economic terms with difficulty.

For a chemical substance to be dangerous either in a global or in a restricted local sense, certain criteria are important to consider: (i) manufacture, distribution and release; (ii) secondary substances; (iii) persistence in the environment; (iv) bio-accumulation; (v) population at risk; (vi) toxicity, and (vii) the effects of the chemical product in question, on the physical environment.

Clearly, the main purpose behind operational criteria-setting is, *inter alia*, to identify chemicals which exist in the environment, which of these are pervasively persistent and are widely disseminated, and lastly, which ones behave in such a way as to place human and environmental health at risk.

For the purpose of this paper, some of the above will be briefly discussed.

Manufacture, distribution and release of chemical substances are important because, among other things, these parameters point to the geographical spread of the chemical in question, its dispersion and distribution and the likelihood that increased demand for the products will further aggravate their environmental load. Widespread release of chemicals in the environment always denotes the possibility of exposure of a large number of organisms, ecosystems and human populations to these chemicals, resulting in many instances in bioaccumulation of the chemicals in various organisms. It must, however, be noted that a toxic chemical may not always automatically produce adverse human health or environmental effects when released into the environment; toxicity only refers to the potential of a chemical substance to cause harm in organisms.

In principle, therefore, the hazard or danger of a chemical can only be assessed properly if two types of information are available: data on environmental occurrence and distribution, from which the degree and time-course of exposure

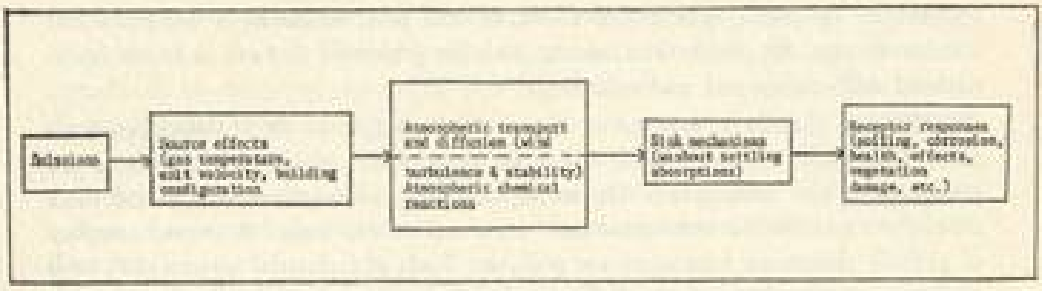

Fig. 1 - A flow chart showing the progress of air pollutants from sources to receptors. (*Source*: Shaw and Munn, 1971).

of man and other organisms can be estimated; and data on the chemical toxicity to a variety of organisms.

In the case of airborne pollutants, the magnitude of the problem is dependent upon three factors: the volume and nature of emissions, atmospheric processes and receptors at risk. An air quality system is shown in the scheme of Figure 1 from emissions to pollution receptors. Both the emissions and the atmosphere form integral parts of the system, which determine the rate and extent of ambient concentrations of pollutants affecting the populations at risk. Figure 2 depicts some of their effects. It should be noted that as in the case of ozone, the substance itself may not exert the direct effect, but when it reacts with another, a health hazard occurs. The results of the reaction of ozone with hydrocarbons can be irritating substances such as formaldehyde, peroxybenzoyl nitrate (PB_2N), peroxyacetyl nitrate (PAN) and acrolein. Ozone can cause chest constriction, irritation of the mucous membranes, headache, coughing and exhaustion. It also damages materials such as rubber, cotton, nylon and polyester. Ozone and PAN have been associated with increases in asthma attacks and also can cause serious damage to plants, resulting in such symptoms as leaf lesions and reduced plant growth. Figure 3 is a summary of the reactions of ozone and hydrocarbons in the popularly known smog phenomenon.

Both short-term and long-term effects are important in any evaluation of a chemical. In general, information on the toxicity of chemicals is derived from experimental studies carried out under laboratory conditions, epidemiological studies and studies on non-human populations in the field. Of special concern are long-term irreversible health effects in man and other species. In man, these health effects include impairment of various organ functions such as the nervous system, liver, kidney, etc., behavioural, reproductive and genetic effects, and carcinogenicity. (Figure 4).

On the other hand, chemicals may not exert direct toxic effects on man or other species, but may, instead, affect some abiotic parameter of the environment such as temperature, rainfall or nutrient availability.

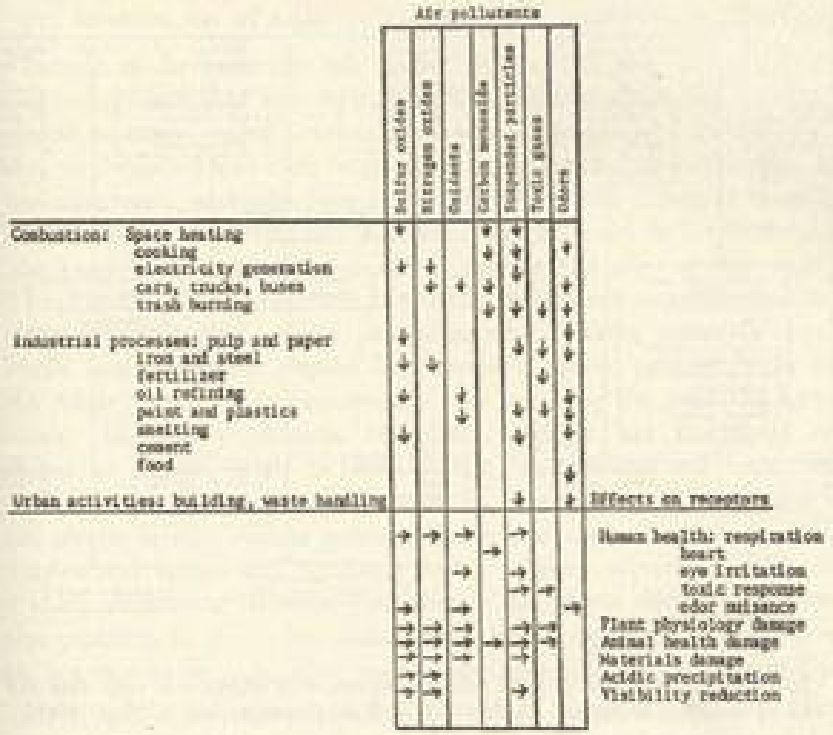

Fig. 2 - Sources, pollutants, effects. (Adapted from R.A. Carpenter and S. Sani, 1983).

