FOOD AND AGRICULTURE ORGANIZATION
OF THE UNITED NATIONS

UNITED NATIONS
ENVIRONMENT PROGRAMME

IMPACT MONITORING OF AGRICULTURAL PESTICIDES

Proceedings of the FAO/UNEP Expert Consultation
on Impact Monitoring of Residues from the Use
of Agricultural Pesticides in Developing Countries
held in Rome, 29 September to 3 October 1975

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1. INTRODUCTION

The FAO/UNEP expert consultation on 'Impact Monitoring of Residues from the Use of Agricultural Pesticides in Developing Countries' which was held in Rome from 29 September to 3 October 1975 was convened in response to the widely expressed need to encourage and provide additional support for studies into the occurrence and environmental impacts of residues from the increasing amounts of pesticides being used in food production particularly in developing countries.

The expert consultation discussed a range of subjects and a summary of these discussions, followed by a series of recommendations, is included in the report that has been published since the meeting (Ref. AGPP: MISC/22). The recommendations cover various steps that are needed to initiate and/or to extend work in developing countries on the impacts of pesticides in the environment. These recommendations were prepared after study and discussion of much background material.

The present volume contains a selection of the papers that were prepared specially for the meeting. The expert consultation recommended that the volume should be prepared to supplement the report which is being distributed with a view to stimulating further activities on the subject.

2. SOME EXISTING COUNTRY ACTIVITIES

2.1 MONITORING OF RESIDUES DUE TO AGRICULTURAL PESTICIDES IN THE PHILIPPINES

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The Philippines has been referred to as a developing country. Just like any developing country, it did not hesitate to embrace several aspects of the imported technologies of developed countries even though it was not really prepared for the implications of this move. It was acceptance in good faith but with the assumption that these technologies were already tried and tested to minimize, if not totally eliminate, whatever adverse effects they may have; unfortunately, such was not always the case.

Pesticide use is a case in point. Not unlike other peoples of the world, we initially hailed the benefits derived from their use but as adverse publicity on these compounds began to surface, we joined the public chorus of condemnation. Sad to say, this criticism does not come out of enlightenment if only because the intelligence base from which to form opinions is absent. Our people, the technocrats most especially, still need a great deal of educating on the pesticide issue. And yet it would be too simplistic to assume that the environmental and health problems attendant to pesticide use does not exist. This meeting sufficiently attests to the existence, if not the urgency, of the problem.

In this connection, whatever the extent of FAO/UNEP participation on monitoring of pesticide residues that will be decided on, it ought to consider existing conditions as well as plans of in-country agencies along the same lines. The following may be considered for the Philippines.

Pesticide usage in the Philippines

For a total land area of 8 million hectares devoted to crop production, the Philippines imported 4,096.7 tons of agricultural pesticides in 1973. It is interesting to note that 37.5 percent of the total production area is devoted to rice, 30 percent to corn, and only 2.7 percent to vegetables. Considering their production technologies in addition to areas, it is safe to assume that the bulk of agricultural pesticide use in the country is concentrated on these crops. Also, in view of the perennial food shortages and the overall undernourishment status of the country, the government launched several intensified food production programs, namely, "Masagana 99" and "Palayan ng Bayan" for rice, "Masaganang Maisan" for corn, and "Gulayan sa Kalusugan" for vegetables. These intensified production efforts naturally required massive use of pesticides for crop protection. Recommendations on crop protection are made through multi-agency Technical Committees. While other quarters view with alarm the fact that no alternatives to pesticides were included in these recommendations, it is inescapable since for a long time, crop protection has been considered synonymous to pesticide use and other crop protection methods have been all but forgotten.

Rice production technology can be viewed as the biggest contributor to pesticide residues in the environment because paddy rice farming is practiced in about 80 percent of the total area for rice production. Eventually, irrigation waters are released to outlet canals which join rivers emptying to the sea or freshwater lakes. Granular insecticides are finding widespread acceptance with carbofuran and BHC (HCH) being the most widely used compounds.

Vegetable production presents the biggest danger from pesticide residues in food since 65 percent of our protein intake is from vegetables. Two major contributory factors to this problem may be mentioned: 1) the calendar method of insecticide application, and 2) the resistance of the diamondback moth, Plutella xylostella, the most serious pest of crucifers, to many insecticides. Other serious pests of vegetables are likewise showing resistance to several insecticides. It is very difficult to wean farmers from age-old habits of calendar application of insecticide in the absence of definitive research results showing the equal effectiveness of fewer but properly timed applications. Also, despite the unnecessary use of pesticides, income from vegetable raising is still lucrative. The resistance problem not only engenders the calendar system of insecticide application but also caused the use of increased dosages and application times. Because of this, the farmer is also in a dilemma since it has reached a point where his choice of insecticides is becoming very limited; for example, in a recent interview with farmers in one of the major vegetable producing areas, we were informed that only cartap hydrochloride (Padan) was still effective against Plutella and that quinalphos (Bayrusil), methamidophos (Tamaron or Monitor) and triazophos (Hostathion) are no longer effective. Even cartap hydrochloride is beginning to lose effectiveness.

Another potential source of environmental contamination due to pesticides is the DDT still being used in malaria eradication programs. Although importation of the compound was voluntarily discontinued as early as 1969 by chemical companies, some of the DDT used for the malaria eradication campaign also manages to clandestinely find its way to the hands of farmers.

Involvement of agencies in monitoring

Although the involvement of government agencies in pesticide monitoring is reason for dismay from several quarters, it must be viewed realistically against priorities and value systems in developing countries. Indeed, if a country is faced with food shortages, why worry about residues? For a hungry stomach, there cannot be any distinction between above-tolerance and below-tolerance residues in food. A developing country is also faced with other development problems and pesticide residue monitoring may have to have a lower priority rating.

1) The Food and Drug Administration

This agency, which is under the administrative jurisdiction of the Department of Health, is charged with the duty of safeguarding the wholesomeness and safety of foods and drugs. While it has toyed with the idea of pesticide residue monitoring for several years, more pressing areas of concern, among them medications, as well as inadequate material support has forced it to default on pesticide residues. This agency, however, has adopted US-FDA tolerances on food for the country and it would be willing to enforce it if a linkage can be made with agencies having analytical capabilities. The technical expertise in this agency, vis-à-vis pesticide toxicology and monitoring need to be upgraded.

2) The National Pollution Control Commission

This agency logically should provide the mechanism for monitoring pesticide residues in the environment but because of other priority areas, e.g., industrial pollution, it has only managed a minimal amount of work on pesticide monitoring. Technical expertise on pesticide toxicology and residue monitoring of this agency also needs upgrading.

3) Bureau of Plant Industry

As an agency under the Department of Agriculture, it operates several experiment stations and has a Crop Protection Division which responds to emergencies and makes long-range crop protection programs. A big boost to its activity is the RP-West German Crop Protection Strengthening Programme which will provide a Pesticide Residue and Quality Control Laboratory with at least 4 gas chromatographs. The laboratory will soon be operational and will receive samples of different crops from the several experiment stations. It may be noted, however, that not unlike other supposed bilateral programs, expertise outside of the concerned Philippine agency was never consulted on plans at the national level and it is still the supposed expert from the donating country who dictates what is best for us. Although the program has a training component, it is limited to gas chromatography and may be considered inadequate from the standpoint of an academic base in toxicology, pesticide chemistry, and analysis as a whole. Also, monitoring of non-crop items is not part of the program.

4) The University of the Philippines at Los Baños

True to expectations of a University taking the lead in a majority of innovative programs, the University, through its Department of Entomology, College of Agriculture, took the first steps in establishing a Pesticide Residue Laboratory. The establishment of the laboratory was coupled with advanced training for staff members in all aspects of pesticide management. Through research projects and donations from the private sector, a respectable laboratory is now operational. A very important backstop to the laboratory is an instrument service group of the University operated through the Department of Agricultural Engineering. This group has staff members with advanced training in electronics so that instrument troubleshooting is not a problem. A related laboratory exists in the Department of Chemistry doing residue monitoring of a nearby lake ecosystem; a sad note here is that the activities of this group will be discontinued by December 1975.

The Pesticide Residue Laboratory assumes a threefold function in accord with that of the University. Research work deals primarily with residues in crops like rice, corn, and vegetables together with limited work on pesticides in the environment. Degradation studies in agroecosystems and analysis of market-basket samples of vegetables are the major areas of concern. As part of its extension activities, it analyzes samples, upon request and at a minimal charge, from farmers and other government agencies. A very important contribution of the University is the offering of courses in "Insecticide Toxicology" at the undergraduate and graduate level and "Pesticide Residues" at the graduate level. The latter course deals with all aspects of pesticide residues especially analysis. The courses will be offered starting the second semester of this school year (beginning October) by staff of the laboratory and concerned sectors have been duly notified.

5) Other Government Agencies

Two agencies deserve special mention, the Philippine Atomic Energy Commission (PAEC), and the Philippine Tobacco Administration (PTA). PAEC has gas chromatographs, does some analysis work for other agencies, but seems undecided on what specific projects to undertake. PTA has obtained a gas chromatograph as part of its laboratory but what is puzzling is that it has had no output and it is running to other agencies for their analysis needs; there seems to be only one conclusion and that is that the instrument is not being put to use. While the PAEC staff are competent in chemistry, their expertise on pesticides needs to be upgraded. There is no question that upgrading of the PTA staff is a necessity.

6) Agricultural Chemicals Companies

So far, two agricultural chemicals companies have analytical facilities but they are used mainly for quality control or in support of sales activities. No monitoring work may be expected from this sector.

Problems in monitoring

From the above discussion of the activities of the Philippine agencies, several problem areas may be mentioned.

1) Trained personnel

The absence of key personnel with well-rounded background in pesticide toxicology/ management, chemistry, and analysis is evident in most laboratories/agencies. While most laboratories have chemists in their employ, they may be categorized as beginners as far as residue analysis is concerned. For one, the chemistry curricula do not give them technical expertise beyond the so-called "cookbook chemistry". In other words, they can follow printed procedures but they cannot innovate because they are grossly inadequate in the theoretical background behind each analytical step. On the other hand, innovation is demanded particularly in developing countries. Training in instrumentation is also inadequate.

For key personnel who can conceptualize projects and innovative approaches, there is no substitute for advanced studies with original independent research guided by a competent adviser. This is where most of our key personnel are lacking; most of them occupy these key positions by reasons of seniority and they cannot be expected to provide dynamic leadership and guidance to their subordinates. Our experience has been that these people are apt to overdramatize their meager results, report results from methods considered non-valid by knowledgeable circles, or conduct irrelevant, if not outdated researches.

A logical consequence of the inadequacy of properly trained individuals is that the few who meet the criteria are literally swamped with work not only through priority national researches but also requests from private parties.

2) Equipment

It cannot really be said that gas chromatographs for monitoring purposes are lacking in the Philippines because there are several idle in the wrong laboratories or agencies. These agencies naturally want to cling to what they have on the lame excuse that they will make the instruments operational soon. In the absence of a single authority which can divest these agencies of "White elephants", the situation is indeed regrettable. A related problem is that of spare parts of instruments. Most of these parts are not locally available and it takes time to order them from the United States.

Probably, the biggest need would be for gas chromatographs with specific detectors and other sophisticated supportive or confirmatory instruments.

3) Costs

Cost of equipment, supplies, and reagents are generally prohibitive because of the unfavorable rate of exchange with supplier countries as well as the absence of a petrochemical industry. This situation cuts down considerably on the output of laboratories.

Suggested areas of FAO/UNEP involvement

Because it has access to expertise in different fields of pesticide monitoring, FAO/UNEP can provide valuable support to in-country efforts. This involvement may be categorized into two, material help and training programmes.

1) Material or physical support

While there is some analytical equipment in the country, it is usually limited to gas chromatographs and as already mentioned, these are in the wrong agencies. The possible creation of the Philippine Pesticide Board (PPB) with functions similar to the US Environmental Protection Agency, would help the country considerably. It would be advantageous if FAO/UNEP can channel its support through this new agency. If creation of the PPB will not be pushed through, FAO/UNEP can always consider the idea of putting up a monitoring station or giving support for the expansion of an existing Pesticide Residue Laboratory (PRL). Personal bias aside, close linkage of such a laboratory with academic institutions is very advisable — the laboratory would then have a multiplier effect through academic programmes and would be less subject to unnecessary interferences.

If an enlargement of the present PRL of the University of the Philippines at Los Baños would be possible, a proposal we would like to place before FAO/UNEP, it would have the advantage of a ready pool of expertise which could interact with experts in other disciplines within the University, require minimal amount of equipment to be added, make available adequate supportive services especially in glassblowing and electronics, and achieve a multiplier effect of its training component. The probable single major fund outlay would be for a small building to centralize the facilities.

It may also be stressed that since pesticide residues and crop protection are closely associated, the idea of a Regional Crop Protection Center for Asia now deserves another round of serious consideration. Such a regional center would have outreach stations in other Asian countries which could serve as a nucleus for monitoring activities.

2) Training programmes

FAO/UNEP can contribute significantly to the overall in-country monitoring effort through a well-planned training programme. In the Philippines, this cannot be handled any better than is being done in cooperation with the University of the Philippines at Los Baños. Such a training programme should stress not only gas chromatography, as seems to be the vogue nowadays, but should include fundamentals of crop protection entomology, pesticide management, theoretical bases for techniques, and the advantages and limitations of other analytical techniques. These areas are not normally within the expertise of individually oriented agencies.

Since the training component would be incomplete without facilities, it is recommended that material support be given to the expansion of the PRL at the University of the Philippines at Los Baños. With the necessary support, the staff of this laboratory and that of the University can even form the nucleus of a training staff for an Asian Regional Training Programme on Pesticide Monitoring.

2.2 WORK PROGRAMMES AT THE PESTICIDE RESEARCH LABORATORY, MINISTRY OF AGRICULTURE AND COOPERATIVES, BANGKOK, THAILAND, 1962 TO 1974

(With particular reference to environmental monitoring for pesticide residues)

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1) Background of the Pesticide Research Laboratory

The PRL was officially opened in 1967 through funds provided by the Ministry of Agriculture and Cooperatives to enforce the provisions of the 1967 Poisonous Articles Act. It is located at the Central Experiment Station at Bangkhen, 20 km. north of Bangkok. Originally housed in a former classroom, it now occupies a modern four-story laboratory building of concrete construction.

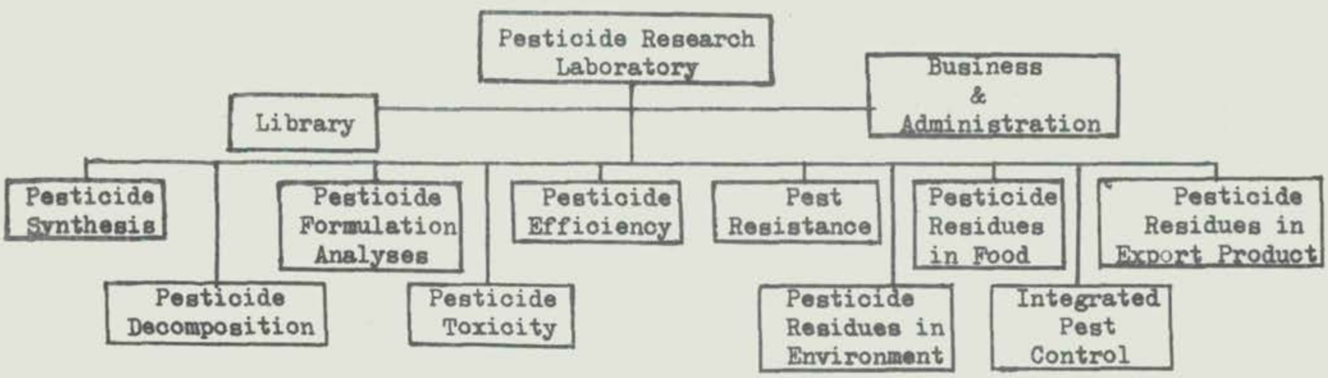
(a) Funding

Total government funds available for the first year's operation were 750,000 Baht or US $36,057 (1 US $ = 20.8 Baht). In the Budget for Fiscal year 1973, the project was provided 4,264,000 Baht. According to the Third Economic and Social Development Plan 1972 - 1976, the annual budget of the project is:

Fiscal Year	Budget (million Baht)
1972	5.00
1973	5.50
1974	6.00
1975	7.00
1976	8.00

(b) Organisation and staff

At present, the Pesticide Research Laboratory has 51 staff. These include: 3 Ph.D., 2 M.S., 20 B.S., 21 Cert. in Agr., 1 Cert. in Administration, 1 Cert. in Electronics, 1 Cert. in Photography, and 2 Cert. in Secondary school. The project is divided into three parts, as described in the following organisational chart.



(c) Activities

The Pesticide Research Laboratory is responsible for study and research on: synthesis, analysis, toxicity, detoxication, advantages and other properties of pesticides used in pest control. Also included are studies on methods for solving problems arising from incorrect usage of pesticides which directly affect man, useful domestic and wild animals, and the environment. The information obtained from research data is forwarded to agriculturists and the public. This provides for more efficient use of pesticides, with less danger to themselves and non-target organisms. The project enforces and carries out provisions of the Poisonous Article Act 1967, and is important in tax collection.

2) Present assistance from the Food and Agriculture Organisation of the UN

Under a 1969 agreement between the Government of Thailand and the United Nations Development Programme, the Food and Agriculture Organisation of the United Nations has provided assistance in the form of equipment, fellowships, and consultants to five organizational units of Plant Protection Project THA 68/526, the PRL being one of the five units. The combined budget of the Project which became operational in 1970 and extends through 1975 is approximately $2,000,000 of which about 35% was designated for the PRL. A second 5 year phase is now under negotiation.

3) Scientific resources - Analytical capabilities

The laboratory has present capability for routine analysis for pesticide residues in water, soils, crops, and animal products by gas chromatography, thin layer chromatography, and spectrophotometric methods. Analyses are largely limited to the parent chlorinated hydrocarbon and organophosphate insecticides which are determined by conventional multiresidue methods. There is a shortage of technically qualified personnel in residue analysis, particularly in the application of more sophisticated methods for pesticide metabolites or alteration products and newer pesticides which are not measured by the common multi-residue methods. The shortage would be accentuated by any expansion of the present work programme to include environmental monitoring. The available GC instrumentation is on the whole adequate, with sufficient flexibility in detection systems (EC, flame photometric, thermionic flame ionization, and Coulson conductivity). However, there is a need for additional capability in fluorometric analysis, atomic absorption spectroscopy, and liquid-liquid chromatography. This would include instrumentation and training of analysts. Additional constraints are the excessive costs and delays in procuring high purity solvents, special reagents, cylinder gases and glassware. The establishment of regional or mobile laboratory units would greatly facilitate any large scale environmental monitoring programme. At the present time all samples must be transported to Bangkhen for analyses.

4) Pesticide usage in Thailand - regulatory control

The importation of pesticides in Thailand showed a steady increase from 1957 to a peak in 1969 of 15 million Kgs. with a value of 230 million Baht. The available figures show a slight drop in recent years. Much of the imported pesticides are technical grade active ingredients which are reformulated here, so that the actual retail sales values are considerably higher than the indicated value of imports. The full spectrum of pesticides are represented but the most widely used are the chlorinated and organophosphate insecticides. It is known that pesticides are heavily used on certain crops, notably cotton, and it follows that certain geographical areas of high use now bear a considerable burden of the more persistent pesticides in soils. The importation and use of pesticides in the Kingdom is controlled by the Poisonous Article Act of 1967, as amended in 1974. As noted above, the Pesticide Research Laboratory was established for the purpose of enforcing the Act. The actual administration of the Act is by a Poisonous Article Control Board with memberships from Ministries of Agriculture, Public Health, Industry, Defense, Interior, Economic Affairs and Customs Department.

5) Programmes and findings of the Pesticide Research Laboratory

Summary reports of the Pesticide Research Laboratory since its inception in 1968 and through 1974 are:

A. Pesticide residues

Residual life - Pesticides were applied by spray application to: Chinese cabbage, Chinese mustard, coriander, lettuce, cabbage, and onions. The vegetable crops were harvested for pesticide residue analysis.

Market samples

Vegetables and fruits - A total of 1,769 samples of vegetables and fruits from Bangkok and nearby markets were analysed by chemical methods. Excessive levels of residues, potentially harmful to consumers, were found in 687 samples, or about 38% of the samples. Residues were principally organophosphorous insecticides: malathion, diazinon, dimethoate, dibrom, phosdrin, parathion and methyl parathion. High quantities of carbamate insecticides were found in some samples, and DDT residues were found in several samples.

Fish - Samples totaled 453 collections of salted fish purchased in markets. Residues found consisted primarily of organochlorine residues.

B. Pollutants

Soil - Samples from farmers' fields in the North-East, North, and Central plain area were analysed for pesticides. This was part of the programme to assess the quality of the environment; 443 samples were analysed. Residues of DDT, dieldrin, endrin, DDE and TDE were found in: 48.7%, 28.6%, 35.9%, 21.2% and 5.2% of the soil samples from the North, Central, and North-East areas, respectively.

Water - About 300 samples of water were collected from the main rivers and water sources in the country. Residues found were mostly DDT and dieldrin, but concentrations have not yet reached harmful levels.

(1) Degradation: Deterioration of DDT, diazinon, and 2, 4-D in soil was studied. There was only partial degradation of DDT in clay, sand, sandy loam, and clay loam soils. There was rapid deterioration of diazinon in these soils. Studies with 2, 4-D were incomplete.

(2) Decontamination: Vegetable samples treated with: DDT, Parathion, phosdrin, carbaryl, malathion, and dimethoate were studied. Water and detergent washing reduced residues by 50 - 75%.

C. Formulation Analysis

Highly sensitive TLC and GLC methods were employed in the analysis of 2,375 pesticide samples. Samples were obtained from Ministries, Departments, and various institutes and agriculturists.

D. Toxicology

From 196? through 1974, experiments on acute oral toxicity of pesticide to mice have been carried out. The pesticides studied included dieldrin, dimecron, zinc phosphide, parapel, diphacinone, toxaphene, DDT, TDM (toxaphene-DDT-methyl parathion **mixture**), DDVP, lindane parathion, endosulfan, lannate, and lethane. The chronic toxicity of TDM mixture was also studied. The accumulation of DDT, DDE, methyl-parathion, and parathion in rats and humans was studied. Tissues a alysed included blood, urine, brain, liver, kidney, fat, sex organs.

E. Integrated Pest Control

The purpose of this project was to develop an effective and economic method for control of pests on cotton. The programme was initiated at Amphur Nampad and Fakta, Uttaradit Province to 1965 and expanded in the years through 1974 to include experimental plots in Sukhothai Province. The programme has successfully demonstrated that surveys on populations of predator insects and economic pests in conjunction with the judicious use of chemical treatments lead to reduced cost for insect control and increased yield in cotton.

6) Proposal for assistance under the UNEP/FAO Monitoring Programme

The preceding description of the Pesticide Research Laboratory demonstrates that the operations of the Laboratory are consistent with the aims and objectives of the Impact Monitoring of Residue Project described in the UNEP Project 010 14 005 (306). However, current efforts have to be expanded in order to obtain more substantial information on the following subjects:

A. Pesticide Residues

(1) Persistance of pesticide residues, especially in cotton field where pesticides are heavily employed.

(2) Decontamination of pesticide residues at household levels.

(3) Existence and stability of pesticide residues in water and soil.

(4) Effects of soil or water pH, humidity, or other aspects of the physical environment.

(5) Studying the existence of elements, for example, mercury, lead, cadmium in the environment.

B. Integrated Pest Control

(1) Obtain more reliable methods to control pests by minimizing pesticide usage or utilizing the "Dirty-field techniques" or using selective insecticides. The purpose will be concentrated on cotton fields.

(2) Publicize the methods to the farmers.

C. Toxicology

(1) Studying the effects of pesticides and its tolerance level to chicken, rat, rabbit or other mammals under prolonged periods of feeding.

(2) Pinpoint appropriate pesticide synergists to be used in the field in order to minimize amounts of pesticides used.

D. Environment

(1) Survey the natural habitat of living things. Observe the changing trend of the population.

(2) Studying the particular effects of pesticides on various wild life. Under these future proposals, special funds are necessary for the following:

Subjects:

(a) Trained scientists in different areas of studies. A short and long term training period are needed.

(b) Laboratory facilities and equipment: many kinds of instruments are essential such as atomic absorption, gas-liquid chromatography, pH meter and spraying machines.

(c) Chemicals and solvents: Government supplies of chemicals and solvents are usually inadequate for lab work and study.

(d) Consultants and experts: for preliminary conduct of studies in certain fields of importance.

(e) Transportation: vehicles for field surveys are needed. A mobile laboratory van equipped with pesticide residue analysis equipment and other facilities.

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2.3 AN ENVIRONMENTAL AND ECONOMIC STUDY OF THE CONSEQUENCES OF PESTICIDE USE IN CENTRAL AMERICAN COTTON PRODUCTION

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The aim of this project is to develop a systems management programme to reduce the environmental effects of pesticide use in Central American cotton production.

The project includes documenting the environmental effects of pesticides used in cotton, including both the economic and public health aspects. At the same time, emphasis is given to substituting an integrated cotton pest control programme for the routine spray schedule. The initial efforts of the project have in part focused on gathering and organising existing data. Extensive sampling and residue analysis has been undertaken, and some preliminary results are presented here.

Detection of pesticides in the environment

The detection of pesticides in the environment is intimately related to the study of the consequences of pesticide use. The presence of pesticide residues can be viewed as a "consequence" of pesticide use if one considers "critical" levels of contamination as inherently undesirable. Conversely, one could study the degree of contamination through its effects, such as human, plant and animal poisonings.

This summary discusses pesticide contamination in Central America, measured both directly and by analysing documented examples of its effects on living things. Direct measurement covered time as well as space dimensions, and to some extent, so did the study of environmental consequences. The latter consists at the present time almost entirely of human poisonings in the four Central American countries that grow cotton.

Most of the components of the Central American environment are contaminated with organo-synthetic pesticides. Only 10 out of 846 samples analysed between 1974 and 1975 were absolutely free of pesticides. Seven of these 10 samples consisted of water, and most pesticides used on cotton are not water-soluble.

The over-all level of contamination was not very high, but pesticides concentrated on a few products abundantly. Most samples had less than one part per million (ppm) of DDT and its metabolites (DDT was the material most frequently found). Beef and cow's milk, however, had the highest levels of contamination. They ranged from a low of 0.02 ppm to a high of 102.59 ppm of DDT plus metabolites for beef, and from 0.30 to 32.31 for milk. The maximum levels are way beyond tolerances for countries like the United States.

There is no certainty as to what are the effects of occasional doses of this magnitude on human beings. However, levels of 5 ppm of DDT plus metabolites in beef cause economic damages to beef exporters. In the past three years, Guatemalan and Salvadorean exporters lost a total of $720,000 because of rejections in the United States market.

The samples analysed covered areas of high and low pesticide use in three Central American countries. Samples from Nicaragua could not be obtained in the first year. For that reason, it was impractical to compare levels of contamination in countries with and without widespread integrated pest control. Nicaragua is the only country where integrated control is noticeably used.

Table 1 shows the environmental components analysed and their mean levels of contamination.

Table 1. Average levels of contamination for selected items in Central America, 1974/75

Item	No. Samples	Mean Residue (DDT + Metabolites in PPM)
Cow milk	139	4.22
Beef	225	5.91
Cheese	18	3.30
Fruit	10	0.15
Shellfish	109	0.70
Wildlife	10	2.65
Grain	91	0.068
Water	53	0.0073

Source: Central American Research Institute for Industry.

Contamination was pervasive, although higher levels were naturally found in high pesticide use areas. Mean levels of contamination for beef and milk were significantly higher in cotton-growing areas (90% of all pesticides used in Central America is sprayed on cotton). Table 2 shows mean levels of contamination found in cotton and non-cotton areas for these two products.

Table 2. Contamination of beef and milk in cotton and non-cotton areas of Central America

Item	PPM of average level of contamination (DDT + metabolites) Cotton Areas	Non-cotton Areas
Beef	4.418	0.4143
Milk from one cow*	5.870	0.3500
Milk from whole herd	3.47	0.3500

*Repeated samples from the same animal to minimize error.

The levels of pesticide residues in milk behaved differently through time in cotton and non-cotton areas. Residues were both lower and more stable in non-cotton areas. This is because most pesticides are sprayed on cotton during the months of September, October, November, and December. During these months DDT residues in milk were highest.

Milk has been found to be a very good reference point for monitoring pesticides. It is easily obtained, contains sufficient fat, and sampling errors can be reduced by monitoring the same animal and analyzing its feed and water.

The results of milk samples analysed in zones with different pesticide loads at different times suggested that the contamination of this product is directly related to pesticide use in cotton. Three farms were monitored; one in the middle of the cotton area, another very near to cotton and the last one some 45 kilometers away. Sampling started April 21 and has been going on every week to the present time, although the results presented here cover the period through July 3 only. Samples were obtained from the same cow every time as well as from a mixture of milk from the whole herd.

The highest average contamination occurred in milk from the farm in the middle of the cotton area. The levels were 3.47 ppm for the whole herd and 5.87 ppm for the control cow (DDT + metabolites). For the milk from the farm near cotton these averages were 1.13 ppm and 0.93 ppm, respectively. For the samples taken 45 kilometers away from cotton the average for the whole herd was 0.35 ppm between April and July of 1975.

In the two zones nearest to cotton the levels of contamination showed a close association with supposed insecticide use in cotton. During April the levels were at their highest, and showed a decreasing tendency until the end of August, when pesticide applications are started in cotton farms, and when the levels go back to what they were in late April. Furthermore, the effects are more clearly seen the closer a farm is to cotton areas.

As most pesticide contamination studies, the present one is of a preventive nature. We do not know what social benefits and costs are associated with each level of contamination. We want to know, however, where most of the poison is accumulating, which levels it is reaching, through which channels, and how it behaves through time.

One thing is certain: pesticide use in cotton production was partly responsible for 3630 cases of human intoxication in 1973, of which 15 cases were fatal. The total figure is lower than the one for 1972, when 6078 pesticide intoxication cases were reported, with 15 fatalities. All of these cases were confirmed through actual examination of medical files in four Central American countries. The number of intoxications is lower for 1973 probably because of more widespread preventive medicine programmes. Preliminary figures indicate that the number of cases for 1974 will be even lower.

The number of pesticide poisoning cases is closely related to pesticide use in cotton production. More significantly, most cases occurred during the months of intensive pesticide use. According to 11 years of monthly data from El Salvador, 74.5% of all cases occurred during the months of September, October, November and December.

Table 3 shows the total number of pesticide intoxications in recent years.

Table 3. Non-fatal pesticide poisoning cases in Central America, 1972-1974

Country	1972	1973	1974
El Salvador	3163	1703	1274
Guatemala	2313	1621	946
Honduras	30	43	37
Nicaragua	557	243	*
Total	6063	3615	*

*Not available yet.
Source: ICAITI

Table 4. Fatal poisoning cases in Central America, 1972-1974

Country	1972	1973	1974
El Salvador	5	5	6
Guatemala	2	0	2
Honduras	4	6	0
Nicaragua	4	4	*
Total	15	15	

*Not available yet.
Source: ICAITI

The different activity of different types of pesticides suggests that in order to detect contamination one has to develop suitable methodologies. Direct analysis makes it possible to detect highly persistent toxics such as those belonging to the group of chlorinated hydrocarbons (DDT + Toxaphene). The short stable life of organophosphorous pesticides (ethyl and methyl parathion) makes direct detection very difficult. Yet the organophosphorous pesticides are among the most toxic substances currently used; they are responsible for almost all of the cases of human intoxication reported.

For this reason, pesticide monitoring works best as part of multi-disciplinary environmental management programmes. An understanding of the effects of pesticide use will aid in detecting sensitive policy areas, especially in underdeveloped countries where environmental expenditures are less obviously profitable. For instance, it may be more economical to set up preventive medicine programmes than to reduce pesticide use or shift crops to less than optimum areas. Within this context, multi-disciplinary analysis can provide answers to the numerous dilemmas that arise in environmental management.

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2.4 THE PROBLEMS OF PESTICIDE USAGE IN SUDAN

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1) Agricultural usage of pesticides

Cotton, which is an important cash crop for the Sudan, is by far the biggest single consumer of pesticidal treatments. In the Gezira scheme (2 X 10^6 acres) which is the main cotton production area, the crop receives a seasonal average of 6-7 sprays of mixtures of organochlorine and organophosphorous insecticides. Other cotton production areas include the Blue and White Nile schemes (total area 400 X 10^3 acres), Khashm El Girba (300 X 10^3 acres), Nuba Mountains (80 X 10^3 acres) and Tokar delta (40 X 10^3 acres). Crop spraying is carried out regularly in all these areas, although less frequently than in the Gezira, ranging from two sprays in the case of Tokar delta and Nuba Mountains to six sprays in Khashm El Girba. The most widely used compounds are DDT, dimethoate, endosulfan, toxaphene, carbaryl, monocrotophos and parathion-methyl. Considerable amounts of dieldrin, aldrin, BHC and mercurial fungicides are also used for seed treatment of cotton and other crops prior to sowing.

Regular application of BHC and dieldrin for the off-season control of Sorghum bug (Andat) and locust; and that of 2,4-D against the water Hyacinth in the White Nile are also important features of pesticide usage in the Sudan. Other minor uses include the use of phosphine (Phostoxin) and methyl bromide for stored pests control and that of some organophosphorous compounds against the pests of wheat and vegetables.

The amounts of major pesticides currently used are shown in Table 1.

Table 1. Annual usage of major pesticides in the Sudan*

Pesticide	:	Quantity (lbs active ingredient)
DDT	:	3 x 10^6
Dimethoate	:	1.7 x 10^6
Toxaphene	:	1 x 10^6
Endosulfan	:	1.4 x 10^6
Carbaryl	:	3.5 x 10^5
Parathion-methyl	:	2.5 x 10^5
BHC	:	3.0 x 10^4

*Estimated from miscellaneous records for 1974/75

In view of the country's ambitious agricultural development plans which are already under way including the establishment of three new major sugar cane plantations and one major Gezira-type scheme, the usage of pesticides is expected to increase within the near future. Moreover usage of herbicides is expected to become a common practice particularly in areas of crop intensification, e.g. in the Gezira and Khashm El Girba. Pesticide usage in vegetable and fruit production is continuously increasing due to the rising cash value of these commodities in both local and foreign markets.

2) Problems associated with the use of pesticides

Despite the increasing usage of pesticides followi g the introduction of DDT in the Sudan Gezira in the mid-forties and until recently, very little concern was shown over the environmental consequences and ecological impact of this practice. During a period of thirty years of chemical crop protection in the Gezira, scores of beneficial organisms might have been progressively eliminated, numerous vital ecological processes disrupted, and irreversible damage done to the wild life. In the absence of accurate records and because of the involvement of other factors of ecological significance, such as changing cropping systems, it is very difficult to identify precisely what effects did take place and whether they were mainly related to pesticide usage. Examples of problems cited below will be restricted to cases where the causal role of pesticides has been strongly implicated.

(a) The successful control of the cotton jassid Empoasca lybica De Berg with DDT applications was followed by the rising pest status of the cotton whitefly Bemisia tabaci Genn., which was previously less important. Presently the whitefly is the main pest of the Gezira cotton inflicting severe economic damage, although its role as a leaf curl vector has been reduced through the successful breeding of disease-resistant cotton varieties. Not only did the whitefly assume a major pest status, but also the duration of its pest activity on the crop was prolonged over nearly most of the growing season. Particular damage was caused by its survival on the crop towards the end of the season, thereby lowering drastically the grade of the cotton lint by contaminating it with honey-dew secretions. The reasons behind these changes are rather complex and are far from being explained as yet.

Another pest which has been gaining in importance over the last ten years in the Gezira, is the bollworm Heliothis armigera Hbn. It is rather surprising that the increase in bollworm danger has accompanied closely the intensification of chemical spraying in the Gezira. The control of Heliothis in itself poses serious environmental hazards because nearly all the DDT used in the Gezira is directed against this pest.

(b) Although there is no laboratory data on the changes in susceptibility of field strains of the insect pest complex of the Gezira cotton, evidence for the prevalence of pesticide resistance does exist. The increase in the number of sprays from 2-3 in the sixties to over 6 at present and the use of higher doses of chemicals in some cases are valuable guides in this respect. The continuous use of mixtures of insecticides of widely differing chemical structures and at variable dosage rates is likely to enhance the development of broad spectrum resista ce involving majority members of the known pesticidal chemical groups. It is regrettable that despite the long history of entomological research in the Gezira, there never existed a proper resistance monitoring programme.

As an indirect effect of the intensive use of pesticides on cotton in the Gezira, Anophelene mosquitoes which are malaria vectors were rendered resistant to organochlorine insecticides and possibly to some of the organophosphorous compounds. During the last three years the Gezira has experienced a terrific resurgence of malaria. Analogous situations were also reported from some Central American cotton growing countries.

(c) Acute intoxication of fish, birds and wild animals is of common occurrence, especially when compounds such as parathion-methyl, monocrotophos and endosulfan are used. However, the highly developed extension and advisory service of the Gezira administration keeps such risks at a minimum. In other cotton growing areas, there are reasons for concern over these effects, especially where highly concentrated ULV chemicals are being introduced.

(d) The Gezira is a fairly densely populated area which also produces large amounts of grain, milk, poultry and meat products. Large scale aerial spraying during the cotton growing season creates a critical situation for human health in this area by polluting the total environment. So far no epidemiological studies were done and the range of pesticide residue concentrations in the Gezira population is not known. Therefore, there is an urgent need for the collection of this type of data before the significance of associated problems could be estimated.

3) Suggestions for future work

The range of problems encountered to date show that basic changes in the current crop protection policy are needed before a useful programme on pesticide residues could be drawn up. Part of the solution lies in the adoption of a programme of integrated pest control in the Gezira. Failing this, the rate at which new chemicals are being approved for use on cotton and other crops in the Gezira would place in jeopardy the efforts directed towards minimising environmental hazards of pesticides. Given the chance of possible FAO/UNEP expert and technical aid, full advantage should be taken of it by stepping up our capabilities for pesticide studies and coordinating these effectively with the pest control programmes.

The following are suggested priority areas, within the field of impact monitoring, in which work should be supported:

(a) Effects of pesticides on the structure of the cotton pest complex

Work on this problem bears strong relevance to the integrated control studies. As mentioned in section 2, major problems are encountered in this area and the specific role of pesticide usage is not known. This is a kind of continuous programme where all candidate pesticides could be studied under a variety of experimental conditions.

(b) Studies on the mechanisms of pesticide dissipation and transformation under the Gezira conditions

Such studies form the backbone of any pesticide impact monitoring activity. The limited work done so far on some organochlorine insecticides indicated some characteristic differences from the known behaviour of these compounds in temperate localities and under different farming systems.

(c) Impact monitoring of pesticide residues in the Nilotic ecosystems

Several areas are of interest in this respect. Foremost is Lake Nubia on the Sudan/Egypt border. This is a large reservoir of water formed by the construction of the Aswan Dam and is an important fisheries ground for both the Sudan and Egypt. By virtue of its geographical position away from the main pesticide areas in Sudan, it is an ideal monitoring station for studying riverian residue transport and their effects in the biggest man-made lake. The White Nile system south of Khartoum, where regular application of 2,4-D is taking place, is another candidate area.

(d) Studies on the effects of herbicide use on soil fertility and flora in the Gezira

Recent large scale trials with herbicides gave promising results in the control of weeds in groundnuts. It will not be long before the usage of herbicides in the Gezira and possibly Khashm El Girba will be widespread. Studies on this newly introduced class of pesticides are just timely and are necessary to prepare the ground for research-guided weed control practices.

4) Government departments involved in pesticide research and the possible role of the FAO/UNEP programme

At present there are three departments in the country which have the basic capabilities for tackling pesticide residue research. These are (1) The Agricultural Research Corporation, Wad Medani, (2) The Plant Protection Directorate, and (3) The Ministry of Health Government Chemist Laboratory, Khartoum.

While residue work is a fairly well established activity at the Agricultural Research Corporation, the two latter departments are just beginning, with the help of the German Federal Republic in the case of the PPD and with aid from UN/IAEA for the Ministry of Health.

A suitable method for offering support for investigation in this field through the FAO/UNEP programme would be the development of a system slightly more generous than the 'research contract' which is usually granted by the IAEA. Project proposals should be approved by the National Pesticides Committee, a government inter-departmental body responsible for all aspects of pesticide usage in the country. The application of a research contract-type aid is certainly less expensive than major UN agency involvement and at the same time will prove more satisfying to the participant scientists as they will be able to cater effectively to the specific needs of their laboratories or projects.

In concluding this contribution, I would like to express my thanks to the officers of the Plant Protection Service of FAO for inviting me to attend this meeting and to the Director of the Agricultural Research Corporation, Sudan, for his permission to participate in the exercise.

2.5 ENVIRONMENTAL PROBLEMS ARISING FROM THE USE OF PESTICIDES IN MALAYSIA

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1) Introduction

Malaysia is situated north of the Equator in the Tropical rain zone. The total area of the country is 129,000 square miles including the States of Sabah and Sarawak on the island of Borneo. Temperature ranges from 70 - 90°F and rainfall from 60-160 inches with an average of 100 inches. There is a total cultivated area of 7 million acres, with a population of about 11 million people.

The main crops are natural rubber (*Hevea brasiliensis*), palm oil (*Elaeis guineensis*), coconut and rice. In 1974, Malaysia produced 1/3 of the world's palm oil; it also grows about 85% of its own rice consumption and within a few years hopes to be self-sufficient. Other crops grown are vegetables, fruits, cocoa, coffee, tea, tobacco and pepper. Cotton is not cultivated. There are still potentially large acreages of agricultural land available and the choice of crop is important in developing the land.

At present pesticides are controlled under the Poisons Ordinance 1952 enforced by the Ministry of Health. In order to provide more meaningful control of pesticides, the Pesticides Act, 1974 will be implemented in the near future. This will include the registration or approval of pesticides which controls the nature of labelling, packaging, toxicity, hazards and efficacy of pesticides. In addition, pesticide manufacturers, packers, re-packers, retailers and commercial spray applicators will be licenced in order to control the various aspects of pesticide manufacture and use, including factory effluents. The nature and quantity of pesticide residues in food will also be controlled under the Act.

A UNDP/FAO project for the Strengthening of Crop Protection Services is presently in operation in the country. To assist in the control of pesticides we have with us an eminent scientist Dr. de B. Ashworth on a one and one-half year assignment. Preparations are being made for the implementation of the Act and a new pesticide analytical laboratory is being planned which should be operational in about two years. This laboratory would be used for formulation analysis of pesticides sold in the country and for investigation or for control of residues in food and the environment including industrial effluents.

2) Pesticides used in the country

A total of about 135 (active ingredient) chemicals are sold in various formulations and trade names. Appendix 1 shows the import of pesticides into Peninsular Malaysia. Most pesticides are imported as technical material and formulated in the country. In addition, several pesticides are manufactured locally as shown in Table 1. The cost of pesticides sold in the country is estimated in Table 2.

Table 1. Local manufacture of pesticides

Pesticides	Year	Quantity*	Value (Malaysian $Mil.)
Dalapon	1973	2,381.5 tons	8.1
Sodium chlorate	1974	5,400 tons	5.5
MSMA	1974	326,856 gals.	3.3
2,4-D	1974	200,000 gals.	2.0

*A small quantity of these may be exported, while the rest are locally used.

Table 2. Estimate of pesticides used (1974)

Pesticides		(Malaysian $ Mil.)
Herbicides		57.0
Insecticides		15.0
Fungicides		3.5
Miscellaneous		1.5
	Total	77.0

At present under the Poisons Ordinance 1952 about twelve pesticides are prohibited from manufacture or import into the country based on their acute toxicity. Unfortunately all of these pesticides except endrin are organophosphate or carbamate insecticides which degrade rapidly in the environment.

In an irrigated area in northern Peninsular Malaysia (MADA) about 250,000 acres of land is cultivated with rice, and two crops are grown per year. It is estimated that in 1974* about 1,400 tons of granules of BHC or endosulfan was used. This amounts to an average of about 0.6 lbs. of active ingredient per acre.

3) Some problems encountered

A survey conducted in North Central region of Peninsular Malaysia in 1970 revealed that endosulfan was the most widely used insecticide on rice. BHC was the next popular insecticide. Endosulfan was found to be acutely toxic to fish, although toxicity by BHC was also claimed by some farmers perhaps due to application of high levels. Other insecticides such as dieldrin, endrin and azinphos-ethyl also caused fish mortality although such effects were not noticed in irrigation canals and ponds adjacent to rice fields (Yunus and Lim, 1971). Appendix 2 shows the pesticides being recommended on padi.

Carbaryl which is recommended against leafhoppers does not appear to be toxic to fish at the normal rate of application and as it does not accumulate in living tissues in the same way as chlorinated hydrocarbons, it can be considered safe to padi field fish.

*Source: F.A. record of sales and projections.

Endosulfan is very toxic to fish and is recommended not to be used in padi fields where fish production is important. However, from experimental results in Malaysia it is found that it is unlikely that the drainage system is polluted by the correct usage of endosulfan. This is particularly so with endosulfan granules because the surface concentration never reaches more than 23 p.p.b. There is a greater possibility that foliar application could escape into the drainage system since the initial concentration after spraying was almost 1,000 p.p.b. in the experiment. It was found in this experiment that residues of endosulfan concentrated in the gonad and viscera of fish to a concentration of 73 p.p.m. whereas the concentration in muscle tissue was undetectable being less than 0.3 p.p.m.

BHC is less toxic to fish than endosulfan although there have been reports of fish mortality after the use of BHC which may be attributed to excessive usage of this chemical. BHC foliar application also has higher acute toxicity than granules although it is less toxic than endosulfan. However, it is a chlorinated hydrocarbon and tends to accumulate in biological systems (Moulton 1973).

Work has been done which shows that Gamma BHC residues are not a significant problem in the rice soil in the tropics (Yoshida and Castro 1970). Similarly the degradation of diazinon (Sethunathan and Pathak 1971) in rice field water in the Philippines has been recorded. Seed dressing of rice is not practiced and mercuric compounds are not used on rice.

The use of sodium arsenite for weed control in rubber has been practised for a long time. Arsenic poisoning of livestock is rather common. It has been estimated that after application of 22 Kg per hectare of sodium arsenite, an animal weighing 10 kg would need to graze an area of only $0.3m^2$ ($3.2 ft.^2$) in order to ingest the lethal dose. The top soil (0-10 cm) from a rubber plantation which had repeatedly applied sodium arsenite was found to contain a residue of 175 ppm arsenic as compared to 23 ppm in the soil from the inter-row areas in the same site. The cultivation of groundnuts and soya bean in the soil of high arsenic content showed that the plant weight and seed weight of groundnuts reduced while pod and seed formation were suppressed by arsenic (Anon, 1973).

Sodium arsenite has also caused fatalities among people through various accidents. The leaching of arsenic into wells from which water is obtained for drinking has also caused problems. However the use of sodium arsenite as a weedicide will be prohibited with effect from 1st January 1976.

The hazards of pesticide residues may be important on vegetables which are sprayed with various pesticides particularly insecticides against leaf feeding insects. No work has been done on the determination of pesticide residues of vegetables although Plutella larvae fed in the laboratory on leafy vegetables purchased from the market suffered a high mortality level (Balasubramaniam; unpublished).

The outbreak of pests as a result of using broad spectrum insecticides on oil palm in Malaysia has been demonstrated by Wood (1971). Similarly several cases of severe outbreaks of leaf eating caterpillars are known to have followed the use of broad spectrum residual insecticides on oil palm (Wood 1972) as a result of harming the natural enemies of pests.

4) Conclusions and acknowledgements

One of the major problems of developing countries is the isolation of the scientist; the lack of opportunity to hear and discuss with people facing the same problems as he does. This problem is magnified by poor library facilities thereby making meetings such as this all the more important.

It is also of great interest to hear the problems in other countries and to meet scientists which also allows one to maintain contacts. I would therefore draw the attention to the importance of FAO as an international centre for agriculture, which could thus provide the means for scientists to work together and evaluate problems from the world point of view.

It is also important to realise that the behaviour of pesticides in the tropical environment is different from that in the temperate regions. The nature and quantity of pesticide residues on food and the general environment will also differ from that of temperate regions.

I would therefore urge FAO to make available more advice on the safety and quality of pesticides particularly under tropical conditions. This should include suitability of formulations for application by less sophisticated sprayers, stability on storage and appropriate packaging. Developing countries do not have the resources or know-how to do this work by themselves. Perhaps if the meeting agrees and it were felt appropriate, it might be possible to pass a resolution on these lines which might be forwarded to the Director-General of FAO.