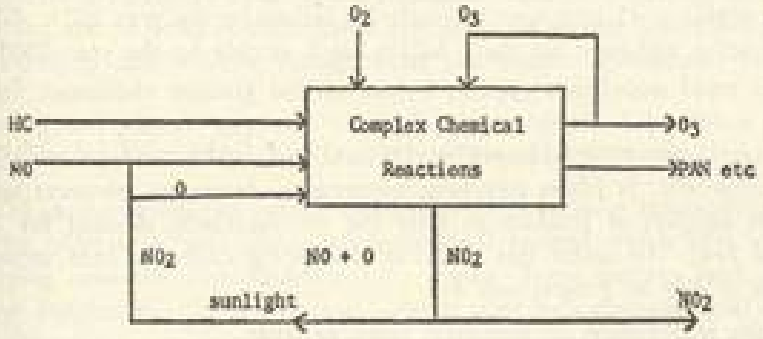

Fig. 3 - Summary of the photochemical smog reaction.

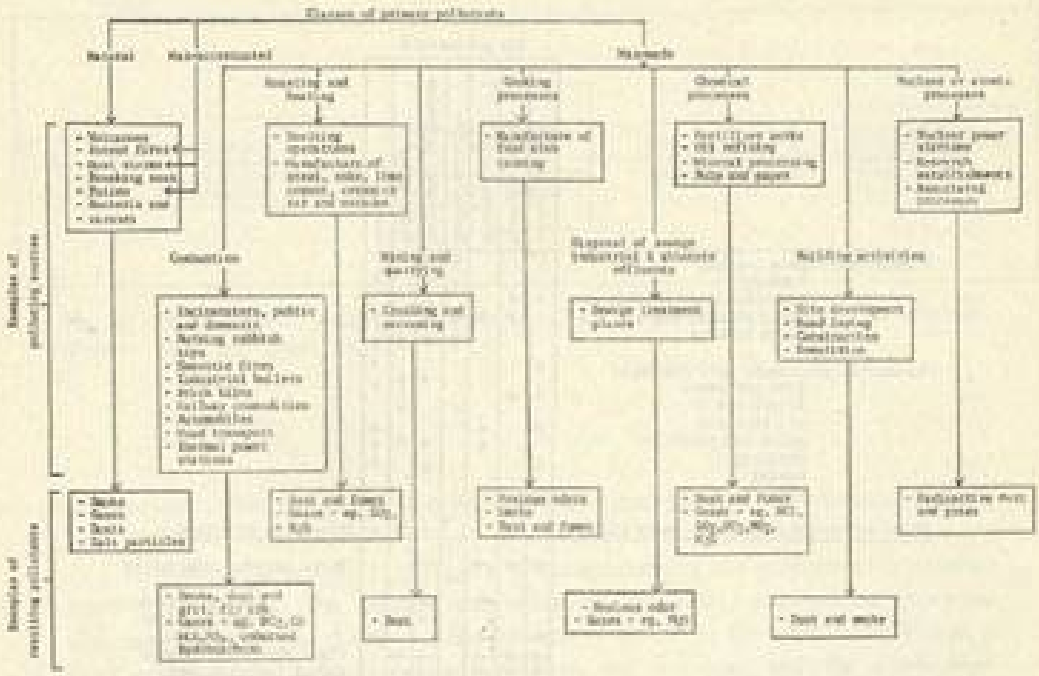

Fig. 4 - Some major classes and types of polluting sources with examples of each class and type and of resulting pollutants. (Adapted from R.A. Carpenter and S. Sani, 1983).

2. Developing Countries and the Need for Pesticides

Between 1980 and 1985, population in developing countries increased by an average of 1.2% and 3.0%. For Africa, the continent with the highest population growth rate of 3.2%, the 1980 population of 500 million is expected to triple within a 45 year span to reach 1.5 billion by the year 2025. Globally, the population will have hit the 6 billion mark already by the year 2000.

This rapid population growth is one of the greatest challenges for man, creating multifaceted problems for all those managing development-population, policy makers, economic planners, agricultural and health workers and Governments themselves. It places increasing pressure on decreasing resources and calls for larger supplies of produce to meet the ever-increasing demand for energy, fibre and food. To arrest this situation, developing countries have increasingly continued to rely on programmes for:

(i) the introduction of high-yield plant varieties

(ii) the expansion of arable land through reclamation of swampy and other areas

(iii) increasing land productivity through irrigation, and

(iv) intensive use of agrochemicals - chemical pesticides and fertilizers.

Because of the important role played by chemical pesticides in public health and agriculture and how they have helped to improve the quality of peoples in developed societies, many developing countries are placing on them increasing reliance to do the trick in their battle against poverty, disease and hunger. Indeed, in increasing cases, pesticides have helped prevent untold misery in many tropical and subtropical lands. Pesticides have been and continue to be extensively used for the control of the mosquito vector of malaria and other vectors such as the snail host vector of schistosomiasis and in this sense have contributed some extent to the steady increase in world population while making accessible large tracts of fertile land previously plagued by dangerous insects, particularly in the case of the tsetse vector of trypanosomiasis, and releasing the land for agricultural activities. In crop production, herbicide, fungicide and insecticide use has continued to expand, while in food storage, rodenticides and fungicides have played an exceedingly important role in the destruction of mycotoxins or the human disease carriers such as rodents. The role of these chemicals in agricultural production and human and veterinary health is likely to continue to expand, at least in the developing countries even though the greater severity and complexity of pest problems in the tropics indicate that losses, especially in green revolution crops, continue to be high, since most of the pesticides still go to cash crops.

Nevertheless, indications are that basic food crops will become substantive consumers as years go by, as there is room for substantive saving of harvests. Already, rice is a major world consumer of pesticide chemicals, which, as Figure 5 shows, in 1978 experienced losses of up to 48% in Asia alone attributable to diseases, weeds and insects.

Because of the likely growth in pesticide use in developing countries, it is prudent to review what is known of the negative phenomena of both a direct and indirect nature which result from large-scale use of pesticides in agricultural production and public health, so that planners can earnestly examine alternative pest control strategies in terms of the biological limits to their long term sustainability and also in terms of their cost-effectiveness for society, and actively promote efforts seeking new ways to manage pests and protect agricultural productivity.

2.1 *The Green Revolution and oversimplification of agroecosystems*

The green revolution, which essentially operates as a monoculture, is fast replacing older and more diversified agricultural systems which have evolved in developing countries over countless crop cycles. Local farmers have deep and intimate insights into the relationship between their local environmental conditions and patterns of crop growth and yield, and are adept in designing simple but practical technological packages minimising risks and ensuing, albeit low level, yields from their fields. This knowledge has not been harnessed as the cropping

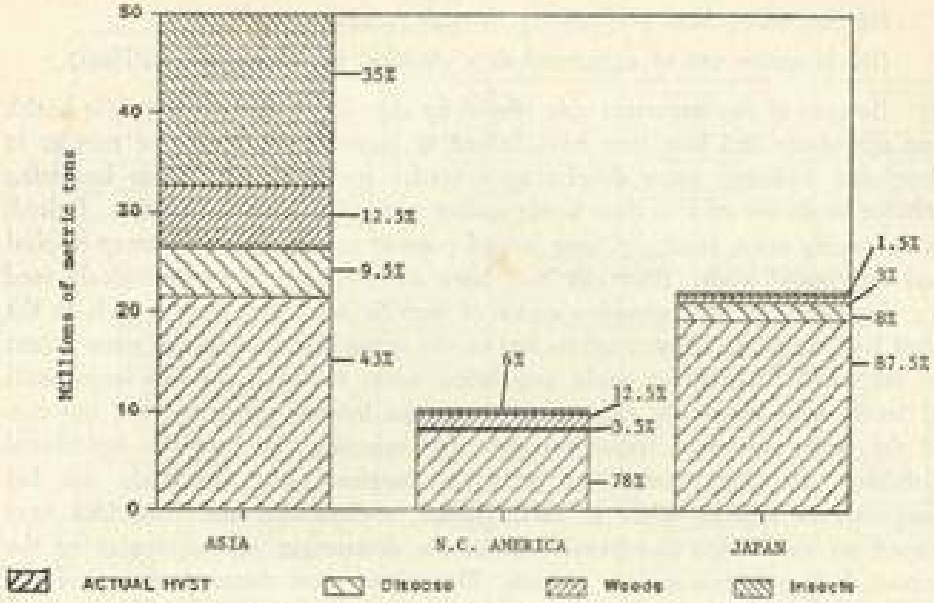

Fig. 5 - Breakdown of rice losses by region (Note Asia 1/10th Scale).

systems of the green revolution begin to be inttroduced. Shifting cultivation systems traditionally use a variety of plant varieties, combining those that supply food, fiber and cash income with others which will produce something even in years of extreme climatic variation or in the face of attack by insects. The systems are quite stable, but their stability comes at the expense of low total yields per hectare. Encouragement to raise productivity therefore comes with greater levels of input, intensity of cultivation, and a simplification of the cropping systems. All these changes can, and usually do, lead to increased pest problems, because insects are efficient exploiters of simplified ecological situations, and with greater pest populations, ever-increasing and ever more expensive applications of chemicals are required, thus compounding environmental risks and dangers.

Moreover, application prescriptions and formulations of pesticides (type, dosage, mode of application, etc.) do not on the whole pay sufficient attention to the wide variability in ecosystem structure and function geographically. Consequently, a form of pesticide application which seems to be efficient and safe in one may not necessarily be efficacious when applied to another ecosystem in a different geographic setting even on the same crop.

2.2 *Build-up of pesticide resistance*

Due to their great capacity for adaptation to meet new ecological challenges, many insects are today known to be able to face chemical pesticides and even

withstand them. For example, many pests attacking cotton and rice are no longer controlled by chemicals. By 1980 there were over 480 recognized cases of resistance by arthropods of agricultural, medical or veterinary importance. Since then, more species have been reported to have developed resistance and/or multiple resistance. In 1985, the World Health Organization reported that resistance had spread to all the commonly used classes of pesticide compounds, such as organochlorines, including DDT and dieldrin/HCH groups, organophosphates, carbamates and even pyrethroids. Furthermore, laboratory selections have given evidence of potential resistance development in the bacterial larvicide *Bacillus thuringiensis* serotype H-14, one of the most promising biological control tools of the 1980's. In the majority of the cases where disease vectors are reported to have developed resistance, the main cause has been attributed to the large-scale application of pesticides for crop production.