Finally, I should like to thank FAO and UNEP very warmly for the opportunity to attend this meeting and for providing financial assistance. I would urge the Agencies to do all that is possible to encourage such meetings in future.

APPENDIX 1

PENINSULAR MALAYSIA IMPORTS OF PESTICIDES*

	1971 Quantity	1971 Value ($)	1972 Quantity	1972 Value ($)	1973 Quantity	1973 Value ($)
1. Insecticides etc. Liquid (gal.)	105,063	3,164,450	88,992	2,379,854	125,404	3,579,356
2. Mosquito coils (cwt.)	18	10,722	127	35,840	10,303	846,289
3. Insecticides etc., other than liquid (cwt.)	20,758	2,847,928	11,067	1,992,965	11,460	3,158,084
4. Weedkillers - Liquid (gal.)	19,123	495,807	25,020	235,754	25,314	607,194
5. Weedkillers - non-liquid (cwt.)	8,626	1,348,159	1,171	776,197	1,671	529,051
6. Sodium arsenite powder (cwt.)	15,047	634,556	18,231	707,906	27,712	1,143,962
7. Sodium arsenite liquid (gal.)	0	0	0	0		145
8. Weedkiller liquid containing monosodium acid methane arsenite other salts and derivatives of methylarsenic acid (gal.)	0	0	0	0	22,823	540,248
9. Weedkiller liquid other (cwt.)	0	0	0	0	3,291	52,607
Total Value		8,501,622		6,128,516		10,456,936

*Reference: Peninsular Malaysia Monthly Statistics of External Trade, Department of Statistics Malaysia, Kuala Lumpur.

APPENDIX 2

PESTICIDES RECOMMENDED ON PADI

Pesticides	Formulation
Gamma BHC	granule, EC
Endosulfan	granule, EC
Diazinon	granule, EC
Carbaryl	WP
DDT	EC
Fenitrothion	EC
Malathion	EC
Dimethoate	EC
Zinc Phosphide	Bait
Coumachlor	Bait
Coumatetralyl	Bait
Chlorophacinone	Bait
Edifenphos	EC
Carbendazim	WP
Benomyl	WP
Blasticidin-S	WP
2,4-D amine	liquid
2,4-D butyl ester	WP
MCPA	liquid
Paraquat	liquid
Dalapon	WP

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3. SOME INTERNATIONAL ACTIVITIES AND PROGRAMMES

3.1 GERMAN TECHNICAL COOPERATION PROGRAMMES ON RESIDUE PROBLEMS WITH PESTICIDES

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Technical assistance in the field of plant protection has been practised for more than twenty years by the Federal Republic of Germany. During this time large amounts of pesticides have been applied on agricultural crops. Worldwide, mankind started to consider pesticide residues and to draw up decrees and laws containing official tolerances the levels of which were apt to frequent changes and corrections according to better knowledge, new active ingredients on the market or more sensitive analytical procedures.

Countries with such laws and decrees soon began to check residue levels in local food and food stuff as well as in imports of agricultural products. A fair amount of agricultural imports was and still is coming from countries of the third world which are still using persistent chlorinated pesticides for one reason or the other. In this way it could happen that countries with very strict tolerances - and Germany is one of them - which introduced plant protection practices including the use of pesticides to the countries of the third world had to reject their exports because the residue levels were exceeding the set tolerances. And there are examples of such rejections. Aware of the residue problems with pesticides in countries of the third world where the export of agricultural products in many cases is the only source of foreign exchange the German Technical Assistance started a corresponding project on a worldwide scale in 1973.

The main objectives of this project are to assist countries of the third world.

1. to protect their local population from the consumption of agricultural products containing high amounts of pesticide residues and to avoid possible health hazards.

2. to produce agricultural products of high quality for exports, i.e. which will meet the pesticide residue tolerances of importing countries.

3. to plan and build up their own national testing facilities for residues.

4. to train local staff in residue analysis, locally and abroad

5. to improve - if necessary according to the determined residue status in countries under question - plant protection practices to more favourable ones resulting in acceptable low residue levels.

Under the project activities residue laboratories were started in Sri Lanka, in the Sudan, and in the Philippines. A small pesticide lab unit in Teheran, Iran was supplemented with additional equipment; a short term expert will be sent to train local staff in residue analysis in the near future. A further laboratory is in its advanced planning stage in Casablanca, Morocco and residue work will start by the end of this year.

One important aspect of the project is the training of counterparts. So far, eleven counterparts from nine different countries have been trained successfully in Bad Dürkheim, Germany (Institute for Gas Chromatography) in December 1973 and 1974 during courses, each of two weeks, in gas chromatography with special reference to pesticide residue analysis. The teaching language was English.

Staff members of the laboratories in Sri Lanka and in the Sudan could also be trained locally.

In 1975, we are conducting another training course in Germany which will start on the 29th of September. The more theoretical part of the training - with some practical labwork on handling, operating, and maintaining gas chromatographs in the above mentioned institute for Gas Chromatography - will be continued in lab work in different residue laboratories in Germany where extraction and clean up procedures for residue determinations can be learned.

The future activities will be intensified. Presently we are constructing the project's own laboratory, on a small scale only, but large enough to do some research such as adjusting methods to local conditions abroad, to train counterparts, and to determine residues in samples from such countries where testing facilities are not yet available. This lab will be located in Darmstadt, Germany and is adjacent to one of the best equipped residue labs in Germany so that additional facilities such as mass spectrometry for special problems can be utilized. The equipment of our lab in Darmstadt as well as that of the labs abroad is standardized which will help to solve problems of maintenance and spare parts.

In its first phase the analysis programme of the newly established residue laboratories will be confined to the determination of chlorinated pesticides. Later, according to the progress and demand of the individual labs, organophosphate pesticides, fungicides, herbicides, etc. will be considered step by step.

Test samples and standard mixtures will be sent regularly to the labs to check accuracy.

Residue data from abroad will be collected, evaluated and published. If necessary these data will be used to change or/and improve agricultural practices in close cooperation with local extension services in order to lower residues to acceptable values.

Due to steadily increasing residue problems in countries of the third world and in order to be able to fulfill future tasks within the project our staff will be increased from one expert to three before the end of this year.

Also in future we will continue to strive for close cooperation with national as well as international agencies for technical assistance, with universities, manufacturers of pesticides, and government institutions. If our efforts are to be successful we have to coordinate our programmes and do everything to avoid duplication of projects. Only in this way quick and effective assistance to countries of the third world will be possible.

3.2 ACTIVITIES OF THE BRITISH MINISTRY OF OVERSEAS DEVELOPMENT IN THE FIELD OF PESTICIDES AND ENVIRONMENT

(A brief statement)

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(1) Agricultural progress and the improvement of public health in developing countries are closely tied to appropriate measures for the control of crop pests and disease vectors. The Ministry of Overseas Development of the UK (ODM) is active in these fields through scientific units such as the Centre for Overseas Pest Research (COPR) and the Tropical Products Institute (TPI). Control measures, both at present and in the foreseeable future, frequently involve pesticide use on a scale likely to increase rather than diminish. The limited specificity of such chemicals makes effects on non-target organisms difficult to avoid. ODM is aware of these problems and has established an Environmental Co-ordinating Unit under the control of Dr. D.W. Hall to ensure adequate consideration of environmental aspects of ODM activities.

(2) Research activities in the field of pesticide ecology and residue monitoring associated with both crop protection and vector control are being carried out under the auspices of ODM in Nigeria, Botswana, Malawi, Kenya and the Caribbean. A scheme in association with the World Health Organisation in Ghana is also under discussion. Current projects are associated with both terrestrial and aquatic ecosystems.

(3) The scheme in Nigeria is a cooperative venture between The International Institute for Tropical Agriculture (IITA) and COPR concerning the behaviour and biological effects of DDT in agricultural soil as a result of pest control in cowpea. Work has been in progress since 1973 and will extend until at least 1978. The aim of the programme is to establish whether the pesticide influences the productive capacity of soil by interfering with soil processes and populations in such a way that nutrient cycling is disrupted. A wide range of biological responses is being monitored in an attempt to develop suitable methodologies for future studies in different agricultural situations. In 1976 the work of the COPR group will become more closely integrated with the IITA Farming Systems Programme and extend to studies on the interaction between chemical and biological control agents in mixed cropping regimes. Ancillary work on pesticide effects on the decomposition of organic material in a cotton agrosystem has been funded on a small scale by COPR in Kenya.

(4) In Botswana a joint COPR/TPI project has been mounted to investigate the effects of endosulphan on freshwater fauna in the Okavango Delta. Feasibility studies on the eradication of *Glossina* from this area are being undertaken by the Botswana Department of Animal Health using ULV aerial spraying techniques. Since this chemical is known to be highly toxic to freshwater fauna there is concern over the effects on the potential of the area as a fisheries resource in addition to more general environmental considerations. COPR is assisting with studies on insecticide application and its behaviour and effects in the marsh ecosystem. Particular attention is being given to fish and aquatic invertebrates which serve as food organisms. TPI is undertaking residue analysis of biological materials and advising on other aspects of the residue programme. The project began in 1975 and is expected to continue for two years with a possible major expansion should a large-scale eradication programme be undertaken.

(5) Toxicity testing, partly funded by WHO, takes place at the COPR Molluscicides Unit in London in which chemicals such as Bayluscide and Frescon used in the control of bilharzia vectors are examined for sub-lethal effects on Tilapia. This programme is to be extended to cover both food fish and other freshwater organisms in association with the WHO and the Onchocerciasis Control Programme, particularly in relation to the use of Abate. Discussions are being held with authorities in Ghana for simulated field testing of Abate in experimental ponds.

(6) In addition to ecological studies on pesticide effects, ODM is involved in monitoring of pesticide residue levels in certain developing countries. A study of the concentration and distribution of DDT following cotton spraying in Southern Malawi is being conducted by TPI with special reference to the contamination of fish populations in the Shire River. A biological input from COPR is planned should it be felt necessary. A wide range of analyses for pesticides in tropical foodstuffs submitted by developing countries is carried out in London by TPI and ODM has sponsored the establishment of residue analysis facilities in Nairobi and the Caribbean to serve as monitoring units. An active programme for the development of pesticide control legislation is associated with the latter.

(7) An ODM sponsored workshop meeting was held at COPR in February 1975 on the implications of pesticide use for tropical freshwater and terrestrial ecosystems. Papers were presented by experts in various fields to serve as background to a series of discussions designed to formulate recommendations for future studies on the environmental impact of pesticides in the tropics. The meeting was attended by representatives of a number of developing countries, FAO, UNESCO and WHO in addition to the invited speakers. A report incorporating the agreed recommendations will shortly be available.

3.3 PESTICIDES AND MAN AND THE BIOSPHERE PROGRAMME

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UNESCO has been involved for a long time in the promotion of the ecological sciences among which one could mention the arid zones and humid tropics' programmes, the elaboration of soil and vegetation maps, the sponsorship of a great number of seminars, conferences and courses on ecological problems and the continuing collaboration with governmental and non-governmental international organizations in the realm of the environment.

The Man and the Biosphere Programme (MAB), as defined at the first session of its Council in November 1971, is an intergovernmental and interdisciplinary programme of research, which emphasises an ecological approach to the study of the interrelationships between man and the environment. Taken textually from the report of this Council session, the general objective of MAB is "to develop the basis within the natural and social sciences for the rational use and conservation of the resources of the biosphere and for the improvement of the global relationship between man and the environment; to predict the consequences of today's actions on tomorrow's world and thereby to increase man's ability to manage efficiently the natural resources of the biosphere".

As a consequence, special emphasis is placed in MAB research on the ecological effects of man's manipulation of ecosystems, and on the repercussions of the environmental changes on man, considered as a biological, sociological and economic entity.

The structure of MAB is based mainly on national committees established by the countries themselves. To date, 73 national committees have been constituted and more are envisaged in the very near future. International governmental (UNEP, FAO, WHO, WMO) and non-governmental (such as ICSU and IUCN) organizations cooperate and collaborate with the MAB programme.

Regarding the functioning of MAB, the research areas are centred around 14 major MAB projects defined by its Council. Seven of these projects focus on specific segments of the biosphere having an ecological or geographical basis. Such is the case for Projects 1, 2, 3, 4, 5, 6, 7 and 11, which refer specifically to the interrelationships between man and the tropical forests ecosystems, temperate and mediterranean forest landscapes, savanna and grasslands, arid zones, aquatic ecosystems and mountain and tundra ecosystems, island ecosystems and urban systems. Actually, the core programme of MAB centred around these ecological or geographically oriented projects. The remaining projects of MAB relate primarily to significant human impacts or relevant related processes occurring in all parts of the biosphere. These are projects Nos. 8, 9, 10, 12, 13 and 14, which deal respectively with conservation processes, impact of pesticides and fertilisers, impact of major engineering works, human genetic and demographic aspects, the perception of environmental quality and pollution and monitoring. There is, moreover, an interaction between the two major project areas and, in fact, the impact and process-oriented projects provide a constant input and unifying concept for the ecologically and geographically oriented projects.

In connection with the above, MAB Project No. 9 on the Ecological Assessment of Pest Management and Fertiliser Use on Terrestrial and Aquatic Ecosystems, attempts to forecast the major difficulties that are likely to occur in the next few decades stemming from the fact that crop pests are artifically controlled in intensive agriculture and forestry through two principal kinds of activities, namely, crop breeding for pest resistence and application of chemical pesticides. These difficulties are likely to be surmounted only through major international effort to develop alternative strategies for the management of pest populations.

Two particular categories of problems are of world-wide concern. The first concerns the broad environmental consequences of widespread use of chemical pesticides; the second, the declining effectiveness of chemical control in many areas. In solving problems of the first type, and in developing new approaches, sound ecological research on new methods is essential. This internationally coordinated ecological project is a necessary complement to the specialized agronomic approaches to pest control activities being pursued by individual nations and FAO.

The ecological research to be undertaken, in close cooperation with the competent international organizations, such as FAO, WHO and WMO, will be directed toward obtaining information which will be of value to all countries in pest management and enhancement of productivity with a minimum of adverse effects on non-target species and on the environment. In many cases, collection of baseline information will be necessary in order to analyse the current status of terrestrial and aquatic ecosystems, or of populations of selected indicator species, before assessment of the impact of pest management can be made.

In June 1974, a consultative group met in FAO Headquarters in Rome, which addressed itself to the types of research that might be usefully undertaken within MAB on the effects of pesticides on terrestrial and aquatic ecosystems. The final report will be published as MAB Report Series No. 24, following additional consultation between FAO and UNESCO. (Editorial Note: Has now been published.)

The MAB Council, at its Third Session in September 1974, recognized that Project No. 9 had already been included in the proposed problem area of various geographically-based projects. It also agreed that, due to its uniqueness in approach, Project 9 could stand as a project on its own although there could be significant interphasing with the studies on pollution.

3.4 THE NEED FOR IMPACT MONITORING OF RESIDUES IN FOODS FROM THE USE OF AGRICULTURAL PESTICIDES IN DEVELOPING COUNTRIES

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Introduction

Different types of foodstuffs are not evenly produced in various parts of the world and consequently international movement of food is instrumental in providing adequate and balanced nutrients to all populations. However, the international distribution of food is not automatically regulated, but is influenced by marketing stimuli such as those of supply and demand. Export of food implies, by and large, a financial gain for the exporter as well as for the producer.

If the continued use of pesticides has been essential to the production and protection of increasing amounts of food and other agricultural products, experience has also shown that various precautions were essential and had to be carefully followed to ensure correct use and to avoid excessive residues. In most countries legislation to ensure safe and effective use has been introduced, or is under consideration, and maximum residue limits or tolerances for pesticide residues in food have been established by many national authorities with a view to protecting the health of the consumer. Apart from the question of interpretation, it has to be recognized that countries in different parts of the world have different pesticide requirements for controlling local and regional pests under prevailing climatic conditions. Inevitably, this results in differing levels of residues and different requirements for tolerances and this may interfere with the international movement of food. FAO and WHO have, therefore, been requested by Member States to initiate effective programmes to ensure the protection of the health of the consumer and to facilitate international food trade.

Historical

For many years, the FAO Working Group of Experts on Pesticide Residues and the WHO Expert Committee on Pesticide Residues have been entrusted by the two sponsoring organizations, the World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO) with the responsibility of assessing the hazards to man from the occurrence of residues of pesticides in food. These two expert bodies meet each year alternatively in Geneva, Switzerland and Rome, Italy, and their meetings are known as the Joint FAO/WHO Meeting on Pesticide Residues, the FAO Working Party being mainly responsible for recommending residue limits in food and appropriate methods of analysis for pesticides, and the WHO Expert Committee being mainly responsible for evaluating the toxicological data, and, when appropriate, establishing acceptable daily intakes (ADIs). The Joint FAO/WHO Meeting on Pesticide Residues serves as an advisory body to the Codex Committee on Pesticide Residues which is responsible for proposing international tolerances for pesticide residues in specific foods. This Codex Committee is a subsidiary body of the Codex Alimentarius Commission which operates in the framework of the Joint FAO/WHO Food Standards Programme.

The problem

In carrying out its work the Joint FAO/WHO Meeting on Pesticide Residues has relied upon scientific information and data provided by national governments, industry, academic institutions and other data-generating institutions. In many instances the lack of residue and toxicological data has prevented more effective work from being carried out by the Joint Meeting. This situation has been commented on in paragraph 5.1 on page 19 of the report of the 1974 Joint Meeting:

> "Very few governments submitted information directly, and in most instances the amount of information was small. Although many useful and relevant data were supplied by manufacturers of compounds evaluated for the first time, submissions by industry were largely deficient in residue data on compounds for re-evaluation. In some instances members were aware of the existence of information that had not been made available for evaluation. The Meeting therefore urged that every effort should be made to seek the cooperation of governments, industry, and others to ensure that complete data relating to all compounds reviewed at the Meetings are made available."
>
> (FAO/WHO, 1975a, p. 19)

Another aspect of the problem is illustrated in the paragraph 47.F of the report of the sixth session of the Codex Committee on Pesticide Residues:

> "The consideration of Codex tolerances in the light of the acceptable daily intake established by the Joint Meeting and estimates of the 'potential daily intake' (as calculated from tolerances and food consumption data) and 'actual daily intakes' as determined on the basis of whole diet studies) to ensure that Codex tolerances do not represent appreciable hazard to health, poses a number of difficulties. By intensifying work in this field in encouraging governments to carry out appropriate studies to determine the actual amounts of pesticide residues ingested, and by ensuring that an estimate is made of the 'potential daily intake' of all pesticide residues under consideration by the Committee, the situation could be greatly improved. Another difficulty is experienced as a result of an increasing public awareness of the presence of chemicals in food which forces individual governments to make all efforts to reduce, for example, pesticide residues in food. As a consequence the Committee is facing an increasing demand to lower Codex tolerances as far as possible."
>
> (ALINORM 72/24A)

The situation in developing countries facing these and related problems has been illustrated at the 1975 and most recent session of the Codex Committee on Pesticide Residues by one delegation which

> "drew the attention of the Committee to the position of the developing countries who were often not able to afford the necessary resources so as to keep up-to-date with the more sophisticated methods of analysis. On the one hand, the use of pesticides was encouraged by the necessity of increasing agricultural production and also by the promotion of pesticides by manufacturers. On the other hand, these same countries, by applying lower and lower tolerances on imported foodstuffs, could

limit export from developing countries of these same agricultural products to the most important markets. The maximum limits should, therefore, not be established at a too low level although they should be satisfactory from the point of view of public health."

(ALINORM 76/24, p. 22)

Conclusions

In order to ensure that the international tolerances being elaborated by Member States under the auspices of FAO and WHO are consistent, not only with the actual good agricultural practices in the developed countries, but also with those in developing countries, the proposed impact monitoring of residues from the use of agricultural pesticides should be initiated as soon as possible. It might also be noted that the Joint FAO/WHO Food Contamination Monitoring Programme sponsored by UNEP has been initiated (UNEP-0102-73-004) and close collaboration between these two programme areas will prove most fruitful.

REFERENCES

FAO/WHO (1975a) Pesticide residues in food. Report of the 1974 Joint FAO/WHO Meeting of the FAO Working party of Experts on Pesticide Residues and the WHO Expert Committee on Pesticide Residues, FAO Agricultural Studies, No. 97; Wld Hlth Org. techn. Rep. Ser., No. 574.

ALINORM 72/24A (1972) Report of the Sixth Session of the Codex Committee on Pesticide Residues; 16-23 October 1972, The Hague, The Netherlands.

ALINORM 76/24 (1975) Report of the Eighth Session of the Codex Committee on Pesticide Residues; 3-8 March 1975, The Hague, the Netherlands.

3.5 PEST MANAGEMENT AND RELATED ENVIRONMENT PROTECTION PROJECT OF UNITED STATES AID WITH UNIVERSITY OF CALIFORNIA

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The United States Aid for International Development program is delighted to be able to participate in this important Food and Agriculture Organization-United Nations Environment Programme technical consultation on the impact monitoring of residues due to the use of agricultural pesticides in developing countries. On behalf of the U.S. AID Program, I am very happy to relate to you the activities of this program in these areas.

The U.S. AID Program is vitally interested in monitoring because the subject emphasizes the importance of safe and effective pesticide management. In pursuit of these goals the U.S. AID has implemented a far reaching research project with the University of California entitled "Pest Management and Related Environmental Protection" and Dr. Ray F. Smith is the Project Director. This University of California/U.S. AID project brings together a consortium of universities including North Carolina State, Cornell, Oregon State, University of Florida and University of Miami School of Medicine. The activities of this project are divided into those related to pest management and those related to pesticide management. The latter involves the area of monitoring. Two reports are available which describe these activities (See References). The first describes the UC/US AID Project in both pest and pesticide management activities. The second illustrates the facilities for pesticide management by presenting a collection of papers presented in a seminar and workshop in Manila, and highlights the "agro-medical approach" to related problems.

In earlier years, three major agro-medical problems have been recognized in the developing countries: (1) pesticide residue contamination, (2) increased human and animal poisonings from concentrate and the pesticide residue in the field, and (3) the resurgence of malaria. These problems reflect the impact of pesticides in the environment and involve both man and his eco-system and emphasizing the need for a multi-disciplinary agro-medical approach. The U.S. AID Program sought to attain these goals of safe and effective pesticide management through (a) training, (b) the establishment of a quality control program in the laboratory and (c) research.

(a) Training programs

Training programs have been held in El Salvador, Indonesia and the Philippines, and under discussion for the future are programs in Egypt and Pakistan. Such programs are usually set up as a result of an in-country request to The U.S. AID Mission for assistance, and the program takes the format of first, a seminar workshop which is followed by fellowships to chemists, physicians, and entomologists. These have been supported by WHO, PAHO, UNEP, and U.S. AID Programs at different times.

(b) Quality control programs

Following these training programs, laboratory capability is reinforced through joint participation between regional laboratories, the University of Miami School of Medicine, Oregon State University and the developing country through the implementation of a regional quality control check sample program. Standards have been provided by the U.S. Environmental Protection Agency.

(c) Research program

The research training program will focus on collaborative studies on a wide variety of human and environmental factors which will help further the safe use of pesticides in agriculture particularly addressing the subject of special problems of pesticide management in a tropical environment. Thus, we have approached the government of the Philippines as to whether they have any interest in collaborative research on special treatment of clothing of workers exposed to pesticides in the tropics. Within the collaborating universities, in-house research is concerned with improvements of formulation, chemo-dynamics of pesticides in the tropics and the potential of surveillance of the pesticide laborer through urinary alkyl phosphate and phenolic studies.

The emphasis both in training and collaborative research is to provide technical assistance of collaborating countries which is holistic and multi-disciplinary. For these reasons, these discussions on impact monitoring on agricultural use of pesticides in the developing countries is of special interest and we look forward to discussions which will resolve such issues as training, etc. and collaboration at all levels of international development.

REFERENCES

(1) Annual Report 1975 "Pest Management and Related Environmental Protection" U.S. Agency for International Development/University of California.

(2) Report on 1975 Seminar and Workshop in Pesticide Management at Ramon Magsaysay Center, Manila, Philippines (Feb. 1975).