The impact on human health of pesticide resistance in vectors is of greatest significance in developing countries. Insecticides are the main method of control of vectors of tropical diseases such as malaria, yellow fever, sleeping sickness, filariasis, the leishmaniases, and onchocerciasis. The rising incidence of resistance to pesticides is therefore reducing the choice of effective compounds for vector control, a situation that is steadily worsening.

2.3 *Outbreaks of secondary pests*

A chemical pesticide may effectively control a pest but soon afterwards there may be a dismaying outbreak of another quite different pest, which hitherto had been known, but had been relatively harmless. This disaster is due to the chemical killing, not only of the first pest, but also of other, inconspicuous insects which had by checks and balances kept down the members of the second species. With the removal of their enemies, the abundant reproductive capacity characteristic of insects allows the second species to build up to some dangerous numbers in only a short time. This is the way in which more than one new pest may arise. In Nicaragua two to three decades ago, for example, the cotton farmers had to contend with only two species of caterpillars. Now, as a result of pesticide applications, they have more than ten different species to control.

2.4 *Destabilization of ecological regulatory mechanisms*

While a pesticide may have initial success against a pest, a farmer's complacency may soon disappear when he notes that the pests' or vectors' numbers are rocketing back to as bad or worse than before. This can happen when the chemical kills off natural enemies of the pest or vectors as well as the pest/vector itself. Firstly, the pesticide treatment does not kill all the individuals of the pest or vector within the area of application but only a proportion, sometimes relatively small, of its population. Secondly, the control area may be re-invaded from unsprayed areas.

Thus, the reinforcements of the pest or vector, having no natural enemies to check them in the sprayed area, multiply enormously.

2.5 *Pollinator mortality*

Pollinator mortality caused by pesticides is a subject of considerable importance and interest. Many pesticides are tested for honey-bee toxicity; however, in certain regions such as North America there may be thousands of other native bees whose pesticide susceptibility may vary widely. Moreover, under such situations, many more species of insects are known to act as pollinators. Increased mortality in native pollinator species may affect the reproductive success of a wide variety of plants and trees, and hence the potential impact of increased pollinator mortality from pesticide applications in agro-ecosystems and forestry may be significant.

2.6 *Effects on nitrification and cellulose breakdown*

Pesticides may have profound effects on communities of soil microorganisms. Many bacteria are capable of metabolizing pesticides. However, decreased nitrification and cellulose breakdown have also been recorded and reduced rates of litter decomposition have been measured in DDT-contaminated soil in abundance, though the significance of such changes is unknown. Possibly more important are the shifts which may occur in the microflora after certain applications of fungicides. It has been documented for instance that, after the application of certain precursors such as benomyl, the incidence of certain root-infecting fungi decreased but that at the same time a considerable increase of other fungal diseases occurred.

2.7 *Effects on irrigation canals*

Herbicides are used on both agricultural and non-agricultural land, including waterways, roads and forests. Of particular concern is the use of herbicides in canals for rice pest control because herbicides kill the plants *in situ*. The death and decay of the vegetation in the water is likely to alter dissolved oxygen, nutrient and other chemical parameters of the water substrate affecting the animal community that depends upon the vegetation for food, shelter and breeding sites. Regrowth of vegetation following herbicide application is often eliminated or much reduced, and this too can have profound and permanent effects on both the animal and plant communities, although in certain instances the removal of dense floating mats of vegetation may prove beneficial by allowing increased light penetration and species diversity. The indiscriminate use of herbicides in or near sensitive ecosystems, such as mangroves, should be viewed with concern.

2.8 Pesticides and the human food chain

Man is exposed to chemicals in three main ways — by inhalation, by ingestion and through contact with his body surface. As far as the general population is concerned, food (including drinking water) is the major source of exposure to most toxic chemicals. These substances reach human food by many routes. Some contaminate it directly in preparation or processing. Others pass from the soil to plants and thence, via herbivorous animals, to meat or milk. Strictly speaking, a food chain is a sequence of the latter kind, and discussion of toxic chemicals and human food chains should always concentrate on the circumstances under which potentially hazardous materials reach man via intermediate organisms.

Pesticide chemicals present in food and water can be derived from a variety of sources: (i) through direct deposits onto the aerial parts of food plants during aerial spraying operations, (ii) residues taken up from the soil or irrigation water via the roots of food plants, (iii) residues taken up from the aquatic environment by fish and other aquatic organisms, (iv) residues of agricultural pesticides and metabolites, and breakdown products thereof, and (v) pesticide residues present in river or stream water used for drinking.

It can be stated with a lot of certainty that there are absolutely no safe pesticides; thus the term "safety" when attributed to a pesticide, is only relative. There are, however safe methods of application.

As a general rule, undesirable effects of pesticides are a result of insufficient efforts to optimize the selectivity of the control methods applied. It has been estimated that in general only five per cent of the pesticide applied reaches the target pests or vectors, the rest drifting away into other parts of the ecosystem and obviously affecting non-target species. A case in point is the aerial application technique. Another example is pesticide usage in the aquatic environment by whatever means. It goes without saying, therefore, that the selectivity of chemical control methods can often be markedly improved by proper choice of formulation and application techniques as well as by the judicious selection and use of the pesticide itself.

3. Anticipating Environmental Risks in Planning Development Projects Containing Pest Control Elements

In planning an irrigation, agricultural, or settlement project, one needs to consider in advance the range of pest problems likely to occur, and the economics of their control. All of this depends on a broadening of the traditional responsibilities of the professionals who plan large-scale projects and invoking team-work in pest management programmes. Each professional who is to be involved in project planning could detract from achieving wholesome benefits from the results of the implemented project.

3.1 *Economic Planners*

When economists consider an investment in an irrigation or agricultural project, their analysis should include the project's direct benefit to the welfare of the people through increased productivity of crops, and also the indirect benefits or damages through changes in the people's health. The cost of pest control and the value of improved productivity can each be predicted with some accuracy. Although public health benefits and damages are more difficult to predict, systematic explicit analysis should enable the planner to make rough approximations. Then possible changes in the project to avoid or remedy damages may be evaluated and compared in a more complete economic appraisal.

3.2 *Dam Construction Engineer:*

The engineer's assignment should include consideration of the range of social, economic, and environmental consequences of building a dam and associated structures. These include issues of alternative land use, displacement of homes and communities, and the health hazards resulting from the storage of water. The engineer should be involved in plans to control the breeding of pests in the reservoir and in precautions for limiting the exposure of the construction labor force to health hazards.

3.3 *Irrigation Engineers*

These professionals should be concerned with the whole range of impacts associated with irrigation projects. Water is becoming an increasingly valuable resource, and its efficient and conservative use not only will prevent waterlogging of soils from overirrigation but also decrease the breeding places of insect vectors responsible for important water-borne diseases such as malaria and the snail host responsible for schistosomiasis.

3.4 *Agronomists*

Although cropping systems are the foremost concern of agronomists, they must be aware that water control is essential for environmental management of both health and agricultural pests.

3.5 *Project Administrators*

Administrators are usually generalists with wide experience in development planning. In the site selection and planning phases, they should seek out and be guided by the technical advice of pest management experts and public health professionals. A major contribution they can make to the project is to assure that

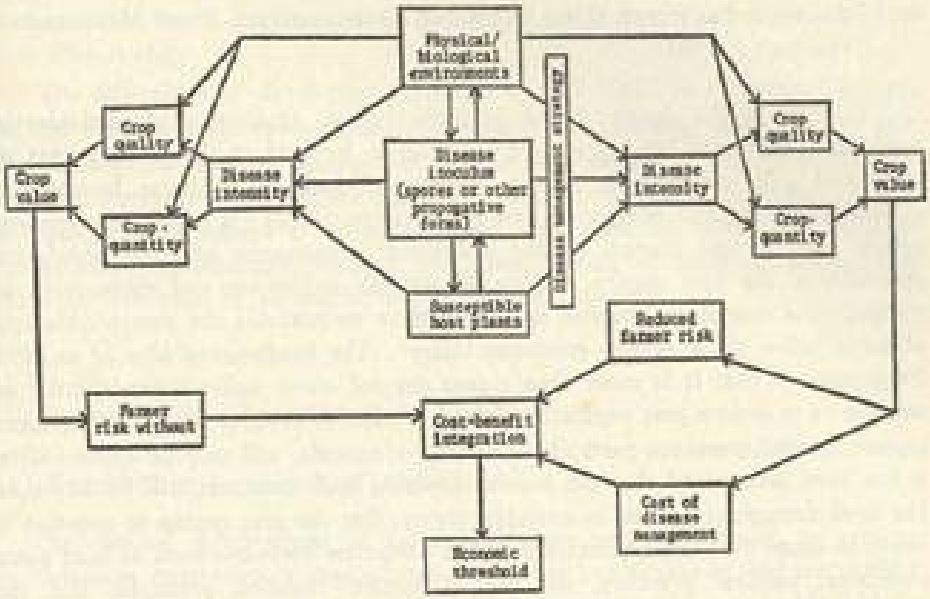

Fig. 6 - Factors that determine the economic threshold for a plant disease pest. Economic threshold = The population level of a pest that produces damage equal in value to the cost of preventing the damage. (Adapted from P.W. Weatherly, 1983).

competent pest control experts are engaged to monitor pest problems and devise effective control programmes.

3.6 *Sociologists*

In a development project, emphasis should be placed on helping the residents assume responsibility in their daily lives for management of the environment, including pests. The sociologist can develop ways to educate the people regarding the relationships between environmental conditions and pest problems.

3.7 *Public Health Administrators*

If a major project is contemplated, such as for a new settlement area, then public health experts should be called in at an early stage to consider health hazards associated with potential pest problems. They would be responsible for coordinating the work of malariologists, entomologists, sanitary engineers, and pest management experts to devise pest control programmes appropriate for local circumstances.

4. Judicious Pesticide Use: the Case of Integrated Pest Management Strategies (IPM)

In view of the dangers posed by indiscriminate application of pesticides in agriculture, increased attention must continue to be paid to the development of integrated pest management systems which will help to minimize human and environmental health. Integrated pest management (IPM) "is a pest management system that, in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible with a view to maintaining the pest populations at levels below those causing economic injury". The fundamental idea of an IPM Programme is that it is more than a pest control effort using a combination of techniques to reduce pest population levels. Under an integrated pest management system, control measures, particularly through chemicals, will only be applied after it has been determined that the cost of applying such measures will be less than the total damage, converted in monetary terms, that the pest species in question is likely to cause (economic threshold). IPM comprises measures such as host plant resistance, cultural practices, the use of natural enemies, pesticides and the application of legal regulatory systems of quarantine. Before any technique is used, the IPM manager must consider all available and technically feasible control methods in the light of what is known about their biological and economic efficacy and seek to mobilize an array of expertise in implementing the selected strategic package, being prepared to change plans in a dynamic situation. The primary set of IPM options lies in the ways one can maintain, enhance, introduce or reintroduce limiting forces in the ecosystem that serve to provide natural checks on the growth of insect pest populations. Conversely, an IPM programme should avoid incompatible combinations of control methods, especially the use of a technique that may inhibit or destroy the natural controls that already exist in the ecosystem.

A well-planned IPM programme will have the following components:

— Conceptual model which relates alternative pest control tactics to current understanding of their effects on the pest. The model should show the impact on the pest of the range of possible programme components, environmental variation, crop conditions, and alternative crops.