3.6 POSSIBLE CONTRIBUTION ON THE BASIS OF THE JOINT FAO/IAEA CHEMICAL RESIDUES AND POLLUTION PROGRAMME

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1) Introduction

In relation to the possible problems of chemical or radioactive residues which find their way as trace contaminants or pollutants of the environment, food and living organisms, priority has understandably,and appropriately, been given to assessing direct risk/benefit ratios for man.

However, it is hardly debatable that unacceptable harm could be done if it has not already been done, to environmental quality and resources without involving direct or even apparent risks to man. The biosphere contains millions of interdependent species of fauna, flora, mesofauna and microorganisms, and their vital substrates or media and which comprise discrete terrestrial or aquatic so-called "ecosystems". It is also important when considering the actual or potential impact of agricultural pesticides in this context to take into account the spectrum of chemical and radioactive contaminants as a result of man's activities.

Firstly: It is important because the significance of a pesticide residue may actually depend biochemically upon the presence or past presence of other contaminants resulting in a potentiated (e.g. synergized) additive (e.g. one or more anticholinesteratic poisons or mutagenic agents) or attentuated (e.g. development of a cross-resistant strain of the species as due to a past history of exposure to another residue)effect.

Secondly: It is important in order to identify priorities correctly. For example an organochlorine pesticide residue might indeed be able significantly to inhibit the growth of planktonic species of an aquatic ecosystem, but the effects would be negligible and overwhelmed by even minor changes in micro or macro nutrient status, due for example to municipal waste discharge or agricultural nitrogen waste.

Finally, in the context of chemical monitoring it is not only important first to identify priorities and critical situations (i.e. the "critical pathway" approach adopted by radioecologists and radiation protection specialists for the control and monitoring of radioactive discharges) but to identify indicator organisms which, by virtue of their bio-concentration potentialities, are natural integrating type sampling mechanisms.

Documented evidence for these introductory remarks will be found in my paper entitled "Comparative ecotoxicology of halogenated hydrocarbon residues" scheduled for publication in Environmental Quality and Safety (Georg Thieme Verlag, Stuttgart and Academic Press, New York).

Against this background attention is drawn to aspects of the Joint FAO/IAEA Chemical residues and pollution programme which may represent a potential input of possible use to any programme for "Impact monitoring of residues due to uses of agricultural pesticides in developing countries".

2) Coordinated international programme of isotopic tracer-aided studies of the origins, fate and significance of trace contaminants (including agricultural nitrogen residues) which may affect agriculture, food and fisheries

Five ongoing programmes involve one or more collaborating Institutes in Arab Republic of Egypt, Austria (cost-free basis), Brazil, Bulgaria, Canada (cost-free basis), Denmark (cost-free basis), Ghana, Greece, Hungary, India, Israel, Japan (cost-free basis), Korea, Lebanon, Malaysia, Mexico, New Zealand (cost-free basis), Netherlands (cost-free basis), Pakistan, Peru, Philippines, Romania, Switzerland (cost-free basis), Uganda, U.K. (cost-free basis), USA (cost-free basis) and Yugoslavia. These programmes are mainly financed from the IAEA regular programme allocation for research contracts and under IAEA/SIDA and IAEA/Federal Republic of Germany agreements.

The initiation of a new programme of isotopic tracer-aided studies of chemical residue-microbiological interactions in aquatic ecosystems was recently recommended by a Joint FAO/IAEA advisory group and is likely to be implemented in 1976. One of the ongoing programmes is concerned with the appearance and fate of pesticide and other chemical residues (e.g. oil extraction solvents) in edible seed and derived oils (especially cotton seed, cake and oil which are of considerable importance to developing countries). Other particularly relevant aspects of the coordinated programmes involve the behaviour and bio-concentration of toxic metals (e.g. mercury) in fish, plants and animals, in areas where industrialization of a developing country has overtaken traditional agricultural or fishery practices but where the sophisticated research and controls for trace contaminants and waste discharge problems, taken for granted in advanced countries, are lacking. Current investigations are concerned with the fate of insecticide residues in rice and flooded rice paddy. Important findings have been the demonstration of the vital role of soil bacteria in degrading the insecticide residues, the effects of the residues on the microflora themselves, and the role of microbiological substrates such as soil organic matter, returned plant residues, residues such as rice straw.

3) Training courses in nuclear techniques for chemical residue and pollution problems

Safe and effective use of nuclear techniques (stable and radioactive isotope tracers, radioactivation analysis, etc.) require special laboratory facilities and training. Courses are organized to help suitably qualified graduates of developing countries to use these techniques to identify and study their own problems under their own conditions. Very successful courses have already been held in Austria, 1972 (FAO/IAEA/SIDA), Brazil, 1974 (FAO/IAEA/SIDA), the next is scheduled for the Arab Republic of Egypt in November, 1975 (FAO/IAEA/UNDP). A further course is envisaged for the Far Eastern Region in 1976/77. The courses provide methodology for studying a range of problems relevant to the present FAO/UNEP meeting. E.g., non-destructive techniques for measuring bio-concentration *in vivo* (e.g. plants, fish), monitoring by radioactivation analysis for trace contaminants such as mercury, arsenic, potential of fertilizer nitrogen to move into groundwater, nature and persistence of pesticide residues in food, plants, soil, etc. Side effects of pesticides on non-target organisms, e.g. wild life as a result of locust control operations, effects of acaricides on dipped cattle for tick control.

4) Technical assistance

Fellowship training, expert advice and equipment are provided under the IAEA regular programme, by UNDP through IAEA and under certain bilateral agreements. Technical assistance is subject to request by the member states and approval by the Governing Board of IAEA.

5) Collection and dissemination of information

This is illustrated by the following references to publications generated by the Joint FAO/IAEA programme. Of particular interest may be the occasional compilation and publication of the Joint FAO/IAEA Summaries of Information: Foreign chemical and radioactive residues in the biosphere:

FAO/IAEA	Nuclear Techniques for Studying Pesticide Residue Problems	Proceedings of a Panel Vienna, 16-20 December 1968	IAEA, Vienna, 1970 STI/PUB/252
FAO/IAEA	Nitrogen-15 in Soil-Plant Studies	Proceedings of a Research Co-ordination Meeting, Sofia, 1-5 December 1969	IAEA, Vienna, 1971 STI/PUB/278
FAO/IAEA	Pesticides Residues and Radioactive Substances in Food: A Comparative Study of the Problems	Report of a Panel of Experts, Vienna, 12-16 October 1970	IAEA, Vienna, 1972 IAEA-144
FAO/IAEA	Radiotracer Studies of Chemical Residues in Food and Agriculture	Proceedings of a Combined Panel and Research Co-ordination Meeting, Vienna, 25-29 October 1971	IAEA, Vienna, 1972 STI/PUB/332
FAO/IAEA	Isotope Tracer Studies of Chemical Residues in Food and the Agricultural Environment	Proceedings and Report of Research Co-ordination Meetings, Ispra, 30 October - 10 November 1972	IAEA, Vienna, 1974 STI/PUB/363
FAO/IAEA	Effects of Agricultural Production on Nitrates in Food and Water with Particular Reference to Isotope Studies	Proceedings and Report of a Panel of Experts, Vienna, 4-8 June 1973	IAEA, Vienna, 1974 STI/PUB/361
FAO/IAEA	Radio-labelled Substrates for Studying Biological Effects of Trace Contaminants	Report of a Research Co-ordination Meeting Vienna, 8-11 October 1974	IAEA, Vienna, 1975 IAEA-170
FAO/IAEA	Isotope Ratios as Pollutant Source and Behaviour Indicators	Proceedings of a Symposium, Vienna, 18-22 November 1974	IAEA, Vienna, 1975 STI/PUB/382 ISBN 92-0-010375-S

FAO/IAEA/ WHO	Methods of Radio-chemical Analysis	WHO Technical Report Series, 1959, 173	WHO, Geneva, 1966
FAO/IAEA/ WHO	Comparative Studies of Food and Environmental Contamination	Proceedings of a Symposium, Otaniemi, 27-31 August 1973	IAEA, Vienna, 1974 STI/PUB/348
FAO/IAEA/ ILO/WHO	Mercury Contamination in Man and his Environment	Technical Report Series No. 137	IAEA, Vienna, 1972 STI/DOC/10/137
FAO/IAEA	Studies of the origin and fate of chemical residues in food, agriculture and fisheries	Proceedings and Report of two Research Coordination Meetings 5-9 November 1973, 4-7 June 1974	In press
FAO/IAEA	Aquatic productivity: Isotopic Tracer Aided Studies of Chemical Biological Interactions	Report and recommendations of an Advisory Group Meeting 16-20 June 1975	In preparation
FAO/IAEA	Summaries: Foreign Chemical and Radioactive Residues in the Biosphere - Introduction Background Notes and summaries published in subsequent numbers of Chemosphere		Chemosphere, 1973 2 (2), pp. 37-52

(These summaries provide concise information and data on individual substances (e.g. dieldrin) or groups of substances (e.g. fertilizers) and relating inputs, sources, chemical fate, biological significance, typical and background levels found in food, environment and living organisms, internationally recommended primary protection standards, derived limits, etc. Each summary is limited to one sheet and is fully referenced to provide for detailed follow-up).

4. SPECIFIC TECHNICAL ISSUES AND PROPOSALS

4.1 PESTICIDE RESIDUE PROBLEMS IN FLOODED RICE ECOSYSTEMS

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Conditions of high temperature and high humidity as generally exist in a tropical environment increase the pest populations. Moreover, the new high yielding rice varieties and intensive cropping provide a favourable microclimate for the build up of pests particularly at high nitrogen fertility levels. Recent outbreak of 'hopper burn' in rice caused by brown planthoppers in areas planted to new varieties in Kerala, India stands witness to this. Consequently, pesticides are increasingly used in India realising the yield potential of these varieties. Insecticides constitute 66 per cent of all the pesticides used in Indian agriculture in terms of quantity. Commercial formulations of a chlorinated hydrocarbon, benzenehexachloride (BHC) and an organophosphate, parathion,are extensively used for controlling common rice insects in India. During the year, 1970-71, about 39,000 metric tons of 39 pesticides in technical grade were produced within the country; production of BHC alone amounted to 17,000 tons.

The potential hazard of BHC entry into the food chain has caused concern in Japan leading to its restricted use in rice. Such restrictions on indigenously available BHC would slow down the intensified efforts to increase the vital food production in India and other developing countries because of the high cost and non-availability of substitutes. Recent reports show however that BHC and certain other chlorinated hydrocarbons are fairly rapidly degraded in tropical rice soils under flooded conditions as reviewed by Sethunathan (1973). The present review discusses the more recent progress in studies on pesticide residue problems in rice and rice soils. How certain cultural practices employed in rice cultivation such as flooding, intermittent flooding and organic matter incorporation influence their persistence in rice soils is also emphasized in this review.

1) Effect of cultural practices

Cultural practices generally employed in rice cultivation during land preparation and thereafter seem to influence the rates of degradation of certain insecticides. The practices so far known to alter the degradation rates in rice soils are (a) flooding, (b) organic matter amendments, (c) intermittent flooding and (d) liming.

(a) Flooding

Rice fields are inundated at some stage of plant growth. Following flooding, the bulk of the soil is reduced and anaerobic microorganisms, obligate or facultative, become predominant. Interestingly, certain chlorinated hydrocarbon insecticides, known for their extreme stability in aerobic nonflooded soil systems, undergo rapid decomposition on flooding the soils, primarily due to the action of anaerobic soil microorganisms. Since the first report by Raghu and MacRae (1966) on rapid breakdown of BHC in flooded soil ecosystems, the instability of other chlorinated hydrocarbon insecticides such as DDT, methoxychlor and heptachlor has also been demonstrated in flooded soils and in anaerobic cultures as reviewed recently (Sethunathan, 1973; Watanabe, 1973). Available data indicate that these insecticides persist for only 3 to 6 months in several tropical soils under flooded conditions in contrast to their residence time of several years under non-flooded aerobic systems (Table 1).

Table 1. Stability of certain insecticides in flooded soils

Insecticides	Period of Persistance* (days)
Chlorinated hydro- carbon	
γ - BHC	30-90
α - BHC	30-90
δ - BHC	30-90
β - BHC	30-90
DDT	30-90
Methoxychlor	30-60
Heptachlor	30-90
Endrin	>55
Organophosphate	
Diazinon	70
Parathion	20-60

*In nonflooded soil, chlorinated hydrocarbon insecticides included in this group persist for several years and organophosphates only for six months.

Recent intensive studies in our laboratory employing C^{14} labelled insecticides showed that the extent of degradation of gamma- and beta-BHC in different soils was related to the redox potentials (Eh) attained by the soils following flooding (Siddaramappa and Sethunathan, 1975). The sharp drop in Eh to negative values within 20 days after flooding apparently helped in the rapid microbial degradation of both isomers of BHC in alluvial, laterite and pokkali (acid sulphate, saline) soils. No degradation occurred in autoclaved samples of these soils despite flooding. In contrast, the highly oxidized conditions even after 41 days of flooding retarded the degradation of BHC isomers in sandy and kari (acid sulphate, saline) soils. Moreover, microbial activity in these soils is expected to be low, because of low organic matter content in sandy soil and highly acid conditions in kari soil. The data on the negative relationship between BHC degradation and Eh of the flooded soils are summarized in Table 2. The data demonstrated that rapid decomposition of gamma- and beta-BHC can occur in microbially active soils capable of attaining an Eh of -40 to -100 mV within few days after flooding. The problem of residue accumulation does exist, however, in problem rice soils such as kari soil characterized

Table 2. BHC degradation and changes in redox potentials in Indian rice soils under flooded conditions

Incubation (days)	Alluvial	Laterite	Acid sulphate, saline Pokkali	Acid sulphate, saline Kari	Sandy
			Gamma-BHC recovered, cpm x 10^4/20g soil		
0	51.7	52.2	44.9	43.3	49.4
20	2.3	19.4	25.3	31.5	47.2
41	0.8	1.3	2.1	24.8	42.4
			Beta-BHC recovered, cpm x 10^4/20g soil		
0	71.8	75.6	63.4	49.6	79.9
20	16.2	45.2	58.9	42.0	73.5
41	1.9	2.9	20.6	36.0	65.5
			Redox potential (Eh), mV		
0	+235	+255	+250	+380	+220
20	-120	- 50	- 80	+160	+150
41	-145	- 75	-100	+165	+ 45

by extreme acidity, high salt content and low microbiological activity.

Most recently, the fate of another chlorinated hydrocarbon insecticide, endrin, in several Indian rice soils under flooded conditions was studied using radiotracer technique. Endrin decomposed rapidly to 5 or 6 metabolites in most soils except a sandy soil (Gowda and Sethunathan, 1975). Maximum degradation of endrin occurred in pokkali soil despite its high salt content. However, endrin metabolites showed extreme resistance to further degradation under continued flooding. Consequently, the total radioactivity recovered in the solvent fraction of the soils was relatively high despite rapid loss of endrin (Table 3). More information is needed, however, concerning the characterization and toxicity of stable metabolites of endrin for predicting the safety in the use of endrin in rice.

Table 3. Persistence of endrin in Indian rice soils under flooded conditions

Incubation (days)	Endrin* recovered, cpm x 10^4/20g soil: Alluvial	Laterite	Acid sulphate, saline Pokkali	Acid sulphate, saline Kari	Sandy
0	48.8(68.7)	48.3(65.0)	35.2(59.2)	39.0(58.1)	67.5(100.3)
25	32.6(61.4)	20.4(73.7)	8.4(29.8)	28.6(40.8)	58.1(79.5)
55	5.3(41.4)	2.4(36.5)	2.2(33.6)	12.0(28.7)	41.5(68.6)

*Endrin recovered after tlc separation of residues in the solvent fraction. Figures in parenthesis represent total radioactivity partitioned in the solvent fraction.

Note: The decline in total radioactivity in the solvent fraction was not proportional to endrin loss due to extreme stability of metabolites formed under flooded conditions.

Despite worldwide extensive studies on pesticide metabolism, information on the fate of pesticides in saline agricultural soils is rather limited. The contrasting results obtained in our studies on the behaviour of BHC and endrin in two types of saline acid sulphate soils (locally known as kari and pokkali) have applied significance; particularly because a substantial portion of rice growing soils in the coastal areas of India are characterized by high salt content.

The fate of the organophosphates, parathion and diazinon, in flooded soils has also been investigated. Reducing conditions caused by flooding and organic matter amendments hasten the nitrogroup reduction of parathion to aminoparathion and an unidentified metabolite (Rajaram and Sethunathan, 1975). Recent studies, however, show that rapid hydrolysis of parathion can occur by biological action in flooded soils particularly after 2 or 3 additions of the insecticide (Sethunathan, 1973). Evidence from flooded soils suggests that biological hydrolysis of parathion in soils is more widespread than hitherto believed. Likewise, rapid hydrolysis of diazinon occurs in flooded rice fields when appropriate microorganisms build up after repeated additions of the insecticide (Sethunathan, 1973). No residue problems seem to exist with respect to parathion and diazinon since both hydrolysis and nitro-group reduction are essentially detoxication mechanisms in the metabolism of organophosphates. However, extreme susceptibility of these insecticides to biodegradation in flooded rice fields may render them uneconomical as far as developing countries are concerned.

(b) <u>Effect of organic matter</u>

The incorporation of organic materials such as rice stubble, green manure or farmyard manure into the soils during land preparation is one of the common practices employed in rice cultivation. The addition of organic sources accelerates the reduction of soil components to lower states of oxidation leading to a faster Eh drop under flooded conditions. Such reducing conditions caused by flooding and accentuated by organic amendments seem to enhance the degradation of certain chlorinated hydrocarbon insecticides such as DDT and BHC which exhibit a striking negative correlation between their degradation and Eh. Alfalfa amendments hastened the Eh drop to 250 mV within 4 weeks after flooding when DDT degradation to TDE commenced at a rapid rate (Guenzi et al., 1971). Likewise, more rapid degradation of gamma-BHC occurred in rice straw amended soil than in unamended soil when the insecticide was incorporated in an aqueous solution (Siddaramappa and Sethunathan, 1975). Rice straw lowered the Eh to -40 mV in 11 days as compared to +90 mV in unamended soil and thereby accelerated the degradation of BHC. Rapid degradation of gamma- and beta-BHC occurred, however, in both rice straw-amended and unamended soils when they were incorporated in ethanol. Ethanol was as effective as rice straw in lowering the Eh leading to negative potentials even in unamended soils within 7 days. This has applied significance since pesticides are often incorporated into the soils in a solvent such as ethanol or acetone, because of their extreme insolubility in water. A high content of organic matter enhanced the degradation of certain chlorinated hydrocarbons, methoxychlor, heptachlor (Castro and Yoshida, 1974) and endrin (Gowda and Sethunathan, 1975); but experimental evidence for correlation between Eh and their degradation has not been provided.

Recent reports show that direct microbial metabolism does not account for the widespread occurrence of reductive dechlorination of DDT to TDE in anaerobic environments. Because, this reaction occurred even in oxygen-free sterile systems containing ferrous compounds (Glass, 1972; Parr and Smith, 1974) or reduced iron porphyrins (Zoro et al., 1974). Glass proposed a mechanism for conversion of DDT to TDE whereby electrons furnished by the reduced organic substrate were transferred to the DDT molecule via ferrous ions thus initiating a free radical reaction. Whether such a mechanism is operating in the enhanced degradation of BHC in flooded soils rich in organic matter is yet to be explored.

The addition of organic sources also hastened the nitrogroup reduction of parathion (Rajaram and Sethunathan, 1975) and pentachloronitrobenzene (Wang and Broadbent, 1973) under flooded conditions. The common practice of incorporating organic materials in rice culture tends to influence parathion degradation depending on the pathway involved. Thus, the organic amendments increased nitrogroup reduction of parathion in the order: glucose > rice straw > algal crust > farmyard manure. Isotope studies revealed that rice straw accelerated the conversion of parathion to aminoparathion and an unidentified metabolite possessing ethoxy label and P=S bond. In contrast, the organic sources inhibited the biological hydrolysis of parathion in flooded soil inoculated with parathion-hydrolyzing enrichment culture (Rajaram and Sethunathan, 1975); but at the same time nitrogroup reduction was enhanced. Thus, despite the inhibition of hydrolysis, the persistence of parathion was not increased. Perhaps, the addition of organic sources may increase the persistence of similar organophosphates, for example, diazinon which decomposes principally by hydrolysis at P-O-C linkage.

(c) Alternate oxidation and reduction cycles

The rice field is generally subjected to alternate cycles of flooding and drying with concomitant increases in anaerobic and aerobic microorganisms. Alternate oxidation and reduction in a rice soil may provide an environment more favourable for extensive metabolism of pesticides than oxidation or reduction alone. This is particularly true for molecules possessing ring moiety since ring cleavage reactions require oxygen. For example, diazinon is rapidly hydrolyzed in flooded soil, but its hydrolysis product, 2-isopropyl-6-methyl-4 hydroxy pyrimidine, resists ring cleavage under continued flooding (Sethunathan and Yoshida, 1969) and in anaerobic cultures of *Flavobacterium* sp. (Sethunathan, 1973). The pyrimidine ring is metabolized readily, however, to carbon dioxide in nonflooded soil (Getzin, 1967) and in aerobic cultures of *Flavobacterium* sp. (Sethunathan and Yoshida, 1973). Similarly, anaerobic degradation of parathion, a related organophosphorus compound, stops at aminoparathion; but under aerobic conditions further degradation of this intermediate takes place (Graetz et al., 1970). Recently, more extensive destruction of DDT was reported under a combination of anaerobic and aerobic conditions than in either system alone (Pfaender and Alexander, 1972). A *Hydrogenomonas* sp. metabolized DDT to TDE, and several metabolites under anaerobic conditions; subsequent exposure of the incubation mixture to aerobic conditions resulted in the formation of another metabolite, PCPA, formed by ring cleavage. In flooded soil, DDT is readily converted to TDE which persists. Perhaps, alternate flooding and drying cycles as occurring in rice fields may assist in more extensive degradation of DDT past the TDE stage.

(d) Effect of liming

Following flooding, the pH of acid soils generally increases and stabilizes at near neutral values after a few weeks. This increase is not pronounced, however, in soils of low organic matter and some acid sulphate soils. Microbiological activity is expected to be low in soils of extremely low pH. Inasmuch as the degradation of pesticides in soil is microbiological in most cases, an increase in soil pH by the common practice of liming would provide an environment favourable for biodegradation. In this regard, Parr and Smith (1974) reported that liming a muck soil from pH 5.3 to 6.8 caused a rapid conversion of DDT to TDE in moist anaerobic environment. DDT degradation was greatest when the muck was amended with alfalfa meal, lime and Fe^{2+} under flooded anaerobic conditions. The enhanced DDT degradation was associated with the pronounced effects of liming in increasing the bacterial population and lowering the potentials to negative values. In contrast, recent studies in our laboratory showed that liming an acid sulphate saline soil from pH 3.1 to 6.0 was not effective in increasing the degradation rates of gamma- and beta-BHC under flooded conditions despite negative potential and increased bacterial population in limed soils (Siddaramappa, 1975). Presumably, this soil harboured microorganisms incapable of degrading BHC. More work is needed to determine whether liming in combination with organic matter and periodic flooding would accelerate the degradation of BHC in this problem rice soil.

(e) Other amendments

Free oxygen, potassium nitrate and manganic oxide, known for their exceptional capacity to stabilise the redox potentials at high levels even under flooded conditions, retarded the degradation of gamma-BHC in flooded soils (Yoshida and Castro, 1970) and in bacterial cultures (Sethunathan, 1973). This would largely explain the relatively long persistence of this and related chlorinated hydrocarbon insecticides in predominantly aerobic nonflooded soil system. Wang and Broadbent (1973) reported that potassium nitrate and molecular oxygen retarded the nitrogroup reduction of pentachloronitrobenzene to pentachloroaniline in flooded soils amended with glucose. Recent studies showed that a factor that inhibited the biological hydrolysis of parathion developed in rice straw-amended soil under flooded conditions; but the presence of free oxygen or potassium nitrate prevented its formation (Rajaram, 1975). More work is needed to determine whether the increased rates of fertilizers in rice culture would influence the degradation rates of pesticides.

2) Effect of pesticides on biochemical transformations

There are some reports on the effects of pesticides on certain biochemical transformations affecting soil fertility under flooded soil conditions.

(a) Heterotrophic nitrification

Experimental evidence points to active nitrification in the thin oxidized upper layer of flooded soils. Although the autotrophs, *Nitrosomonas* and *Nitrobacter*, are known to be involved in a two-step nitrification process, recent evidence suggests that heterotrophic nitrification is more widespread in natural ecosystems than hitherto believed (Verstraete and Alexander, 1973). Most recent studies show that heterotrophic nitrification of ammonium to nitrite can also occur in the simulated oxidazed zone of a flooded soil amended with a fungicide, benomyl at concentrations inhibitory to autotrophic nitrifying bacteria (Gowda et al., 1975). Oxidation of ammonium to nitrite in benomyl-amended soils and by a benomyl-tolerant bacterium, *Pseudomonas* sp., even in the presence of autotrophic nitrification inhibitors, N-Serve or AM confirmed the role of heterotrophic nitrification in benomyl-amended soils. Nitrification is not desirable in anaerobic environments such as flooded soil, in view of the great instability of nitrite and nitrate and consequent loss of nitrogen in gaseous form through denitrification in such ecosystems. Moreover, intermediary products reported from heterotrophic nitrification by an *Arthrobacter* sp. (Verstraete and Alexander, 1973) such as hydroxylamine, 1-nitrosoethanol and nitrite are known to be toxic. Accumulation of such products even in small quantities in benomyl-amended soils, although not demonstrated in this case with the exception of nitrite, may pose an indirect environmental pollution hazard in addition to direct toxicity of benomyl.

(b) Nitrogen transformations

Flooded conditions in rice fields favour populations of blue-green algae and certain heterotrophic bacteria (obligate or facultative anaerobes) possessing exceptional capacity to convert atmospheric nitrogen to ammonia. In one instance, a distinct increase in the blue-green algal populations was observed when gamma-BHC at 5,6 and 50 kg/ha was applied to flooded soils, presumably due to elimination of small algae-eating animals (Raghu and MacRae, 1967). Applications of gamma-BHC at 6 kg/ha also resulted in significant increases in nitrogen fixation. Mineralization of nitrogen was not adversely affected by applications of gamma-BHC and diazinon at recommended levels.

3) BHC residues in rice ecosystem and rice plant

Scientists at the International Rice Research Institute, Philippines and elsewhere have done extensive studies on the residues of BHC in rice and paddy ecosystems (IRRI, 1968) as summarized below:

(a) Residues in soil and paddy water

Residues of BHC in the soil and paddy water reached very low levels in about 25 days. In a recent study (IRRI, 1971), a commercial granular formulation of BHC containing different isomers was applied to flooded rice fields at 6 kg active ingredient (a.i.)/ha at 10, 40 and 70 days after transplanting. Soil samples collected at harvest showed an average recovery of 80 ppb of gamma-BHC, 615 ppb of alpha-BHC, 262 ppb of B-BHC and 202 ppb of delta-BHC. Soil analysis from plots receiving the highest rate of gamma-BHC, 45 kg a.i./ha showed recovery of insecticide in quantities similar to those treated with only the normally used 6 kg a.i./ha (IRRI Reporter, 1968). Soil residues were very low even in plots treated continuously with high rates of gamma-BHC for 5 cropping seasons.

(b) Residues in rice grain

When granular formulations of BHC are used in rice fields, residues of BHC isomers recovered from the grain are far below the established tolerance limits. Lipid-rich bran accumulated the residues to some extent; but milling removed the bran and thereby minimized the residues in polished grains. From the view point of Indian agriculture, an investigation on the terminal residues (Winteringham, 1971) of pesticides in parboiled rice would be of great importance since more than 40 per cent of the consumed rice in India is parboiled (Wimberly, 1971). Parboiling is a process of soaking and steaming of the paddy followed by drying before milling. Parboiling increases the cooking quality, retention of more vitamins and milling quality in the grains. No attempts have been made, however, to study the retention of pesticide residues in rice grain after parboiling.

(c) Residues in rice straw

Rice straw has more residues of BHC than soil and grain. Residues of gamma-BHC in rice straw from plots treated with BHC granules averaged 1.5 ppm; other isomers were recovered at levels 5 to 10 times as high as those of gamma-BHC (IRRI, 1967, 1971). Kawahara and Nakamura (1971) reported that residues of alpha- and beta-BHC in rice straw were higher than those of gamma- and delta-BHC. These isomers appeared to be relatively persistent in rice straw. Reports from Japan show that beta-BHC which is less degradable than other isomers accumulates in milk although this isomer is only a minor component in the commercial preparations of BHC used in agriculture.

Chlorinated hydrocarbon insecticides are fat soluble and tend to accumulate in lipid-rich tissues of the plant. An interesting observation by Sridhar et al. (1973) revealed the presence of characteristic lipid globules, two or more in chlorophyll containing parenchymatous cells of rice leaves. Perhaps, these lipid globules would explain the higher residue levels of BHC isomers in the rice leaf.

The common practice of exposing rice straw to the sun in the tropical countries may minimize the residues, but only to some extent. In countries such as India, where rice straw is used as main cattle feed, the potential hazard of accumulation of BHC and related chlorinated hydrocarbons in milk is to be considered with serious concern.

4) Perspectives and conclusions

The importance of flooded soil as an ideal medium for detoxication of certain persistent pesticides has been demonstrated recently. The reducing conditions caused by flooding and accentuated by organic matter amendments hasten the anaerobic biodegradation of certain pesticides. The extent of degradation of DDT and BHC was related to redox potentials of the soils. As for BHC, no residue problem appeared to exist in microbially active soils capable of attaining an Eh of -40 to -100 mV within two weeks after flooding. The monitoring of Eh as a useful environmental parameter in predicting the persistence of BHC in ecosystem such as flooded soil, lake sediments and oceanic environments needs further study.

The extent of degradation of pesticides in saline rice soils merits more extensive study since a substantial portion of rice growing soils in the coastal areas of India is characterized by high salt content and often extremely low pH.

The alternate oxidation and reduction as generally exist in a rice soil may assist in more extensive degradation of certain pesticides than in either system alone.

The rate of degradation has been determined for a limited number of insecticides under flooded conditions; but little is known of the stepwise processes involved in the degradation of these compounds in flooded soils and in anaerobic cultures.

Rice straw has more residues of chlorinated hydrocarbon insecticides than the grain and soil despite their application to the flooded rice fields as granules. In countries such as India where rice straw is used as a major cattle feed, the potential hazard of their accumulation in the milk is of great concern.

Little is known regarding the 'terminal residues' of pesticides in parboiled rice although 40 per cent of consumed rice in India is parboiled.

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4.2 ENVIRONMENTAL PROBLEMS ASSOCIATED WITH THE USE OF PESTICIDES TO CONTROL CERTAIN DISEASE VECTORS AND PESTS OF LIVESTOCK

Paper prepared by the
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Introduction

1. The title of this Technical Consultation refers to environmental problems arising from agricultural pesticides and this is often construed to mean only chemicals used in direct crop protection. However, large amounts of chemicals are also utilised in other pest control activities which also need consideration. Direct agricultural usage includes the protection of livestock from various vector borne diseases, such as African animal trypanosomiasis carried by the several species of tsetse fly, East coast fever carried by species of ticks, and against attack by biting flies such as stable flies and tabanids which have a variety of effects from death to reduction in milk yield.

2. However it is also important not to overlook pest control operations related to the maintenance of the health of the agricultural work force in developing countries and this category would include chemicals used for malaria mosquito control, for the control of vectors of such diseases as onchocerciasis and filariasis and for the control of human schistosomiasis. The World Health Organisation is of course the major UN agency concerned with most of these latter diseases, but FAO is involved in the control of livestock diseases, in particular trypanosomiasis and other diseases due to biting flies and ticks. Also because human schistosomiasis is a disease particularly affecting the agricultural work force in developing countries, and especially that growing section of it working in irrigation schemes, the increasing use of molluscicides for vector control in schistosomiasis can be claimed to be an important agricultural problem.

3. This paper therefore deals with these two problems, livestock disease vector control and schistosomiasis control, particularly from the point of view of programmes of research required to investigate the environmental effect of control programmes. Reference is also made to the on-going WHO project on onchocerciasis both because of its effect on the agriculture of the infested region and because of the environmental problems and programme involved.

Livestock disease vector control

4. African animal trypanosomiasis is carried by the various species of the genus Glossina, widely distributed over the African continent and recognised as one of the main obstacles to efficient land usage in many developing countries; a conservative estimate of the land area denied to livestock by tsetse fly is 5×10^6 km^2. The problem is complicated by the occurrence of human trypanosomiasis, transmitted by certain species of tsetse fly. The principal control methods for this disease may be summarised as follows:

A. Against the parasite

(i) Chemotherapy

(ii) Trypano-tolerant cattle

B. Against the vector

(i) Habitat modification

(ii) Biological control

(iii) Chemical control

These methods and their environmental consequence will now be considered in turn.

5. Chemotherapy comprises the use of trypanocidal drugs such as Homidium or Diminazene and the use of prophylactic drugs such as Pyrithidium and Isometamidium. The use of trypanocides has become widespread and it is estimated that some 8×10^6 treatments are carried out every year. However the danger in both these methods is the production of chemoresistant trypanosomes, an effect which has some claim to be called environmental since it seriously affects the possible deployment of chemotherapy in traditional animal production in developing countries and focusses attention on other techniques.

6. The breeding of trypano-tolerant cattle may seem to be the most desirable technique, but socio-economic factors mitigate against it, because the development of the breed is slow and expensive, immunity is subject to variation and can break down under conditions of malnutrition, excessive work or other diseases, and yield is questionable. However clearly this is a method of considerable importance from the environmental point of view and the need for continued research and development in this area has been noted in the Report of the FAO Expert Consultation on Trypanosomiasis (FAO AGA/TRYP/74/2E).

7. As regards the development of new methods of parasite control and the use of immunological techniques it is relevant to record here that this forms an important part of the objectives of the International Laboratory for Research on Animal Diseases (ILRAD), an institute of the Consultative Group for International Agricultural Research newly established in Kenya. Basic research on the parasites to discover new methods of control is being undertaken in several countries, but it seems unlikely that this will produce any practical and economic control techniques in the short term.

8. In the long history of the campaign against African trypanosomiasis, attack on the vector has figured largely. A method much favoured some 20 years ago was the modification of tsetse habitat by bush clearance, both mechanically and by chemicals, and the destruction by shooting of wildlife which acts as the disease reservoir. The ecological consequences of such methods vary considerably with the eco-system in which it is employed, and few data are available as to its long term effects, such as soil erosion, which in complex systems may take time to manifest. The key to success of this technique is rapid re-settlement of human population and this requires environmental studies in itself.

In some areas, game destruction has resulted in good tsetse control, as described by Potts et al (1952) for the Shinyanga experiment, but because of the recent trends in world opinion, particularly in relation to wildlife conservation, these methods of habitat modification are unlikely to be favoured for use in the future. However, an interesting environmental paradox is posed by the increasingly large areas of tropical Africa which are now set aside as National Parks and Game Reserves. These constitute, by definition, large reservoirs of trypanosomiasis and yet most conventional forms of vector control are unacceptable in such areas. It may eventually be for consideration whether the economic, especially tourist, advantages of such parks outweigh the trypanosomiasis problem to an extent which precludes all control action.

9. It is quite clear, however, that if a successful campaign of eradication of trypanosomiasis is to be mounted in Africa, some method of acceptable tsetse control in such areas must be developed and this clearly should be an area of concern for UNEP. It seems unlikely that there are any beneficial effects ascribable to tsetse fly in any ecosystems and indeed their biting probably adversely affects game animals, so that the eradication of fly would be beneficial to game parks. It is desirable therefore that some attention be paid to this aspect of the problem. The development of efficient tsetse traps, for example, perhaps chemically baited, may well be at least a partial answer here, and of course the development of an efficient method of biological control (see below) would be a complete answer.

10. However, biological control of tsetse flies has long been an elusive goal and studies of the biology of the fly suggest that because of its essentially mobile nature the use of parasites, predators and pathogens are unlikely to be of any great value in the foreseeable future. Likewise the use of genetic control techniques, while holding considerable promise for the future, can only be at present envisaged as one component of long term integrated control campaigns, where initial reduction of fly populations, to make genetic control economically feasible, is by insecticides, with consequent danger of some environmental hazards, as described below. In addition, it has become clear as a result of recent work on genetic control of insect pests in general that extremely detailed knowledge of the population structure, both genetic and ecological, in the control area is an indispensable pre-cursor for effective genetic control and while this in itself is an important and useful objective, relevant to other forms of control, it may and probably will take years to accomplish.

11. Far more promising is the use of the sterile male technique in tsetse control and this possibility is being pursued by the joint FAO/IAEA Division on Atomic Energy in Agriculture with the active co-operation of many other laboratories and organisations. The sterile male technique needs for success a cheap method of producing large numbers of sterile insects, competitive with wild males, and a small natural population, whose ecology is well known, into which these can be released. Recent advances in the membrane feeding technique for rearing tsetse flies (Mews, 1971; Jordan 1972)* suggest that a suitable mass breeding technique is not far off, but still a lot needs to be known about tsetse ecology in relation to the use of this method. Small input populations are desirable and this again suggests the technique is best used on low density populations resulting from initial chemical control.

This method, which has already been used with some success on a practical scale against other insects, is clearly one to be developed as having no undesirable environmental consequences. However, the ecological requirements specify an area which is immune from re-infestation due to fly movement either due to natural barriers, or else expensive artificial barrier systems have to be set up. Because of the known flight range and behaviour of tsetse, such barriers must be 5 - 10 km in extent and are made either by destroying the vegetation in the barrier, or by treating the area with residual insecticide, or both. Therefore in working out schemes of this sort care has to be taken in the cost/benefit analysis to allow for the cost, both in actual and environmental terms, of barrier devices.

12. There are other techniques which should be considered under the heading of biological control, such as the development of chemically baited traps, or the use of repellent chemicals applied externally or systemically to the cattle. The latter method suffers from obvious logistic faults as regards application and is unlikely to be efficient enough in operation to warrant the high cost of development. However, chemically baited

traps offer a technique which can be used in relation to low density populations and there are already suggestions from recent research that the discovery of relevant chemicals may not be too difficult, and this therefore is an area of research warranting further work. (See para 23 below.)

13. From the foregoing it must be clear that the method of choice for tsetse control at present and for the immediate future can only be chemical. Chemical methods are used only against adult fly, because the larvae and pupae of all tsetse species live in the soil or are inaccessible for other reasons. Female flies produce one egg at roughly three week intervals; this slow rate of reproduction means that once a population is brought to a low level it will take a long time to recover and hence initial chemical knock-down provides a good basis for low density control techniques such as sterile male or trapping. However, the pupal stage may last for months, and this means that with purely chemical control insecticide applications must be repeated at intervals of three weeks for up to twelve weeks to kill all emerging adults. Clearly such repeated spraying adds to the environmental hazards discussed below.

There are two major techniques of tsetse control; one is the use of chemicals so formulated that they produce a toxic residue on the vegetation where the fly sits, which results in pick-up of lethal doses. Chemicals which are stable in the environment, such as dieldrin and DDT, have been used with much success with this technique. The other method, generally used with less persistent compounds such as the organo-phosphorus group but which can also be used for organochlorines, is the application of the chemical in very finely divided form, either as a thermal fog or by ULV application, to kill the fly by direct contact action.

14. Both these basic methods can be used from the ground or by aircraft spraying, and the choice of method depends on many factors, including the size and nature of the ground to be covered, the desired speed of work and also the knowledge of the behaviour of tsetse populations therein. From the environmental point of view it is clear that aerial blanket spraying of large areas with persistent chemical must present a greater hazard to non-target organisms than the ground application of chemical only to fly resting sites on the lower part of vegetation. There must be a gradation of risk between the various techniques, but so far little comparative work has been done to elucidate these.

15. The environmental hazards due to these control techniques can be summarised as

(a) Direct toxicological hazards.

(b) Residues inimical to public health.

(c) Development of resistance to pesticides.

(d) Effects on non-target organisms.

In any consideration of programmes directed towards the detailed elucidation of these hazards and their ultimate rectification, it is essential to build in at the outset a thorough cost/benefit analysis which takes in both fiscal and socio-economic factors, present and future. Thus it would probably be unjustified, as pointed out by a WHO Scientific Group (WHO Technical Report 560, 1975) to limit the use of an effective pesticide because of possible hazards associated with ingestion of toxic residues. In view of the world food situation, this is particularly true at the present time of agricultural pesticides which clearly improve food production. The value, both monetary and in socio-economic terms, of the extra usable production brought about by the use of the pesticide must be weighed against the possible environmental hazards, and viewed in relation to the likely development of the agricultural economy of the country or area of use. Thus it is not sufficient to consider only presently available compounds and techniques and their possible attendant toxic hazards. An attempt must be made to assess the cost of the development of new compounds of techniques which may reduce or obviate present hazards in particular crops or against particular pests and this inevitably means close liaison with chemical companies and a consideration of the commercial aspects of the problem. It is no longer rewarding to view chemical companies and their profit orientation as the main stumbling block to progress. If it is held that their application of technology has resulted in undesirable environmental effects, the beneficial effects of pesticides must also be considered; and it is also necessary to realise that commercial technology is the only one available to exploit and produce new compounds of an environmentally desirable type. If these techniques and compounds do not appear acceptable as commercial propositions, then government level decisions will be necessary to decide if the use of public money to support a new compound is justified by the potential improvement in environmental position. Programmes in this area should therefore be worked out in close co-operation with industry.

16. An example, particularly important in the present context, is the search for and development of bio-degradable insecticides. Development of a range of these which could replace, to the extent at least compatible with the requirements for persistence, certain presently available pesticides would be obviously advantageous in the reduction of environmental hazard. But the discovery, testing, and development of such compounds will need commercial technology at some point, and will also require facilities for far ranging environmental testing, both in the laboratory and the field as described later. The overall economics of the development of such compounds and their formulation and development will also require careful consideration.

17. The direct toxicological hazards of pesticides have been the subject of assessment by WHO and national governments for many years, their safety to man being assessed in relation to their efficacy. Such evaluation programmes need to be continued, enlarged and made more efficient, and in particular should include field tests whenever practicable.

To carry out such tests it is desirable that developing countries have at least one laboratory in which determination of pesticides and their residues in soil, water and animal and vegetable tissue can be made, and in which some bio-assay tests can be carried out. A survey of such facilities and their availability would be valuable in relation to development and use of pest control techniques in any country or region and this, together with a survey of the available trained manpower and the requirement for future training is important basic information for future planning. It is quite unrealistic to impose regulations designed to reduce environmental hazard unless the basic laboratory and manpower facilities to uphold these are available.

18. The environmental hazards referred to in para 15 (b) and (c) above, the problem of residues and the development of resistance to pesticides, are dealt with in other working papers. They are in any case the subject of detailed consideration by various expert panels both of FAO and WHO, separate and joint, and recommendations for future work already exist for many aspects of work in this field.

There is however one aspect of both these problems which is often referred to but about which little or no reliable data exist. This concerns what might be termed the cumulative synergistic action of agricultural pesticides and those used in human and animal vector control to produce both dangerous residues and, more particularly, pesticide resistance in a wide range of organisms. It is frequently stated, for example, that the continued use of wide spectrum insecticides for agricultural purposes has been a major contributor to the development of resistance in vector species such as malarial mosquitoes. Thus the WHO Expert Committee on "Ecology and Control of Vectors in Public Health" (WHO Technical Report No. 561, 1975) states (para 2.1) that "resistance in a vector ....

is frequently caused by the widespread use of agricultural pesticides", and go on to say that the extent of resistance problems would be "much greater if organised control programmes were carried out on an area wide basis." The amount of truth in these statements is difficult to ascertain; however since these generalisations are technically feasible there is an a priori case for attempting to gather data on this important problem, because there are already proposals for the aerial application of agricultural pesticides on a large scale which might have an effect on resistance in vector species. What needs investigation is the application and distribution of agricultural pesticides in such schemes to see how they might impinge on the various vectors concerned. Interaction will depend on such factors as the mode of application of the pesticide and the behaviour of the various pest species involved.

Thus clearly aerial application of agricultural pesticides will present more hazard in this area than ground application; likewise, vector species like tsetse flies, with protected juvenile stages and a highly mobile adult will be less likely to develop resistance than species like mosquito vectors whose aquatic breeding sites may well be contaminated by the run-off of agricultural pesticides. It is significant in this context that resistance has not been reported for Glossina spp or for highly mobile species of pest like locusts. There are limitations to the development of resistance due to distribution of pesticides and these need investigation.

19. The above considerations are of a general type applicable to most pesticides. Turning now to consider more particularly project studies relevant to environmental problems caused by use of insecticides against tsetse and other pests of livestock, clearly the studies required depend largely on the persistence of the compounds used, and the method of application. Thus, for example, the blanket aerial spraying of large areas with a persistent insecticide must present more hazard to non-target organisms than the restricted ground application of a bio-degradable compound. Between these two extremes there will be grades of danger to the environment, which will depend then largely on the complexity of the ecosystem involved.

20. A generalised requirement is the development of an adequate monitoring system on the distribution, persistence and possible harmful effects of the compound to man. such a monitoring programme, which of course can only be undertaken if the facilities referred to in para 17 are available, should be a continuing activity and must take into account as a basis the methodology of the control campaign and the classes of people and other animal species most at risk as a result of the operations in question. Thus clearly operations with basically different methodology, such as for example, but spraying against malaria, granule application of pesticides to maize for stem borer control, and aerial blanket spraying against locusts or tsetse fly need different monitoring and sampling programmes. It is a truism often overlooked that each type of pest control requires its own monitoring and environmental hazard evaluation scheme.

Thus the basic techniques for tsetse fly control described above need quite different approaches. In ecologically based ground spraying of tsetse resting site vegetation the group most at risk are the spray crews and insecticide handlers, and the environmental effects on non-target organisms are likely to be small and temporary. In the case of aerial spraying, the reverse is true - there is negligible hazard to the spray applicators but a maximum risk to non-target species in the area.

21. Koeman (1973) in an FAO report on "Methods of investigating possibly undesirable environmental effects arising from the uses of pesticides in developing countries" (FAO Report AGPP: Misc/9: 1973) has pointed out those aspects of tropical eco-systems specially relevant to the effects of pesticides. Some factors, such as the more rapid breakdown of pesticides due to high temperatures and similar factors, will tend to minimise damage,

while others, such as the high level of trophic interdependence between species which can result, inter alia, in such effects as the passage of pesticides from prey to predator, will tend to increase damaging side effects.

22. As stated several times above therefore it is necessary to look at each system and problem separately on its merits and because resources are insufficient to cover all cases choices will have to be made. However, this will not be so limiting as it might appear, because some of the basic ecological findings appertaining to one area and species will also be relevant, in a variety of ways, to others.

There is a requirement for both laboratory and field studies. The type of laboratory study will be mentioned only briefly here, as they will be dealt with in other papers, but Figure 1, from Koeman's report, gives a good outline of the various components required to study environmental toxicology. The laboratory studies should include the model eco-system approach developed by Metcalf et al (1971) and also the development of toxicity tests under controlled conditions with indicator species to elucidate both chronic and acute effects of a compound at various dosages. An example of this is the molluscicide testing against fish described in the second half of this paper.

23. However, there is no doubt that the main area in which reliable data are required is from the field - from experimental studies and pilot-scale studies of planned control campaigns.

In the field of tsetse control this is particularly true today when both FAO and WHO hope to commence work on pilot projects which can lead to the formulation of campaigns for the control of tsetse fly in dry and moist savannah respectively. The basic requirement for both these studies is detailed knowledge of the diurnal and seasonal behaviour of the fly in respect of both the vegetation, as a resting site and shield from toxic chemicals, and of the wild host as a food source for the fly and reservoir of the trypanosomes. This must be a long term study but there is one aspect of work which is common to all studies - the paramount need to develop a simple reliable technique for assessing the number of flies in a given area. The work of Vale (1974) in Rhodesia has shown how such research can be approached; there is now an urgent need to test Vale's hypotheses and experimental approach, so far mainly limited to Glossina morsitans, on other species and in other areas of Africa, and develop his methodology. There is no reason to suppose that, given adequate financial support and facilities for such work, that a reliable technique could not be developed within a few years.

The component areas of such research must include the following:

(a) Laboratory research on the basic resting/flight/feeding behaviour of tsetse and their reaction to environmental features such as day-length, temperature and wind speed.

(b) Laboratory studies on the feeding/nutrition cycle of tsetse and their reactions to wild hosts, with particular reference to host seeking behaviour by visual and anemotactic orientation. Coupled with this should be studies on possible olfactory mechanisms and the compounds involved in host finding.