— Pest population monitoring system for determining the state of the pest population at various times and the level of economic damage caused by a particular pest over a period of time.

— Environmental monitoring system for those features of the environment that are known or suspected to influence the pest population.

— Implementation plan to guide the choice as well as the operation of the various alternative control tactics.

The components of an IPM programme are interrelated, and all require consideration of cost-effectiveness in every step of programme design, and since the fundamental goal of IPM is to lower the population level of a pest over a period

of time longer than a single outbreak, short-term action should be part of a longer-term IPM strategy.

The difficulties of developing IPM systems for major pests are well-known and can only be overcome by extensive research programmes, demonstration and actual graded and gradual introduction into national practices. The efforts of the Food and Agricultural Organization of the United Nations and the United Nations Environment Programme to stimulate wide application of IPM through pilot demonstration programmes, training and dissemination of adequate information should be welcomed by all and be continually strengthened.

5. Biotechnology: New Promised Land?

5.1 *Biotechnology in agricultural productivity*

Agricultural development is faced with two paradoxical and, in present circumstances, contradictory imperatives: to increase production to feed the world's rising population and at the same time be environmentally sustainable. Many current practices fall short of adequately addressing and harmonising these paradoxes. Can biotechnology, the newest and perhaps the most exciting of the modern scientific breakthroughs, help meet these twin objectives?

There is no doubt of the potential of biotechnologies in many agricultural areas. If sensitively developed and deployed, they may well help circumvent some of the key problems of the Green Revolution just discussed above. Their full potential may begin to bear on such matters as:

a) the diagnosis, prevention, and control of animal diseases — using monoclonal antibody technology to diagnose, monitor, and research animal disease, and genetic engineering to expand the range of vaccines and other animal health care products.

b) animal nutrition and growth promotion — through the use of such biotechnology products as growth hormones and food additives; and

c) the genetic improvement of animal breeds — e.g., the transfer of genes between different animal breeds.

d) the improvement of specific plant characteristics — through the introduction or manipulation of genes conferring resistance to disease or environmental factors, increasing the amount and quality of primary and secondary plant products, or increasing photosynthesis efficiency; and

e) the genetic manipulation of microorganisms — i.e., whether to enhance the natural processes of nitrogen fixation, to produce insecticides, to control plant diseases or promote plant growth.

As Jack Doyle, the Director of the Agricultural Resources Project for the United States Environmental Policy Institute, for example, wrote in *Altered Harvest* we are "in the midst of a revolution in agriculture, a revolution that will create an

enormous new source of wealth — and power — in our most basic industry: the making of food".

Indeed, these are potentially powerful new technologies, and it is vitally important that they be fully harnessed in the battle to increase the agricultural production in developing countries. But their implications for the environment and sustainable development mean that there are problems and many precautions need be taken. "Unlike the Green Revolution technology which originated in the public research system", as Calgene Vice President Dr. Robert Goodman noted, "the strongest programmes in biotechnology are in the hands of commercial sector laboratories. How will their proprietary technical abilities be brought to commercially unrewarding but highly vital improvement of agriculture in developing nations?". How will this lodging of the 'production command' for agriculture in the hands of a few powerful commercial entities be made available to the millions of poverty-ridden small farmers that constitute the bulk of Third World agricultural producers? And how will this high-tech, which builds upon an already technology overburdened production system avoid driving agriculture into a more high-strong condition, vulnerable to all sorts of monkey-wrenching factors, volatility and costs?

5.2 Specialty Chemicals

One of the major concerns for most developing countries, at least as far as the impact of biotechnology on the specialty chemicals sector is concerned, focuses on the possible displacement of Third World products by biosynthetic substitutes produced in bioreactors in the developed countries. Another way of looking at this problem would be to ask whether biotechnology could provide compensatory routes by which developing countries could add value to their commodity products prior to export.

Some particular chemicals can now be readily marketed as products of biotechnology results. These include such products as amino acids, enzymes, vitamins, complex lipids and aromatic compounds. The international market for amino acids is dominated by such Japanese companies as Ajinomoto and Kyowa Hakko. Fermentation is used in producing such key amino acids as glutamic acid, lysine and phenylalanine — this last being a component of the sugar substitute, aspartame. The impact of sugar substitutes illustrates the way that displacement of primary products by biosynthetics can work, possibly to the detriment of agricultural development in the developing countries...

More worrying for developing countries, however, could be developments which lead directly to laboratory produced consumer products. One American company has patented a microbial process for producing cocoa butter, as an alternative to imports from tropical producers. The method involves cultivating yeasts with emulsion of fatty acids. However, the low price of cocoa butter makes this process uneconomical. A Japanese company, Fuji Oil, had earlier patented a different microbial route to cocoa butter.

Another American company, meanwhile, has been investigating ways in which temperate crop plants could be persuaded to produce substitutes for coconut and palm kernel oils. There has also been a good deal of activity in the flavours and fragrances field. Pfizer, for example, patented a microbial route to carvone, a major constituent of spearmint oil, although the company later dropped the research project. The process used the sewage bacterium, *Pseudomonas*. Four companies are already working on flavours and fragrance targets. The potential for long-term threat to a number of high-value exports from developing countries is thus clear.

5.3 *Biotechnologies and Environmental Management*

The bulk of the debate about biotechnology and the environment has been on the important question of its implications for environmental stability rather than the applications of biotechnology environmental quality improvement. And this is despite the fact that the first patent ever awarded for a genetically engineered microorganism, awarded to Dr. Ananda Chakrabarty of General Electric, covered a microbe purpose-designed to tackle an environmental problem. More specifically, it was designed to biodegrade spilled oil. Subsequent developments have now unearthed new microbial strains able to degrade a growing range of potential pollutants. Combining old-style breeding methods with new genetic engineering techniques, Chakrabarty and his colleagues at the University of Illinois announced in 1981 that they had created a bacterium which can live on a diet of toxic chemicals, including the herbicide 2,4,5-T. Some market studies have predicted that environmental applications of biotechnology will be among the fatest growing.

One study, by Business Communications Co., forecast that, while the total U.S. market for microbes and enzymes could grow by around 7% a year to 1991, environmental clean-up applications would grow at an average rate of 17%.

Biotechnology has many potential environmental applications, as indicated by the following seven examples:

(i) *Cleaner technologies*: If properly designed and operated, fermentation processes can be at least as environmentally acceptable as the technologies they replace — and can be much cleaner. In the case of Repligen's lignin-degradation process, the company sees the environmental improvements offered as a key sales advantage over current pulp bleaching technologies.

If mishandled, such technologies can of course produce pollution problems. In Brazil, for example, the fermentation of molasses and other materials to produce fuel alcohol has resulted in local water pollution problems. However, provided the environmental pressure on industry is maintained, fermentation technology can be operated in such a way that the risk of pollution is very low indeed. At the same time, such technologies as microbial pest control, could help replace environmentally problematic chemical crop protection products.

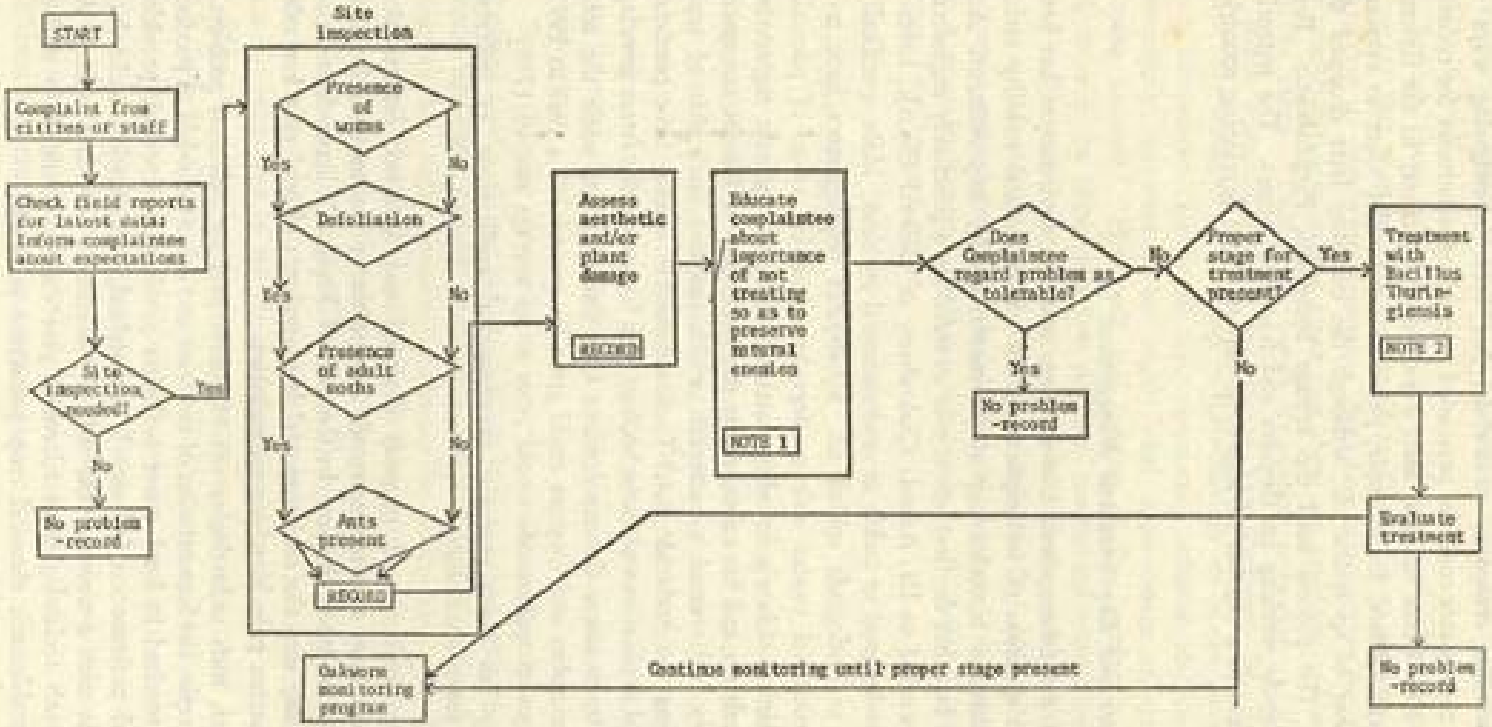

Fig. 7 - The complaint management process for the California oakworm (*Phygonidia Californica*). (*Source*: Smith and Pimental, 1978).

Note 1: The most important natural enemy is the pupal parasite (*Troplectis haberensis*), which usually keeps the oakworm under control. Outbreaks occur about every 7-10 years and endure as long as three seasons.
Note 2: Action threshold is 10 larvae/25-shoot sample.

(ii) *Resource and energy efficiency*: Fermentation processes can help reclaim energy from waste materials, as in the case of BioTechnica's landfill energy technology, and they can also help convert materials that might otherwise go to waste into usable products — as in the case with Phillips Petroleum's Provesteen technology.

(iii) *Environmental monitoring*: Pollution control is only as good as the monitoring system which underpins it. Many companies are hard at work to manufacture simple kits designed to identify particular pollutants. Others have begun manufacturing a quick and inexpensive enzymatic test for detecting pesticide contamination in water. One such system being tried by an American firm which gives a SAFE/NOT SAFE answer, costs $3 a time — rather than $150-$300 for a laboratory test. In the longer term, biosensors — which involve the linking of enzymes or other biological systems with electronic warning systems, could help pick up impending pollution problems at an early stage. This technology is still at an early stage, but it promises many applications applied in the health care area first.