(c) The development in the laboratory and the field of reliable trapping methods, based on the laboratory evidence accumulated by the above studies and the design and production of a variety of trapping devices, using both visual and olfactory stimuli.

Such work can be executed best by a network arrangement of collaborating laboratories in developed and developing countries with emphasis on field work in the latter.

24. Concurrent with the search for reliable tsetse survey methods must go experimental studies on the efficiency and environmental effects of newly developed tsetse fly insecticides. These must include compounds like the new synthetic pyrethroids whose environmental effects must be determined. Dosage, formulation and application methods, designed to produce the required lethal dose at the right site and lasting for the minimum time necessary, must be determined and methods to reduce drift and enhance precise placement developed. These studies on new compounds need to be carried out in a comparative manner with established compounds such as DDT and dieldrin and, in particular, accurate data on the effect of these new compounds on non-target organisms need to be established.

25. Since it seems likely that the urgent requirement for tsetse clearance, in some areas at least, will mean the employment of aircraft spraying, this is a priority area. It is necessary to carry out comparative trials with small aircraft to determine their efficiency, cost and environmental side effects with dieldrin and endosulphan, and two or three new promising compounds. To carry out such tests requires ideally the setting aside of an experimental area of several square kilometres. The initial step will be to carry out a survey of terrain, vegetation and non-target organisms, both terrestrial and aquatic, and establish major meteorological and spray sampling stations; spray samples of both the paper, cascade and whirling arm type should be utilised. The preliminary study of non-target organisms should enable the designation of certain possible marker or indicator species. Ideally again these should be tested against the toxic chemical so that LD_{50} and LD_{99} data and their variation are known for populations. Pre-spraying collection of samples and their examination for pesticide residues are necessary to establish pesticide baseline data. Again, ideally, the fauna to be examined should include small mammals, both carnivores and plant eaters, birds, reptiles and various invertebrates, preferably representative of ground dwellers (e.g. crickets) and flying species. For aquatic habitats, fish and some invertebrates such as shrimp or crayfish should be selected.

A large sampling programme is required, both pre- and post-spraying, and facilities for the examination and preservation of specimens for chemical residue analysis and for the determination of approximate population densities and distributions. Since, for reasons given above, tsetse eradication requires repeated spraying in one area, the whole sampling programme must be capable of being repeated at the necessary intervals.

This type of programme will give some indication of acute effects of the spray campaign, but to measure long term effects then ideally the experimental area needs to remain undisturbed and unsprayed for at least a year, during which further sampling and residue analysis is undertaken and population surveys continued.

26. It is obvious that the above is an ideal programme, and putting it into practice will be very difficult. For example, for derivation of population numbers and distribution, ideally a non-killing sampling method is required, particularly for small mammals whose numbers are likely to be relatively low. In most cases such methods are not available and need research to develop them. There are also great difficulties in the ecological interpretation of the data which are obtained and particularly in the interpretation of long term trends, which is what the study is ultimately about.

The capacity of animal and plant populations of different species to recover from a set back varies enormously, with many factors involved. Methods to measure population upset are relatively poorly developed but all require good sampling. A good exposition of the practical problems involved and the sort of results that can be obtained by projects like that described above is to be found in Koeman et al (1971) describing changes in a swamp habitat in Nigeria following tsetse fly spraying.

27. But despite the great difficulties and the rather doubtful validity of the results in some respects it is this sort of study which is now urgently required. Unless projects of this nature can be carried out during the next few years then it will not be possible to develop tsetse control techniques which offer efficient fly control with minimal environmental damage. The present work has been too little, too short in duration, covering too few species and with insufficient technical back-up resources. The main reason for this has been shortage of finance and trained manpower.

28. However it is clear that there is growing realisation that projects of this sort are essential if adequate account is to be taken of the need to protect the environment in face of the paramount need to increase food production. It has been calculated (Perfect, 1972) that pesticide use in developing countries will have to be increased by 70–80 times to attain estimated maximum yield per hectare, and clearly this implies greater danger of environmental hazard.

It is therefore not surprising that many countries are now attempting at least pilot scale surveys to determine the effect of proposed tsetse fly eradication compounds. Botswana is a current example, where experimental spraying to eradicate tsetse from the Ikavanga Delta is in progress. This objective holds potential short term dangers environmentally and a co-ordinated research project has just been started in Botswana to determine the possible effects of the insecticide, endosulphan,on the non-target species involved. The methodology of approach, and the difficulties encountered, should be useful in relation to other similar projects.

29. Such national efforts are however few and far between and it is important that longer term and more detailed investigations be carried out. It is not possible nor desirable to have large numbers of these and it is suggested for discussion that UNEP should consider mounting two major environmental investigation projects in relation to tsetse fly control, one in a river or swamp area and the other in dry savannah.

These projects would have as Executing Agencies WHO and FAO respectively; it is further suggested that to develop this approach UNEP should fund the setting up of an expert working party, with participation by both agencies, to draw up details of project programmes, including manpower and costs. These proposals should refer to specific areas where the work can be carried out. These projects should be constructed, insofar as possible, so as to provide data on both short and long term aspects of the problem, as outlined above, but should be regarded only as major pilot studies; while a great deal of valuable data will accrue, it will not be possible to carry out work on all types of ecosystem. However, these projects will clarify requirements in methodology and technique which can then be applied to later work. It is obviously important that these major pilot studies be started as soon as possible, because present national and international plans for augmentation of tsetse fly control will be impeded, and the danger of environmental damage increased, until their results are available.

30. It must be especially emphasised, in connection with proposals such as those made above for investigation of the effect of tsetse control in non-target organisms, that very little indeed is known about this subject and hence any work will greatly increase our knowledge. It may be thought by the average observer that a great deal is known about the effect of agricultural pesticides in the environment, but nothing can be further from the truth.

There have indeed been a very large number of observations on isolated aspects of the problem and some of these - e.g. mercury in fish, effect of DDT on birds' eggs - have been the subject of much international publicity. But these are particular aspects of particular problems. Practically no large-scale long-continued research on the broad ecological effects of agricultural or public health insecticides has been carried out and no analysis in depth on the cost/benefit problems involved has been made. The short term investigations so far carried out - generally as a result of some disaster, such as for example the escape of insecticide into the River Rhine - certainly indicated the very great damage potential that exists in these chemicals; laboratory investigation into the effects of continued exposure to insecticides, even at sub-lethal doses, also suggest that long term effects, at present largely unknown, can occur. But of detailed continued investigation there has been little. Thus papers like that of Newsom (1967) on the effect of pesticides on non-target organisms, adequately summarise the data available, but are full of remarks such as "the effects of insecticides have ..... received a great deal of attention, but relatively few sound data are available from which to draw conclusions".

Pesticides are, by definition,compounds toxic to biological organisms and this has been adequately demonstrated for many non-target species. But the effects of these compounds on populations, and even more on whole eco-systems, is virtually unknown. Since this is the important aspect of the problem as it affects man, surely this is where the thrust of new effort should be? Hence the proposals above for a wide spectrum approach to the problem; this is more difficult than restricted studies on one species, but much more important. It is also important that such work be continued long enough to produce results of general ecological significance, which means several years, and on a scale big enough to measure effects on the eco-system rather than on small bits of it. No more important work than this remains to be done in the pesticide/environment area.

31. Virtually all that has been suggested above as desirable in relation to the effects of tsetse spraying can be repeated in relation to the control of other pests of livestock such as biting flies and ticks. The latter especially warrant attention as vectors of diseases of international economic importance and also because insecticide resistance has already appeared in several important species. It may well be that here is an instance where the phenomenon mentioned in para 18 has indeed occurred, with general use of agricultural chemicals, and particularly the organo-chlorines, helping to induce resistance in ticks. The FAO Animal Health Service have developed a proposal for a global monitoring scheme for this and consideration might be given to expanding this to investigate the possible general effect of agricultural pesticides in this area.

Water borne parasitic dieseases

32. In recent years, schistosomiasis (bilharzia) and onchocerciasis (river blindness) have been studied with a view to large-scale control. At the present time, chemical control of vector species would appear to hold out the most hope for reducing the prevalence of these diseases in areas where they are endemic.

33. In the case of schistosomiasis, drug therapy in the primary host (man) has to be by a single dose for successful mass treatment (due to the impossibility of following-up individual cases), and while such drugs exist, they are expensive and can produce harmful side effects unless administered under trained medical supervision. Biological control of the molluscan intermediary is a possibility, but research in this field is still at an early stage of development. Improvement of tropical public health education and facilities in rural areas would do much to prevent transmission but this is, of course, attendant on general improvements in living standards in such regions, a development which is some way

off in many cases. Clearly, therefore, large-scale chemical control remains the most feasible alternative at present. The last twenty years have seen considerable advances in the technology of molluscicide application, and we are now in a situation where vector snails can be controlled almost routinely under a wide spectrum of environmental conditions.

34. The WHO Onchocerciasis Control Programme (OCP) has as its objective the elimination of river blindness in the area over the next twenty years (this period of control should be sufficient to ensure that all adult worms have died). Here again, drug treatment is available but, of the two chemotherapeutics, suramin appears to be mainly active against the adult worm, while diethylcarbamazine is primarily microfilariacidal. Mass treatment of the human population is in any case very difficult in a programme area of 700,000 km^2 where ground communication is bad and location and follow-up of individuals impossible. Chemical control of the adult vector fly (Simulium damnosum) would be similarly impossible due to the vast area. The aquatic larva of the fly is, however, so demanding in the conditions it requires (very fast-flowing shallow water) that usage of insecticide against this stage is considered to have a reasonable chance of success.

35. The chemical chosen by the OCP for Simulium control is an organophosphate, Abate. This larvicide has been applied in West Africa by the OCP since November 1974, and if harmful side effects do not appear, may well be used throughout the twenty year programme. It has been shown that a ten-minute exposure to 0.05 ppm Abate is sufficient to cause larval mortality. Abate is being applied in single weekly doses to each of the various Simulium breeding sites along many of the rivers in the programme area.

36. Any consequent effect of Abate on non-target organisms in West African rivers may depend on the speed of flow, the stability of the chemical and its ability to sorb onto mud and other surfaces. Provision has been made within OCP for the assay of Abate in water and faunal samples, and for the monitoring of non-target populations by regular sampling, but no detailed results are available as yet. Toxicity data on Abate reveal that it is reasonably specific to insect larvae, having no apparent direct effect on fish in the short term. There are fears, however, that commercially important fish populations in Lake Volta, which are exposed to water frommost of the OCP-affected rivers, may suffer deleterious effects from long-term sub-lethal poisoning and from the indirect action of changes in poisoned insect populations.

37. In spite of the continued search for new and more specific molluscicides, only two formulations are in use on a large scale at present. These are Frescon and Bayluscide made by Shell and Bayer, respectively. A great deal of work has been done to establish the optimum concentrations and times for applying these compounds, their stability and translocation within the biosphere and their effect on non-target fauna and flora. While both compounds are not acutely toxic to mammals, insects or most plant crops, both are toxic to many aquatic animals with exposed membranes such as fish. Indeed Bayluscide is widely used as a fish poison (Lennon et al, 1970), and Meredith (1971) while looking for a simple bioassay method, demonstrated its lethal effect on the protozoan, Spirostomum, at molluscicidal dosages. Similarly, Frescon is toxic to some fish species at routinely applied concentrations (e.g. Shiff et al., 1967).

38. It has been proposed that application of these chemicals at lower concentrations over longer time intervals may be just as effective against the snail while lessening environmental damage. Extrapolating this hypothesis, Cardarelli (1974) has incorporated organotins and other compounds into elastomeric matrices with the idea that such formulations would maintain a very low pesticide concentration in the water for several months or even years. The proponents of the technique also claim that snails will succumb while

other aquatic organisms remain unharmed. Preliminary laboratory results from Matthiessen (1974) have shown, however, that the tropical food fish, Sarotherodon (Tilapia) mossambicus is susceptible to a range of deleterious sub-lethal effects when exposed continuously to very low concentrations of tributyl tin oxide (TBTO). For example, a constant concentration of 8 µg. TBTO/litre produces highly significant growth rate reductions after only 5 weeks' exposure, and most fish succumb to a serious, though usually temporary, lesion of the cornea which interferes with vision. Various behavioural changes have also been observed, and similar though milder effects are found at 5 µg.TBTP/l. Whether such effects will occur under field conditions has yet to be demonstrated (vida infra), but they certainly give cause for concern. Early field results indicate that where water treated with the slow release TBTO formulation is flowing, even only gently, control of snails cannot be obtained (Castleton, 1974). That this is due to insufficient water concentration of toxicant being achieved may be supported by the work by Shiff (1974) in Rhodesia who showed that snail populations could be controlled with slow release TBTO in small dams where water is almost stationary. He notes, however, that no effect could be observed for some weeks, but after this time the snails disappeared very rapidly. Whether this is due to accumulation in adults leading to intoxication only aftera prolonged time interval, or reproduction is being affected, remains to be seen.

39. There is reason to believe, therefore, in the existence of subtle effects on both target and non-target aquatic populations arising from long exposures to low doses of chemicals, and that these may eventually be as disastrous as acute poisoning. Some method of early detection of such effects is therefore desirable.

40. It is contended that much relevant information can be gathered from laboratory trials, matched with concomitant work in the field. The Centre for Overseas Pest Research, London, has developed a flowing water system whereby fish and aquatic snails may be exposed over any time interval to low concentrations of pesticides. The flowing water is necessary in order that fish may be kept alive and healthy for long periods, and also to enable concentrations of pesticides to be maintained at constant levels.

In the present system, London tapwater is dechlorinated with activated charcoal and heated up to 28°C with immersion heaters. The water is then transferred by peristaltic pumps (to eliminate contamination) to any one of 30 test tanks (40 litre glass aquaria) at a rate of 6 litres/hour. This flow rate ensures adequate renewal of tank water which drains away to waste. The water in the test tanks is kept air-saturated by means of diffuser stones and the tanks are exposed to conditions of controlled lighting and temperature. Pesticides can be added continuously to these tanks by means of auxiliary peristaltic pumps or by allowing the inflowing water to pass through columns of slow-release formulations. Under pesticide-free conditions, the tropical food fish S. mossambicus lives and breeds successfully in the tanks, and therefore it is possible to study the effects of indefinitely long pesticide exposures of known concentration on the animal. Factors at present under study include the monitoring of growth rates and the measurement of uptake and release of radioisotope-labelled compounds, as well as routine observation of behaviour and histology. Other apparatus has been developed for the separate incubation and pesticide exposure of S. mossambicus eggs, and it is hoped shortly to begin electronic monitoring of the respiration of exposed fish. Most pesticides enter fish via the gills and it is known that respiratory parameters such as ventilation rate can be very sensitive to low pesticide concentrations (Drummond et al., 1973). Automatic measurement of these parameters will thus allow large numbers of candidate pesticides to be screened quickly for possible sublethal effects.

41. It is suggested that these laboratory-based techniques be used to gain preliminary data on the sub-lethal effects of Abate on fish and snails, bearing in mind that information concerning the acute toxicity of Abate already exists (e.g. Lauzanne, 1973).

Laboratory studies can, however, only give a very general indication of the effects that a pesticide may have in the field. An extension of pesticide screening into the field is therefore essential and Abate has been studied in this way to a limited extent by several workers (e.g. Lauzanne and Dejoux, 1973; Wilson and Snow, 1972). This work suggests that Abate may have severe effects on non-target insect populations but nothing is known of its ultimate effects on fish. Such full-scale field trials have several disadvantages. For example, it is very difficult to sample wild fish populations accurately, it is almost impossible to prevent recolonisation from neighbouring untreated areas and full-scale studies run the risk of doing permanent damage to the environment. This is especially so when one considers an environment such as Lake Volta, in Ghana, and therefore estimates of the potential damage that Abate larviciding may do to the Lake Volta fisheries must be obtained by other means. This also applies to studies of the possible effects of large-scale molluscicidng along the lake margins. Urinary schistosomiasis has reached very high prevalence levels in many lakeshore villages and large-scale control measures in these areas might destroy vast numbers of fish frog which are especially common in shallow water.

42. Therefore the Environmental Protection Council of Ghana, in collaboration with the Ghana Council for Scientific and Industrial Research, the University of Ghana, WHO OCP and COPR London, is now considering setting up in Ghana a centre for testing biocides in the aquatic environment. It is likely that the technique adopted will be long-term studies on fish and invertebrate populations using small fish culture ponds. The advantage of studies in ponds is that all faunal populations can be accurately monitored, and the conditions of the experiment quite closely controlled. Such experiments, while only simulating the Volta system in a very rudimentary way, would nevertheless represent a considerable advance over existing laboratory and field work. Such pond testing is a well-established technique in temperate countries, but it has not been used to any significant extent in the tropics. This omission is important since the behaviour of pesticides in tropical ecosystems can be very different from corresponding behaviour in the temperate zones.

43. The projected system would preferably consist of at least 16 quarter-acre ponds set out in the form of a Latin Square in order to minimise the effects of soil and position. This number of ponds would allow three different pesticide exposures (plus one control) to be made simultaneously, with four replicates of each type. The system would require an adequate pure water supply (ideally from a dam) to each pond, with adequate screening to prevent entry of unwanted fish. The ponds would slope from a shallow end (5 metres) down to a depth of 0.5 metres and would be lined with fertile topsoil to allow the growth of plants, both macrophytes and phytoplankton. While the planktonic population will be outside the control of the experimenter, macrophytes, larger invertebrates, and fish from Lake Volta can be selectively introduced. The system under study can thus vary from the simplest arrangement (one herbivorous fish species) up to complex assemblages of herbivores, carnivores and detritovores. By means of suitable sampling and analysis (coupled with periodic pond draining to allow all fish to be measured), a detailed picture of the effects of low concentrations of a given pesticide on the pond populations can be built up. This sort of study is particularly useful for measuring fish production since true field studies would be hampered in this respect by large numbers of variables that may mask any effects of the pesticide.

44. The Environmental Protection Council of Ghana wish to use this technique to study the effect of biocides in the aquatic environment, with especial reference to Lake Volta. The technique can be used to study the effect of biocides applied to the water system for both public health purposes, as in the case of bilharzia, for water weed control and also to investigate the effects of run-off of agricultural pesticides and fertilisers. Because of this such a testing centre could be used on a regional basis for preliminary investigation of environmental problems of pollution.

45. The operation of such a centre in Ghana would be useful in three ways:

(a) Direct acquisition of environmental data.

(b) Development of methodology and techniques.

(c) Development of a training capability.

This central project could also, of course, besides its use as a national centre, be developed as a regional centre for the testing of all biocides, agricultural and public health, in aquatic eco-systems.

Summary and recommendations

46. Very little long term work on the effect on the environment, at eco-system level, of agricultural pesticides and pesticides used for purposes of public health related to agriculture has been carried out. Most work has been directed towards limited effects of specific pesticides, and what is now needed are one or two large-scale long-term projects to begin the investigation of biocides on an eco-system scale. Such work is difficult but will in the long run generate both data and hypotheses of wide validity in terms of the effects of biocides on eco-systems. It is suggested that the Technical Consultation discusses the possibility of UNEP funding two projects of this type in relation to tsetse control work. One would be in dry savannah with FAO as Executing Agency, the other in moist savannah with WHO as Executing Agency. Paragraphs 23 to 30 of this report make suggestions about the requirements for such projects.

47. It is also suggested that the Technical Consultation consider the proposed biocide testing scheme in aquatic environments of the Environmental Protection Council of Ghana (paragraphs 42-45) both for critical technical comment and for recommendation of support funding by UNEP and other relevant bodies.

48. Apart from these major projects, the following studies, relevant to the objectives of the Technical Consultation, need critical discussion and consideration for support and fundings:

(a) Game parks as reservoirs of trypanosomiasis and other diseases and problems of control therein. (para 8,9)

(b) Pursuance of the sterile-male technique for tsetse fly control. (paras 11,12)

(c) Development of tsetse fly trapping methods for survey and control. (para 23)

(d) Investigations on new insecticides, the development of bio-degradable insecticides, and the need for developing countries to have adequate laboratory facilities for relevant tests. (paras 16,17,24).

(e) The development and application of model eco-system test facilities for both agricultural and public health biocides. (paras 22,40,41)

(f) Possible interaction of agriculture and public health insecticides to produce resistance to pesticides in many pest species of economic importance. (para 18)

49. It is important that, where relevant, some form of economic appraisal including cost/benefit analysis, which should include if possible a study of socio-economic factors, should be built in to all these projects and investigations and the cooperation of industry sought at an early stage. (para 15)

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4.3 SOME SUGGESTIONS FOR FUTURE STUDIES ON SIDE EFFECTS OF PESTICIDES ON THE NATURAL ENVIRONMENT IN DEVELOPING COUNTRIES

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1) Introduction

A proper prediction of the hazards which may be associated with the use of pesticides should in principle be based on two types of information (a) short and long term toxicity data on representative species and (b) data on the possible spatial distribution and fate of the compounds in the environment concerned. The first type of information is indicative for the toxic potential of the compounds while the second type may indicate the likelihood that vulnerable species could get exposed to a dangerous concentration of either the compound itself or one or more of its metabolites or breakdown products.

Up to the present the results of laboratory studies often proved to provide insufficient background information for a proper assessment of the environmental hazards of pesticides. The many cases of unexpected fish and bird mortality referred to in the literature support this statement. There are two main reasons why laboratory studies generally provide insufficient information:

(a) For both economic and zootechnical reasons only a limited number of species can be used for toxicity and metabolism studies under laboratory conditions, which implies that the susceptibility of many species is not investigated at all or only incompletely.

(b) The many varied biotic and abiotic conditions which normally determine the environment of a species in the wild generally cannot be simulated adequately in the laboratory.

Various attempts have been made to overcome the obvious limited predictive ability of the test procedures commonly used in many countries until recently. Improvements made or suggested include:

(i) Improvement of laboratory trials by the introduction of more sophisticated techniques. For instance the use of continuous flow instead of static conditions in fish toxicity studies, a more appropriate selection of test species or the introduction of one or more abiotic variables (pH, temperature, oxygen tension) in the experimental set-up. A major improvement is the application of the so-called model-ecosystem approach in which the effects and fate of compounds are assessed in systems which represent a simplified version of a natural ecosystem, e.g. by using glass tanks containing a number of biotic (animals, plants, microorganisms) and abiotic elements (soil, sediment, suspended matter etc.). These systems have proved to be very adequate for the prediction of the environment fate of chemicals (e.g. metabolism, sorption-desorption etc.) particularly when radioactively labelled compounds are used.

(ii) The pilot study approach, which implies that pesticides or other chemicals are applied in selected plots in the environment. From a careful comparison of the results of pre- and post- application assessments, information may be obtained about possibly undesirable effects.

(iii) Continuous toxicological surveillance, by means of biological and chemical monitoring, for a certain period from the very moment onwards a new compound or new formulation or application method is put into practice. Again pre- and post- application comparisons may reveal what type of environmental damage may occur. If necessary future damage is prevented by taking certain retrospective measures, e.g. by passing on to another active ingredient or another type of formulation and/or application method.

Although it seems unlikely at present that new guiding principles in environmental toxicological research will become available, in due course it may be possible to achieve some improvements by a further development of the research methods mentioned above. An important achievement would be to adapt these methods to the circumstances, needs and present technical facilities in developing countries. Some further suggestions will be mentioned in the next paragraph.

2) Suggestions for future research

A first suggestion is, that previous to any type of impact assessment by means of either laboratory or field studies a regional ecological investigation should be made in the area concerned. At present perhaps too little attention is paid to the large regional variation in the environmental condition and composition of ecosystems in the world, which depend on the marked differences in climatical, physiographical and geological conditions between one place and another. There is a strong tendency at present to extrapolate information obtained from experience with pesticides in temperate regions to tropical areas. However, the environmental distribution and biological effects may be quite different in the latter. It is possible that the rate of breakdown of a compound is much higher in a certain tropical environment than in a temperate region. One can also imagine situations where a tropical eco-system could be more vulnerable than a temperate one, for instance when the time of application coincides with a particularly sensitive phase in the life-cycle of certain species in the former but not in the latter areas. Hence when a certain application of a pesticide appears to be unacceptable in one area for some reason this does not necessarily imply that the compound or the application concerned is unacceptable in other places as well.

The preliminary ecological investigations may reveal certain special needs for additional toxicological studies, for instance to test the susceptibility of certain characteristic locally occurring species or to measure the rate of breakdown of the compound under the prevailing conditions. The various subsequent steps to be taken in an environmental impact study could then follow the outline presented in Table 1.