(iv) *Pollution control*: The biological treatment of effluents is a long-established practice in many countries. Biotechnology, however, is making it possible to improve such processes and to treat increasingly recalcitrant effluents and materials. BioTechnica, for example, is using its lignin-degradation work as a platform for developing biotreatment processes for such substances as polychlorinated biphenyls (PCBs) and dioxin. In Europe, too, companies like ICI and Ciba-Geigy are working on enzymatic detoxification processes designed to break down such materials as cyanides and by-products from the synthesis of s-triazine herbicides. BioTechnica is also working on ways of treating polluted sites *in situ*, but this is not the only possible approach. Because of the concerns about deliberate release and the difficulties of ensuring that a biodegradation enzyme or microbe reaches all parts of a pollution spill or contaminated site, there is growing interest in the use of closed reactors — as used in the work Occidental Chemical is carrying out on effluents from toxic waste sites. Developments in this field have been highlighted at symposia organised by the Council for Research Planning in Biological Sciences — which has also published a book, "Genetic Control of Environmental Pollutants".

(vi) *Land restoration*: Although very few biotechnology techniques have even started exploratory work in the field on evironmental restoration, there is the potential for using plant biotechnology to mass produce plants for the restoration of eroded land in such countries as Nepal. Researchers have looked at ways of breeding new strains of plant able to tolerate conditions — such as high salt content in the soil, drought or extreme heat — that would otherwise make such areas completely infertile. Biotechnology, and particularly tissue culture, has a great deal to offer in this area.

(vii) *Species conservation*: In the face of ever decreasing wilderness space and human invasion of hitherto undeveloped ecosystems one of the most difficult questions facing conservations: do you leave the few remaining individuals of a threatened species in the wild, or do you go in for captive breeding? There are many pitfalls associated with the latter opinion, but biotechnology again has a good deal to offer if this option is finally chosen — particularly if one is dealing with plants. Tissue culture methods, for example, may help to multiply the numbers of a threatened plant, an approach pioneered by such people as Hugh Bollinger. He used such techniques to produce hundreds of plants from several remaining individuals of a threatened Sonora Desert cactus, from the genus *Pediocactus*. A number of hurdles have still to be overcome, but the approach could help maintain some forms of genetic diversity when all else fails.

6. Concluding Remarks

Each country must interpret environmental and human health problems accruing from dangerous chemicals in terms of its own national situation as action at the national level is the most effective. Many national Governments have a long history of action to protect workers in agriculture and public health, and other industries, from occupational hazards, and standards in this respect have steadily increased, aided by the free interchange of scientific information. Action to limit contamination of the environment around points of discharge, and to control the concentrations of food, drinking water and other products that can be significant pathways to man, has also been taken by many Governments. Concentrations of a number of dangerous pesticides, for example, have fallen as a result of such action.

The main role of the international community in this task is threefold. First, through collaborative programmes of research and analysis, the collective knowledge of the world scientific community can be harnessed to support Governments in their regulatory tasks. Second, by formulating procedures for acquiring and sharing the data through information exchange networks, a more widespread and fuller understanding of issues related to chemical problems can lead to international cooperation to deal effectively with the environmental challenge posed by the pollution. Third, once there is an international understanding of the problem, international negotiations can lead to harmonization of standards and regulations where these are desirable in order to avoid interference with trade, or so as to maintain a comparable standard of human safety everywhere .

In recent years, several encouraging initiatives have been launched through the organizations of the United Nations System (WHO, FAO, ILO and UNEP) and other international bodies:

(i) In 1973, the World Health Organization (WHO) with the substantial support from UNEP launched the Environmental Health Criteria Programme to produce assessments of the best available information about the relationship between exposure to specific pollutants, including pesticides, and their effects on

human health and to provide guidelines for the establishment of primary protection standards. Together with FAO, these organizations established the Codex Alimentarius work, which aims at establishing tolerance levels of trace elements in food and other substances directly ingested by man. These programmes have now merged in the broader and more ambitious International Programme on Chemical Safety launched in 1980 in which ILO is also collaborating.

(ii) In 1976 UNEP established the International Register of Potentially Toxic Chemicals (IRPTC). This is a collection through national correspondents of information about the properties of substances judged likely to cause hazards in the environment, for use as a data base by those making national and international decisions.

(iii) A joint Occupational Health Programme has been maintained by WHO, and ILO has adopted an International Convention and Recommendations to reduce occupational risk and through its International Programme for the Improvement of Working Conditions in the Environment (PIACT) it promotes and supports actions of Member States to combat airborne toxic substances.

(iv) The International Agency for Research on Cancer pursues the evaluation of carcinogenic and mutagenic hazards of chemicals, including pesticides.

(v) Within its Ocean and Coastal Areas Programme, UNEP is cooperating with FAO, IOC and other institutions in the monitoring of DDT, PCB's and other chlorinated hydrocarbons and other environmentally dangerous substances in marine organisms and/or research on the effects of these and other pollutants on marine organisms and ecosystems.

(vi) FAO has recently collaborated with other relevant international organizations such as WHO, ILO, UNEP and GIFAP in the formulation of an International Code of Conduct on the Distribution and Use of Pesticides. This Code was adopted by the FAO Conference in 1985 and is now in its initial stages of implementation in collaboration with other organizations of the UN system, including UNEP.

(vii) Lastly, UNEP has already concluded agreements for a Notification Scheme for toxic chemicals whereby importing countries would be notified whether the chemical they intend to purchase has been banned or severely restricted in the country of export.

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