Table 1. Steps to be taken in environmental impact studies concerning the application of pesticides

(1)	Regional ecological assessment, possibly linked up with the regional assessment of the pest problem concerned.
(2)	Evaluation of the adequacy of existing pest control techniques taking into consideration both the available toxicological information (provided by the manufacturer) and the outcome of the ecological investigations referred to under (1).
(3)	Possible additional laboratory studies on one or more compounds.
(4)	Pilot trials.
(5)	Adoption of the most acceptable procedures.
(6)	Retrospective field surveillance by means of biological and chemical monitoring techniques.

(a) Preliminary ecological assessments

Land use and general characteristics of the flora and fauna should be mapped for the region under consideration. This should be tabulated in order to obtain information about (1) the horizontal and seasonal pattern of the eco-system and species distribution, (2) the importance of the eco-systems and species and (3) the major relationships between the species (trophic relationships etc.). Various methods and guidelines are available for this type of ecological assessment. An interesting approach among other techniques could be the life-zone classification procedure as described by Holdridge (e.g. ref. 10).

(b) Toxicological laboratory studies

During the last 25 years much effort has been made to devise methods to measure the toxic properties of chemical compounds. Most of these were designed as models to assess the risks for man, but special tests have also been developed to measure the toxicity of chemicals for wildlife. Some of the main test procedures are presented in Table 2. The standard tests of which the results will be available for any accepted pesticide are marked (*). Tests of special importance for the evaluation of the risks for wildlife are underlined. References are made to publications and books which provide technical details about the test methods concerned.

Table 2. Main test procedures in toxicological laboratory studies

Method	References
I. Acute toxicity measurements	
- Assessment of median lethal dose or concentration (LD_{50} or LC_{50}) in various species and different routes of administration (e.g. oral, dermal, inhalation, medium)*	4, 7, 8, 12, 14, 18
- Skin and eye irritation tests*	4, 5, 16, 17
- Sensitization tests*	4, 16
- Acute mutagenicity tests (dominant lethal assay, micronucleus and metaphase tests)*	11, 19, 21, 24
- In vitro mutagenicity and carcinogenicity tests	1, 11, 19, 21, 23
- Teratogenicity tests*	4, 15, 16
- Biotransformation studies*	

(Table 2 continued on following page)

Table 2 continued...

Method	References
II. Short term toxicity tests (semi-chronic assays)	
- 90 day - exposure tests in rats and other rodent species, 1-year studies in dogs (route of administration generally orally through the feed, occasionally other routes)*	4, 16, 25, 26
- 30-60 day-exposure tests with fish and other cold blooded vertebrates	6, 8, 14
- Biotransformation studies*	
- Model-eco-system studies (studies on small-scale ecosystems comprising soil biota, aquatic biota, etc.)	13, 27, 28
III. Long term toxicity tests (chronic assays)	
- 2 year exposure tests in rats and other rodents (route of administration generally orally through the feed, occasionally other routes*	1, 3, 4, 16, 23, 25, 26
- 1-2 year exposure tests with fish and other cold blooded vertebrates	6, 8, 14
- Reproduction studies comprising more than one generation in both warm blooded* and cold blooded animals	4, 8, 14, 16

(c) Toxicological pilot and field studies

As was mentioned above each large scale application of pesticides should preferably be preceded by pilot studies and be accompanied by additional field observations. A number of assay methods is recommended in Table 3.

Table 3. Recommended assay methods for field and pilot studies

Method	References
I. Biological monitoring: assessment of physiological and behavioural parameters	
- Examination of livestock and wildlife on specific signs of poisoning and aspecific symptoms such as mortality, morbidity, changes in fertility and hatchability of eggs of fish, birds, reptiles etc. changes in routes and activity pattern of migrating fish, changes in sexual behaviour.	6, 7, 8
II. Biological monitoring: assessment of eco-system and population parameters	
- Changes in the diversity of eco-systems or certain taxonomic groups.	2, 7, 8, 9, 14, 18, 20
- Changes in the abundance of certain trophic groups of organisms or selected species.	2, 7, 8, 9, 12, 14, 18, 20
III. Chemical monitoring: assessment of residue levels of parent compounds and metabolites in soil, water, sediment, etc.	
- Examination of the extent of the environmental distribution.	7, 18
- Examination of the occurrence in edible parts of certain species of livestock and wildlife.	7, 25, 26
- Examination of the fate of a substance in the trophic system (e.g. food chain accumulation)	7, 13

3) An example

Some of the proposals made in the present paper will be exemplified from experience gained during observations made on side-effects of tsetse eradication operations in Africa. According to the results available and taking into consideration the research procedure proposed in Table 1, future research on side-effects of tsetse control (and possibly other large scale pest control operations) could in principle proceed as follows.

(a) The preliminary ecological assessment of the area concerned provides information of the type referred to in paragraph 2a. From these data a co-called Landscape Ecological

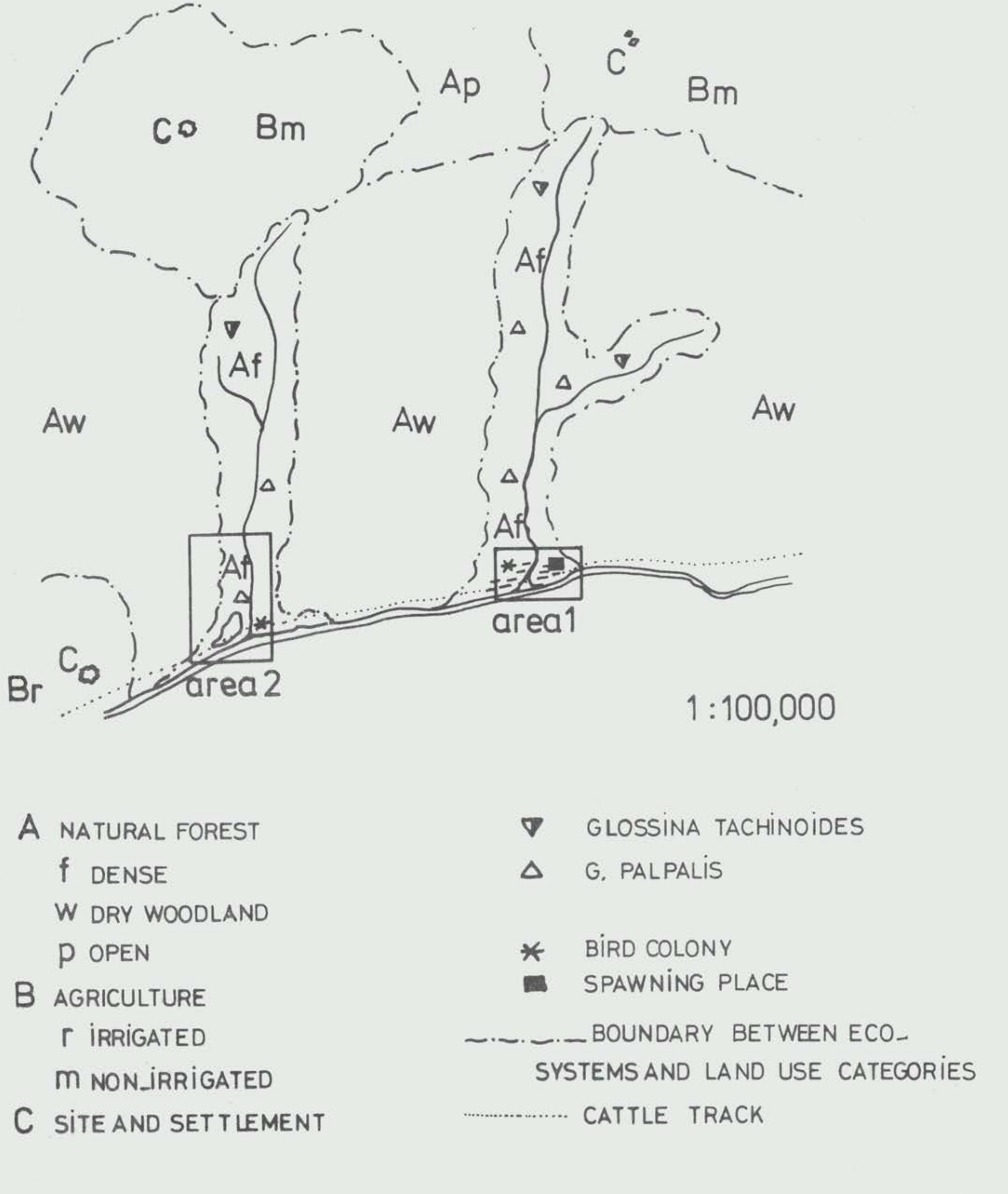

FIG. 1 LANDSCAPE ECOLOGICAL VALUATION MAP

Valuation Map can be designed. As can be seen in the simulated map in Fig. 1, general information on the landscape and land use pattern can be presented as well as special information about certain peculiar ecological properties of the area. It appears that areas 1 and 2 are particularly important for wildlife for the following reasons:

- area 1 represents an important spawning place for economic fish species.
- the diversity of the vertebrate fauna is highest in areas 1 and 2.
- both areas form refuges for a number of rare species of vertebrate and invertebrate animals.

(b) It is considered that the most discriminative tsetse control methods available should be applied to areas 1 and 2 whilst the remainder of the territory will be treated with other methods, which though less discriminative are preferred for technical and economic reasons.

(c) Additional fish toxicity studies are carried out with some of the most promising insecticides and two of the fish species occurring in area 1. Substance X appears to have the lowest toxicity.

(d) A pilot study is performed on two plots covering 10% of the total surface of area 1.

(e) It is decided that areas 1 and 2 will be sprayed by hand with substance X in a discriminative manner, whilst the remainder of the fly habitat is sprayed by helicopter with either substance X or some other compound considered to be acceptable.

(f) During the final operations additional ecological observations are performed. The toxicologists and pesticide (formulation) specialists involved conclude from these observations that the selectivity of the methods possibly could be improved by selecting another type of formulation. A pilot study is planned in one of the next areas to be reclaimed from tsetse.

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4.4 IMPACT OF AGRICULTURAL AND FORESTRY USES OF PESTICIDES ON AQUATIC RESOURCES

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(A shortened version of the paper presented at the meeting)

1) Introduction

A highly productive agriculture is an essential prerequisite for the maintenance and progress of the human race. The developing countries, especially, must use intensive, efficient and modern methods of cultivation to provide sufficient nourishment for their inhabitants. These conditions require the use of large quantities of fertilizers and a constant battle against insect pests. Presently, approximately 5 million people are added each month to a world already deprived of sufficient food for many millions of its inhabitants. Certainly, the extent of arable land is not increasing in proportion to the rise in population to offset the shortages.

There is no doubt that pesticides have contributed materially to increases in crop yields by as much as 30-40% and in potato production by 100%. Insecticides have also helped improve the health of millions of people in the developing countries who are victims of such debilitating diseases as malaria, yellow-fever, filariasis, onchocerciasis, Bilharzia, Chagas, etc. Elimination of pesticide usage will bring a catastrophe to a world already besieged with shortages of food and fodder. There is a thin line of demarcation between abundance and hunger, and pesticides hold that line today. On the other hand, there are certain characteristics and side-effects of presticides which limit their usefulness in agro-ecosystems. The ecological disruptions that result from the unwise use of pesticides are far more of a threat to the environment than the direct pollution of the environment itself. The environmental instability brought about by these practices may create many secondary problems such as: Disturbance of natural regulation of populations; outbreaks of secondary pests; insecticide resistance and cross-resistance; hazards from pesticide residues in the harvested crops; undesirable side-effects on nontarget organisms including parasites, predators, fish, birds and other wildlife, bees and other pollinators, man and his domestic animals, and the crop plant itself.

The non-judicious use of pesticides can cause a disruption of the ecosystem with long lasting consequences. Hence, an integrated system of pest control utilizing all the knowledge man has at his disposal might alleviate the situation. It is doubtful that a panacea would ever be found for pest control. What then are the alternatives? A world of hunger, a poisoned environment; or common sense. Let us hope that the latter will prevail.

2) Impact of pesticides on the aquatic environment

(a) Agricultural practices

The past 25 years have seen a tremendous upsurge in the use of pesticides. Approximately 10 billion lbs. of various pesticides have been used in the U.S. alone since 1945.

Of the 400 million lbs. of insecticides used in 1964, about 90 million lbs. were applied to cotton. In many countries cotton is grown in the same area year after year under intensive cultivation. These practices require large amounts of pesticides to control insect pests and it is not uncommon to spray six or seven times a season to abate attacks by Heliothis, Spodoptera, etc. The result is a heavy contamination of the soil with pesticides and the consequent transfer of some of these residues to adjacent bodies of water by leaching, erosion, winds, etc.

Rice paddies in Japan have relied on heavy usage of pesticides to control rice pests, first with DDT, then with BHC, parathion and other organo-phosphorous (OP) and carbamate insecticides. As in many other countries the first incidence of the impact of heavy pesticide usage was the disturbance in the equilibrium existing between pests and their parasites and predators, especially the reduction in beneficial spider populations in rice fields and heavy fish kills in surrounding areas (Ishikura, 1972). The greatest impact on fish and shellfish populations came from the use of PCP herbicide, as well as contamination of irrigated fields with organomercurial fungicides which were used to control rice blast (Fukunaga et al., 1972). Translocation of mercury in rice plants and grain occurred following foliar sprays. Mercury residues which persisted in the soil for many months were also translocated into the plant through the root system.

(b) Impact on aquatic organisms due to aerial spraying of forests

Systematic attempts were made to study stream bottom organisms before and after aerial spraying with DDT for Spruce budworm control (Graham, 1960). The volume of drifting insects increased 100 fold one hour after spraying, and a reduction of 90% of the insect biomass occurred after one week. Other investigations which extended over a period of four years after a single spraying with DDT (Hastings et al., 1961) showed a drastic reduction in all forms of aquatic organisms immediately after spraying, especially, insect larvae and nymphs of mayflies (Ephemeroptera), caddis flies (Trichoptera) and stone flies (Plecoptera). Case-bearing caddis flies disappeared completely in the four year study period. Stone flies and mayflies took about three years to reach pre-spray levels, but there also were considerable differences in the composition of post-spraying populations. The drastic decrease in the number of Trichoptera, which are mainly predaceous species, may account for an increase in abundance of Chironomids on whose larvae they feed. Similar observations against Simulium control in Canada, Uganda, and the U.S.A. revealed heavy damage to aquatic invertebrates but a more rapid recovery of the species concerned (Muirhead-Thomson, 1971).

3) Factors involved in the dispersion of pesticides

The sea is often considered to be the ultimate sink in the global routes of pesticide movement involving long distance transport. It has been estimated (U.S. Department of Agriculture) that 25% of all the DDT manufactured to date has found its way into the oceans; hence, the seas and oceans may be assumed to be ultimately at risk. However, of greater immediate concern are the inland bodies of water which serve the agricultural and urban demands, especially in developing countries.

There are many ways by which inland waters may be contaminated. One of the major routes is by direct injection into the atmosphere during pesticide application, especially spraying with aircraft. The application of ultra low volumes (ULV) sprays with aircraft is especially effective in the dispersal of large amounts of pesticide through drift action. It has been estimated that from 10% to 70% may be lost from the point of application by drift. Inevitably, much of these residual deposits find their way far beyond target areas and reach the soil and water.

Soils and bottom sediments represent reservoirs of pesticides in the environment. Furthermore, pesticides tend to persist in soils longer than in other environments. Following the DDT ban in the U.S.A. residues of DDT, DDE and other metabolites decreased faster from crops, animal tissues, milk, etc. but remained fairly constant in soils. DDT and DDE appear to be bound to soil particles and, hence, are not available to uptake by plants (Ware et al., 1971). The major pathways of pesticide loss from soil include: volatilization, photo-decomposition, chemical degradation, leaching, dilution, erosion, uptake by plants, microbial decomposition, and co-distillation with water.

Transport of pesticides by air is another major route of water contamination. Strong winds may carry away pesticides bound to water particles and dust particles over long distances. In addition, evaporation through volatilization and co-distillation from surface waters takes place. Eventually, these pesticides return to earth through rain and dust fall-out.

4) Ecosystem transfer of pesticides residues in the aquatic environment

Chronic contamination of rivers and other bodies of water with many of the chlorinated hydrocarbon insecticides is well-documented. However, little is known about the effect on fresh water organisms of chronic exposures to sub-lethal concentrations of pesticides.

There is much evidence of build-up of residues of DDT and its metabolites in tissues of food-chain aquatic organisms. The classical demonstration of the bioaccumulation and biotransfer of a pesticide in an aquatic ecosystem is perhaps the study conducted at Clear Lake, California. (Hunt and Bischoff, 1960; Lindquist et al., 1951; Herman et al., 1969; Rudd and Herman, 1971). Clear Lake was treated with DDD (TDE) three times over a period of nine years for gnat control (Chaoborus artictopus). A total of 120, 726 lbs. of DDD were applied into the lake giving a final concentration of 0.0143 ppm for the first application and 0.020 ppm in subsequent treatments. The drastic consequences of these treatments and the biotransfer to food chain organisms are well Known (Rudd and Herman, 1971). A similar study of pesticide pollution in Lake Michigan showed that approximately 680,000 young Coho salmon fish died in Michigan hatcheries during the last stages of larval growth. Initial investigations revealed that residues in the water were 5-60 times higher than in similar bodies of water in other areas (Johnson and Ball, 1972). In past years, Toxaphene has been used extensively for cotton pests control. Although it is more readily broken down than is DDT it does accumulate in the fat body and in tissues of food-chain organisms.

Most organophosphorus (OP) and carbamate insecticides seldom give rise to persistent residues in the environment over long periods of time. These compounds usually have a higher acute toxicity than the chlorinated hydrocarbons but their chronic toxicity is much lower. They have a short life in water and do not accumulate in the tissues of non-target organisms to the same extent that chlorohydrocarbons do. Residues of 0.3 - 70.0 ppb have been detected for parathion, chlorpyriphos (Dursban[R]), and Abate[R] (Ludwig et al., 1968; Bowman and Orloski, 1966) and lethal concentrations lasted only 8 - 12 days after which no residues could be detected. The same is true for residues in soils, plants, and land organisms (Warnick et al., 1966).

Methylparathion at 3 ppb proved effective against Chaoborus larvae with minimal ecological impact on other organisms, except that zooplankton seemed to be somewhat affected. Fifty per cent of the compound was degraded in 48 hours and no residues remained after two weeks.

Fenthion (Baytex^R) at concentration of 0.025 ppm was lethal to chironomid larvae and Daphnia but was non-toxic to Copepods, Ostracords, Hydra, annelid worms, snails and clams. At 0.1 ppm Baytex was toxic to shrimps and Amphipods but these recovered quickly.

Fenitrothion has been used as replacement for DDT in spruce budworm control in forest areas in Canada. This insecticide was presumed to be short-lived and biodegradable, but monitoring the air and coniferous foliage in the vicinity, as well as at great distances from the point of application, indicated a rather unexpected persistence lasting several months (Yule et al., 1971).

5) Ecological effects of pesticides on non-target organisms

Deliberate chemical control of undesirable aquatic organisms such as mosquito larvae, blackfly larvae, midges, snails, predator fish and trash fish does not end in the destruction of the target species. More often than not these pesticides have a direct or indirect impact on most other organisms present in that ecosystem. Mention has already been made of the effects of spray applications for cotton pests, rice pests, and forest insects on the aquatic fauna.

Many such examples have been recorded in the literature. A summary of the toxicity of several representative insecticides to various aquatic organisms is shown in Table 1. A quick perusal of the data demonstrates that there is no single compound that can be considered safe to all the organisms investigated. Also, not known are the effects on many more aquatic organisms not tested.

For practical purposes "non-target organisms" are those which are considered to play a key role in the ecology of the habitat, particularly with regards to species which form vital links in the food chain (Muirhead-Thomson, 1972). However, this distinction, too, depends on the natural balance among the species present in that habitat.

The direct toxicological effects of pesticides in aquatic organisms are much easier to determine than their indirect effects. That is due to the intricate and subtle interrelationships which exist among organisms dwelling in the same ecosystem, each of which responding in his own way to changes in that environment. These changes include the indirect effects of pesticides on population dynamics, food and energy requirements, reproductive capacity, behavior, host-predator balance, survival of the fittest, photosynthesis, and other factors.

The common objective of all studies on pesticide impact on non-target organisms should include both chronic and acute toxicity determinations, effects of low dosages and sublethal exposure on factors such as those mentioned above, e.g., growth, behavior, reproductive capacity, etc.

6) Fate of organic pesticides in the aquatic environment

The contamination of aquatic environments with pesticides and other pollutants, resulting in detrimental effects on fish and food-chain organisms at lower trophic levels, has prompted investigations on the fate and significance of these compounds and their metabolites in the aquatic environment. The metabolic fate of pesticides in mammals, insects and plants has been the subject of numerous investigations. On the other hand, there is a dearth of information on this subject in aquatic Arthropoda, Crustacea, Mollusca, and other aquatic phyla, especially in non-target organisms which comprise the food chain.

(a) Role of enzyme systems

DDT dehydrochlorinase - the enzyme that converts DDT to DDE - has been detected in vivo in Chironomus sp. larvae (Diptera), Palaemonetes kadiakenis (Decapoda), Gammarus fasciatus (Amphipoda), Daphnia magna (Cladocera), Libellula sp. naiads (Odonata), and Hexagenia billineata (Ephemeroptera). In addition to DDE, other products such as DDD, Kelthane, and dichlorobenzophenone were also formed (Johnson et al., 1971). Most organophosphorus and carbamate insecticides as well as several chlorinated hydrocarbons and compounds of botanical origin are metabolized principally via microsomal mixed-function oxidase (MFO) enzymes. In the past two decades a wealth of information has been accumulated regarding the metabolism of xenobiotics in mammals and insects by the MFO system. Only recently some of this knowledge has been applied to aquatic invertebrates and food-chain organisms.

The amount of insecticide picked up by phytoplankton and zooplankton is probably the first step in the introduction of pesticides in the food chain (Rudd, 1964). In vivo studies with Chlorella, diatoms, dinoflagellates, Hydra, Dugensia, Asellus, Gammarus, Daphnia, Cyclops, Cambarus, Anodonta, Lymnaea, Aeschna, and Aedes Aegypti (Khan et al., 1972a) showed a great deal of variation among the organisms in pickup of aldrin and in epoxidation of aldrin to dieldrin. In most cases, too, the amounts of dieldrin formed (a measure of enzymatic activity) were much below those found in higher organisms and in mammals. Similar epoxidation activities were found in liver enzymes of snails, clams, the green gland and hepatopancreas of crayfish (Khan et al., 1972b) and in an ostracord (Kawatski and Schmulback, 1971).

Mixed-function oxidase activity toward cyclodienes (Stanton and Khan, 1973; Perry, 1974) and desulfuration of parathion to paraoxon (Ludke et al., 1972) have also been characterized in bass (Micropterus dolomeiux) and bluegill (Lepomis macrochirus) fishes. In addition, esterases have been demonstrated in the lobster Homarus americanus. Adamson and Sieber (1974) summarized the extensive data on the pathways of xenobiotic metablism in fishes and showed that, basically, they are similar to those found in higher animals, i.e., oxidation, reduction, hydroxylation, hydrolysis, etc., forming primary metabolites, and conjugation (synthetic) reactions producing secondary metabolites.

The above-mentioned examples give ample evidence that mixed-function oxidase activity in aquatic non-target organisms and in fish is considerably lower than that found in terrestrial animals. This phenomenon is in accord with the works of Brodie et al. (1958), Brodie and Maickel (1962) who proposed a scheme for the evolutionary basis of drug metabolism. In this scheme, the authors suggest that mixed-function oxidases were developed during the course of evolution when marine organisms ventured onto land and found it necessary to dispose of various kinds of foreign lipid-soluble compounds in their food which otherwise would have accumulated in their tissues to toxic levels. Accordingly, aquatic forms of life possess a less efficient MFO system because their gills and permeable skins permit lipid soluble materials free exchange with their surrounding medium.

Accumulating evidence also suggests that certain species of fish, namely, Gambusia affinis can become increasingly tolerant to insecticides (Table 2) through enhancement of the microsomal enzyme system which is brought about by continuous exposure to the toxicants (Vinson et al., 1963; Chambers and Yarbrough, 1973; Wells et al., 1973) and that enzyme induction in fish by pollutants is a possibility (Chambers and Yarbrough, 1973; Mayer et al., 1970). Thus, certain evolutionary changes can be brought about at an accelerated pace through man's interference with nature.

(b) Physical factors

The ultimate fate of pesticides in the aquatic environment may also be affected by physical factors such as: (i) Interaction with particulate matter in soil and water, (ii) interaction with polyelectrolytes and (iii) photo-decomposition. Other factors include volatilization, pH of water, ambient temperature, co-distillation from surface water.

(i) Various organic pesticides react with particulate matter in aquatic systems in different ways. Cationic compounds are adsorbed on clay particles and organic colloids by ion exchange reactions. In the adsorbed state these compounds are immobile in soils and water and their biological activity is greatly reduced. Acidic pesticides are weakly adsorbed by particulate matter and, therefore, are more mobile. Basic compounds adsorb to particulate matter more strongly and their biological activity is more pH dependent, being greater under alkaline conditions. Compounds with low water solubility such as the chlorohydrocarbon insecticides are adsorbed to organic lipophilic particles and are relatively immobile. The biological activity of most organic pesticides depends on the amount of organic matter and sometimes on the clay minerals in the surrounding medium (Weber, 1972).

(ii) Natural organic polyelectrolytes, resulting from the polymerization of degradation products of plant and animal matter, are some of the most active components of soil-water systems entering into physical-chemical reaction by active polyelectrolytes such as humic acid and fulvic acid. The salts of these acids, being water soluble, may solubilize the insoluble pesticides and release them to the surrounding medium (Wershaw and Goldberg, 1972).

(iii) Sunlight decomposes many pesticides in water. Many photolytic reactions of pesticides have been observed in laboratory irradiations conducted in distilled water or other solvents in the presence of suitable reagents such as oxygen, nucleophilic ions, reducing agents, etc. All of these reagents and conditions are found in nature, both in fresh and salt water, in an inexhaustible supply. There is reason to believe, therefore, that such photo-oxidation reactions destabilize pesticides and render them more amenable to further decomposition by microorganisms. Some of the commonly used insecticides such as dieldrin, methoxychlor, parathion and carbaryl, undergo photolytic reactions in the field. The ecological significance of these photoproducts has not yet been fully evaluated, especially their effect on non-target organisms. However, the limited toxicological data available indicate that some of these products especially photoproducts of cyclodiene insecticides are more toxic than their parent compounds to several organisms including some terrestrial animals (Khan et al., 1974). It is also known that certain chemicals enhance, induce or sensitize photochemical reactions, while others quench such reactions, especially oxidations. Among the best known photosensitizers are benzophenone, chlorophyll, certain aromatic amines and several others (Lykken, 1971).

(iv) Chlorinated hydrocarbon insecticides present more a serious problem in an aquatic environment than organophosphorus or carbamate insecticides. This is because of their extreme low solubility in water, a factor which makes them resistant to biodegradation or to chemical decomposition. Since organochlorine pesticides tend to be strongly adsorbed to soil particles drainage water is not a serious source of surface water contamination. In fact, underground water which has percolated through soil contains very low residual deposits of these compounds (Brooks, 1971).

Organophosphorus insecticides have a short half life in water and there is little indication of residue build-up. Deposits of 0.3 – 70 per 10^9 of parathion, chlorpyriphos and abate have been detected in water (Bowman and Orloski, 1966; Ludwig et al., 1968). While these concentrations are relatively low it is evident (c.f. Table 1) that parathion is toxic to Daphnia, Gammarus and stoneflies at concentrations of 0.4 – 11.0 per 10^9 and to bluegill fish at 47.0 per 10^9. Chlorpyriphos is toxic at even lower concentrations, but abate is relatively safe.

Biochemical activities of bacteria constitute an important phase of self-purification of polluted streams. The carbamate insecticides carbaryl, propoxur, pyrolan and dimentilan were more biodegradable in Nile River water under alkaline than under acidic conditions. At pH 7.0 and 20° C carbaryl decomposed completely in 70 days, but at pH 8.0 hydrolysis occurred in only 9 days. Propoxur (Baygon) was more stable at neutral pH but under slightly alkaline conditions complete hydrolysis to o-isopropoxyphenol took place in 107 days. Pyrolan and dimetilan were quite stable in the pH range of 4.0-8.0 which is the range for natural waters (Aly and El Dib, 1972). On the other hand diazinon was more rapidly hydrolyzed in flooded soils under acidic conditions (Sethunathan, 1972).

The persistence in river water of 28 insecticides representing various groups is listed by Eichelberger and Lichtenberg (1971). From this list, it is clear that organophosphorus and carbamate insecticides are less persistent than the chlorinated hydrocarbons. At the same time one should not lose sight of the fact that OP and carbamates are acute poisons and the initial toxicity to various aquatic organisms may be quite high.

7) Monitoring of aquatic environments for pesticide residues and for their effects on non-target organisms

The purpose of any pesticide monitoring system is to assess the impact of pesticide usage on organisms other than the intended target species; to measure the persistence of such residues in the environment where their effect is being assessed, and to evaluate the results in terms of potential chronic damage to the quality of that environment.

In one way or another, residues of pesticides used for the control of agricultural and forest insect pests can be expected to find their way in streams, lakes, irrigation canals, other inland bodies of water and, eventually, to the seas and oceans. A realistic assessment of this impact can only be made when detailed information about population changes in the ecosystem can be correlated with pesticide contamination. Hence, the effect of chemicals on inland water pollution should take into account the following factors:

(i) Listing and quantification of all species present in the ecosystem to to be analyzed.

(ii) Identification of the biological and chemical characteristics of the pesticide.

(iii) Monitoring of the physical, chemical and biochemical fate of the insecticide.

(iv) Trophic accumulation of the chemical and its metabolites in the organisms present.

(v) Magnification in concentration of the pesticide and its metabolites at higher trophic levels in the food chain.

(vi) Short and long term side-effects of pesticides on non-target organisms as reflected in species composition, population densities, reproduction, behavioral changes, and resistance. (Establishment of base lines prior to the application of the pesticide, is desirable.)

(vii) Monitoring the ability of the organisms to re-establish themselves.

Several of the above factors have been studied in the laboratory with a variety of organisms. One of the best known examples is the ecosystem of Metcalf and associates (Kapoor et al., 1970, 1972; Metcalf et al., 1971; Kirwe et al., 1972) which has yielded much information on the biodegradability and ecological magnification of several pesticides. Many aquatic species especially stoneflies, mayflies and caddisflies react badly when transferred to artificial laboratory conditions from their natural habitats. There is also much difference in response of organisms to the test chemical between static tests and flowing water tests and not all insecticides show the same trend in favoring one type of testing or the other.

Almost all workers carrying out laboratory tests on non-target organisms have used modified versions of susceptibility tests. The variations included number of organisms per unit volume of water; holding temperature prior to, during, and after the test; provision for aeration; light intensity; quality of water - whether natural, distilled, reconstituted, dechlorinated; pH; Cu^{++} content; provision for food; provision for cover; exposure time; etc. These variables have not been standardized and most likely they defy standardization because of the requirement for different conditions for different classes of organisms and for expensive and sophisticated equipment which, at present, is beyond the reach of developing countries.

Preferably, then, monitoring of pesticide impact on the aquatic biota should be done in situ under natural conditions to obviate the subjective choice of organisms and the arbitrary testing provisions mentioned above. The monitoring would then be more relevant to the implementation of the project's objectives. Lastly, the monitoring system relevant to the impact of agricultural and forestry uses of pesticides on aquatic resources should be designed so as to reveal major changes that might occur in the aquatic environment due to the input of pesticide contaminants.

Table 1. Toxicity of several representative insecticides on aquatic non-target organisms

LC50's in parts per 10⁹

Insecticide	FISH			AMPHIBIA	ARTHROPODA					
	Trout	Bluegill	Carp	Tadpole	Stonefly	Mayfly	Gammarus	Sand shrimp	Hermit crab	Daphnia
Chlorinated hydrocarbons										
Aldrin	3-50	13-90	—	2000	8	—	12,000	30	300	28
Chlordane	22-50	22-58	—	—	170	—	80-160	—	—	20
DDT	7	8	10	1400	16	12	4	3	7	2
Dieldrin	20-50	5	—	1100	6	12	1400	68	70	240
Endosulfan	3	20	—	—	5-20	—	9-60	—	—	240
Endrin	1.8	0.3	140	290	2.8	5	6	2.8	27	20
Heptachlor	15	19	—	—	4	32	150	110	460	42
Lindane	30	53	90	14,000	8	—	88	—	—	460
Methoxychlor	74	58	—	—	8-17	—	1-5	—	—	0.8
TDE	9	56	—	700	1100	—	1.8	—	—	3.2
Toxaphene	2.8	3.5	4	600	7	47	70	—	—	15
Organophosphorus compounds										
Abate	1500	—	—	2000	100	—	1500	—	—	—
Azinphos-Methyl	14	22	690	680	8-25	—	0.5	—	—	0.2
Carbophenothion	—	225	—	100	—	—	28	—	—	0.01
Chlorpyriphos	20-50	—	—	—	4	—	0.7	—	—	—
Coumaphos	—	—	—	—	—	—	0.1	—	—	1
Diazinon	170	30	—	—	60	—	800	—	—	0.9
Dichlorvos	—	700	—	—	10-23	—	1-2	18	150	0.07
Dichrotophos	8000	—	—	—	1900	—	2200	—	—	600
Dimethoate	1900	2800	—	—	140	—	400	—	—	2500
Disulfoton	—	40	—	—	40	—	110	—	—	—
Ethion	700	230	—	—	14	—	5	—	—	0.01
Fenthion	930	1380	1160	—	130	—	39	—	—	3
Malathion	170	103	6590	—	2	6	1.8	246	118	1.8
Mevinphos	17	41	—	—	9-55	—	310	—	—	0.16
Naled	240	220	—	2200	16	—	160	—	—	3.5
Parathion	2000	47	—	1600	11	—	6	—	—	0.4
Parathion-Methyl	2750	5700	7130	—	—	—	—	11	23	4.8
Trichlorfon	3200	—	—	—	22	—	50	—	—	8.1
Carbamate insecticides										
Carbaryl	4380	6760	5280	—	5-15	—	22-40	—	—	6
Propoxur(Baygon)	—	—	—	—	110	—	25-66	—	—	—
Zectran	10,200	11,200	13,400	—	16	—	76	—	—	10

Insecticide	Trout	Bluegill	Carp	Tadpole	Stonefly	Mayfly	Gammarus	Sand Shrimp	Hermit Crab	Daphnia
	LC50's in parts per 10^9									
	FISH			AMPHIBIA	ARTHROPODA					
Other compounds										
Allethrins	20	—	—	—	28	—	20	—	—	21
Pyrethrins	54	—	—	—	64	—	16	—	—	25
Rotenone	—	22	—	—	300	—	350	—	—	10

Data from Cope, 1965, 1966; FWPCA, 1968; Pimentel, 1971; Sanders, 1969, 1970; Sanders and Cope, 1966.

Table 2. Resistance of strains of the mosquito fish *Gambusia affinis* to various pesticides

Insecticide	Susceptible strain (LC_{50} in ppm)	Resistant strain (LC_{50} in ppm)
DDT	0.030	0.200
Dieldrin	0.016	0.500
Aldrin	0.050	2.100
Endrin	0.001	0.120
Heptachlor	0.070	1.300
Toxaphene	0.020	0.4[illegible]0
Chlorpyriphos (Dursban[R])	0.230	0.595

From Ferguson *et al.* (1965)

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4.5 IMPACTS OF THE USE OF PESTICIDES AGAINST LOCUSTS

a) The FAO/SIDA Locust Project Based in Addis Ababa

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For many years BHC and dieldrin have been the two principal insecticides used against the desert locust (*Schistocerca gregaria*). In some years the amounts applied have been large, for example 200,000 l. of concentrated insecticide in one campaign. The continuing use of these insecticides has been a matter of concern to the countries supporting FAO and at the end of 1971 the FAO/SIDA locust project was established to study the implications of using non-persistent chemicals in locust control. The project is financed by the Swedish International Development Authority with counterpart contributions by the Desert Locust Control Organization for Eastern Africa (DLCO-EA) with whom the project is housed at its headquarters building in Addis Ababa, Ethiopia.

The FAO Expert was able to visit the DLCO-EA headquarters and see exactly what laboratory and other equipment was already available: the list of extra equipment required for the project was prepared early and complemented that of the DLCO-EA. As soon as the funds were available the orders were placed. New laboratories were built after the expert was in post and he was able both to design and then oversee their building.

In considering how to study the implications of using non-persistent insecticides it was first necessary to clarify the use made of persistent insecticides. In locust control, BHC is used because it is an effective, relatively safe and cheap insecticide. It is not used because it is persistent. Often BHC is applied as an oil spray, particularly against adults where its action appears to be entirely by contact. Thus any effective contact insecticide would be a suitable alternative. BHC is also used as a bait or a dust: here again persistence is not a requirement but stability on storage is important.

Dieldrin can have the same uses as BHC where it is effective by its immediate action, e.g. swarm control using an oil solution as a spray. However, it is slow in action and the level of contamination of vegetation is undesirably high so it is not recommended for this purpose. As a stomach poison the persistence and properties of dieldrin make it unique. Field trials and use on a large scale have shown that doses, in some cases less than 10 g/ha can, when properly applied, be lethal to locust nymphs when feeding in the sprayed areas. This startling effectiveness does not now appear to be due to dieldrin itself but to its photoisomerization product, photodieldrin. This substance is about ten times more toxic to locusts then dieldrin. In this type of control the persistence of dieldrin is a necessity. This effectiveness can easily be demonstrated in the laboratory. Most insecticides when applied at a rate of 1 µg active ingredient per seedling blade do not kill first instar nymphs when these are given the vegetation to eat after it has been exposed to the sun for 4 days. However, about 0.3 µg of dieldrin left for 8 days in the sun was fully lethal when fed to the nymphs. In addition to its high toxicity and persistence it is fully cumulative in the locust's body so that small sublethal quantities can be added together to make a lethal dose after a few days.

The lines of work decided upon were threefold:

(1) a study of the effectiveness of insecticides against locusts. Special equipment is available for this and enables the relative toxicity of sprays as contact and stomach poisons to be determined as well as that of other formulations.

(2) a study of the likely hazards involved to man and domestic animals in using a particular insecticide. Since all the alternative compounds so far studied in detail have been cholinesterase inhibitors this work has involved a lot of blood cholinesterase measurements. Vegetation has been sprayed with a variety of insecticides and domestic animals exposed to the treated plants.

(3) a study of the persistence of various insecticides under tropical conditions. These have been mainly the type of experiment referred to earlier in which plants have been sprayed with known amounts of insecticides and left in the sun for varying periods of time before feeding to locusts or chemically analysed.

Briefly, the results of the work to date can be summarized by saying that against adults a number of insecticides are available but against nymphs there is no alternative insecticide available at a reasonable cost.

In addition to the work on locusts, studies have also been carried out to see what undesirable effects are actually being produced by the use of dieldrin and BHC. During the period of the project there have been no large scale outbreaks of locusts in the DLCO-EA area so it has not been possible to follow what happens to applied insecticides during actual control operations. The main line of work has been to study the occurrence of pesticides in the blood of staff working in locust control and plant protection. Blood samples of over 200 staff were examined for the levels of organochlorine insecticides and measurement of cholinesterase activity. It is the insecticide DDT which occurs in the greatest quantity: DDT was measured as total DDT, that is pp DDE plus pp DDT. In Dire Dawa, Ethiopia, the mean level found was over 100 ng total DDT per ml whole blood ranging from 26-258 ng/ml. Blood samples from this station were obtained in August 1974 just after a reported army worm (S. exempta) outbreak against which DDT was used. Another set of data from Mogadiscio, Somalia, ranged from zero to over 300 ug total DDT per ml. whole blood with an average of over 50 ng/ml. The reasons for these high values are unknown, maybe they are related to domestic and not work uses. Examined individually the data were most revealing. For example in Hargeisa, Somalia, two staff had noticeably higher levels of DDT than anyone else. On being questioned one of these staff said he had been regularly spraying DDT some 18 months ago prior to his present employment; the other staff member had transferred some months previously from Mogadiscio where total DDT levels were high.

Some of the levels of gamma BHC and dieldrin were rather high bearing in mind that no large scale control operations against locusts had been carried out for some years. A few people had over 20 ng/ml of dieldrin and others over 10 ng/ml of gamma-BHC.

One essential facility in planning this type of work is the ability to purchase items both in the country where the work is carried out and overseas. Both types of purchases may cause difficulties in some countries, especially a requirement for foreign exchange. A request for foreign exchange could take some weeks or even months before being agreed. When setting up a programme of work this problem must be borne in mind and special arrangements made if necessary. A further problem is library facilities. Provision may have to be made for subscribing to scientific journals and contacts should be made with existing libraries so that photocopies of required papers can be obtained.

b) The FAO/DANIDA Project Based in Teheran

(A note prepared by the FAO secretariat)

Background and Objectives

The continued use of the organo-chlorine insecticides BHC and dieldrin which are currently the chief chemicals used in locust control is being questioned because of concern that the use of these relatively persistent compounds may harm wild life and pollute the environment. Little is known of the residues of dieldrin and of BHC which remain after locust control operations and whether they cause damage. Most research on these compounds has been conducted in temperate climates where the persistence of the insecticides may well be very different from that in tropical areas. More studies were therefore needed to ascertain the fate of these insecticides particularly in tropical areas. Any ban on the use, say of dieldrin, would necessitate the use of other more expensive insecticides of which the environmental effects were not known with any certainty; furthermore, alternative techniques of control of locusts, e.g. biological control, are not available or not sufficiently developed to replace insecticidal applications. This project which is funded by Danish Government aid was therefore formulated in 1973 and commenced in October 1974. Its objectives, over a three-year period, are to study the environmental effects of current locust control methods particularly in India and Pakistan.

Work Programmes

A laboratory to enable residues of the pesticides mainly involved to be detected and measured has been set up and field survey work has been carried out with a view to deciding on the kind of sampling plans that should be undertaken in treated areas to enable findings to be obtained that are meaningful so far as persistence and biological effects are concerned. Preliminary experimental studies of persistence in supervised sites under controlled conditions representative of the conditions actually found in desert areas that have sometimes been sprayed have been planned. The latter work will be preliminary and carried out alongside attempts to monitor residues in areas of known histories of insecticide treatment against locusts.

APPENDIX I

RECOMMENDATIONS MADE AT THE CONSULTATION

8.1 Requirements and priorities

8.1.1 Urgent measures should be taken to initiate missions to analyse and identify the components of specific environmental problems. The priorities should be guided by the following criteria:

(i) Suspected occurrence of undesirable side-effects arising from the residues associated with particular uses of pesticides in agriculture.

(ii) Actual and potential situations of intensive pesticide use, particularly where compounds of high toxicity and/or persistence or situations of known ecological vulnerability are involved.

(iii) Situations where new and possibly potentially hazardous uses of pesticides are planned.

8.1.2 The meeting concluded that major areas for concern were the heavy use of pesticides on cotton and rice, in locust control and in the protection of livestock from pests such as tsetse and that action is especially needed in these areas as soon as possible.

8.2 Organisation of the programme

8.2.1 FAO should, as a matter of urgency, in cooperation with WHO, UNESCO, IAEA and other appropriate agencies coordinate, promote and seek funding for an international cooperative programme for monitoring the environmental impact of agricultural pesticides.

8.2.2 The proposed FAO Panel of Experts on Pesticides and the Environment should be convened and should serve as a formal advisory body to the programme.

For efficient implementation of the Programme a full-time professional officer at FAO headquarters should be responsible for running the secretariat of the Panel and the liaison between the component projects of the programme and the cooperating organisations.

8.2.3 Copies of the report on this Expert Consultation should be distributed widely to developing countries with an accompanying invitation to recipients to draw the attention of the Secretariat in FAO to specific problems of impact monitoring that warrant support within the programme. To facilitate this distribution of information, the main papers contributed to the meeting should also be published.

8.3 Development of the programme

The meeting also recommended that the following specific activities should be pursued as part of the monitoring programme:

(i) Short term visits to developing countries by chosen experts in a consultancy capacity, to advise on existing or potential environmental problems arising from new or existing practices in the use of pesticides in agriculture. This should include preliminary sampling surveys; the provision of advice on the kinds of study needed to investigate possible problems from such uses and the drafting of project proposals for their implementation.

(ii) Individual projects in the programme should be funded and managed by national, bilateral or international organisations as appropriate, and should be provided with technical advice and assistance via the Panel on Pesticides in the Environment to be set up by FAO in association with UNEP for the purpose.

(iii) Once specific projects are identified, support for existing laboratories in plant protection institutes and similar institutions should be given, to raise their competence in monitoring the distribution and impacts of pesticides used in their localities. This may be by the provision of experts on a medium term basis, by training of appropriate qualified staff, with equipment, or in other ways.

(iv) Support for fellowship training of graduate staff, on an intensive basis, in methods of determination of residues, for periods of six months or more, also for selected staff from developing countries to attend seminars and specialised meetings concerned with the monitoring of residues of pesticides in the environment.

(v) Information on the usage of pesticides in developing countries is needed and should be obtained prior to establishing a project in a particular country.

(vi) Efforts should be made to overcome the lack of availability of information and literature relevant to recommended projects.

(vii) Information be made available on research and training programmes organised and supported by member countries which are relevant to the problem of impact monitoring of pesticides.

(viii) Both laboratory and field methods for the detection and measurement of changes in the susceptibility of relevant non-target organisms should be established and, where possible, appropriate organisms identified as indicators of pesticide contamination and monitored.

(ix) To ensure the comparability of results, methods should be standardized and if possible a regular check sample programme be organized.

(x) To permit the maximum degree of participation by all countries, the monitoring techniques adopted should be of a degree of complexity appropriate to the problem.

8.4 Related activities and background studies

8.4.1 The meeting further recommended that, as an essential complement to the monitoring programme, the following supporting activities should be initiated and their progress kept under review by the FAO Panel of Experts.

(i) Support should be given to research into the behaviour and persistence of pesticides in tropical ecosystems.

(ii) Studies should be made of the relationship between long-term soil contamination by pesticides, and plant productivity as measured by crop yield and quality.

(iii) Whenever appropriate the above activities should be coordinated with the "Man and the Biosphere Programme" of UNESCO, with the FAO/UNEP "Cooperative Global Programme for Integrated Pest Control in Agriculture", with the FAO/WHO/UNEP "Food Contamination Monitoring Programme" and with other international monitoring programmes concerned with pesticides.

(iv) In assessing and evaluating the effects of pesticides, the nature of their interaction with the major elements of the environment, in particular, soils, water, plants, animals, man and climate should be characterized.

APPENDIX II

ATTENDANCE AT CONSULTATION

Participating Experts

A.A. Agah, Deputy Director, Plant Pests and Diseases Research Institute, P.O. Box 317B, Teheran, Iran (Vice-Chairman)

A. Balasubramaniam, Senior Agricultural Officer (Pesticides), Crop Protection Branch, Department of Agriculture, Jalan Gallagher, Kuala Lumpur, Malaysia

J.E. Davies, Department of Epidemiology, University of Miami Medical School, Miami, Florida 33152, U.S.A. (Representing U.S. Agency for International Development)

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G.A.B. El Zorgani, Agricultural Research Corporation, Wad Medani, Sudan

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F.W. Kopisch-Obuch, Pesticide Residue Project, D-61 Darmstadt, Rheinstrasse 91, Postfach 4001, Federal Republic of Germany (Representing German Agency for Technical Cooperation)

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B.K. Na'Isa, Chief Veterinary Tsetse Officer, Federal Ministry of Agriculture & Natural Resources, PMB 2005, Kaduna, Nigeria

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A.S. Perry, Institute for Nature Conservation Research, Environmental Toxicology Laboratory, Tel-Aviv University, Ramat-Aviv, Israel

H. Sethunathan, Central Rice Research Institute, Cuttack-6, Orissa, India

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*Presented a paper but unable to attend meeting.

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L.T. Kadry, Land and Water Development Division

P.J. Mahler, Environmental Programme Coordination Unit

R.X. Malik, Food Policy and Nutrition Division

H. Matsuo, Land and Water Development Division

E.J. Mouttapa, Environmental Programme Coordination Unit

E. Pelinck, Forest Resources Division

G.H. Tomczak, Fishery Resources & Environment Division

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