THE VALUE OF WORLDWIDE PESTICIDE RESIDUE MONITORING SYSTEMS

C. L. DUNN

Hercules Incorporated, Wilmington, Delaware, USA

ABSTRACT

The objectives of pesticide monitoring programmes are normally related to assuring safety to man and his environment. Analysis is needed to identify and measure residues. Judgements of environmental consequences resulting from the use of toxic materials must be based in part on sound knowledge of amounts and nature of residues in environmental compartments. Models of varying detail are a means of achieving this knowledge and they can subsequently assist in making judgements concerning any needed controls. Monitoring is an essential part of constructing models and determining the success of measures intended to control contamination (detectable amounts) or pollution (harmful levels). Monitoring programmes can be classed by their intended functions: modelling; scounting: surveillance; isolated verification. Each monitoring programme should be appraised by the usefulness of the information and the cost of obtaining it. Assessments of monitoring programmes in this manner are under study and will be presented.

The assignment of costs in terms of resource allocation should include an estimate of alternative productivity if the resource were utilized in some other endeavours. The benefits of the programme should be accounted for and value expressed as benefit/cost ratio. Because benefit estimates involve social, aesthetic and economic desires and achievements, disputes will arise concerning the validity of value determinations, and decisions will not be made exclusively on a scientific basis. The ultimate value of monitoring systems may thus be in providing a better foundation on which to base both scientific estimates and political decisions.

This paper discusses the background to present and future pesticide use, some principles of monitoring, some specific examples of monitoring programmes and some evaluations and recommendation concerning them.

MAN AND HIS ENVIRONMENT

One mark of civilized man is his desire to look ahead, to anticipate his future and to improve by planning. Man has not always been successful, of course, and some past civilizations have perished because of unsuccessful management of their environments. Rational man will profit by experience, however, avoiding future disaster at least, and improving matters at best. In the business world, it is commonly acknowledged that corporate goals and priorities are, in order of their importance, first, survival; second, profitability; and finally, growth when the first two are achieved. These same goals and priorities apply to man in general if profitability be translated as 'quality of life', which certainly must include the state of his total environment as well as his food, clothing, shelter and culture. It would seem that man's population growth as a non-ordered component of our existence today defeats the orderliness of the idealized system. Nature's way of restoring order, a 'balance of nature' to some, is harsh. Reduction of population by famine and pestilence is still with us, although the drama of famine may today be somewhat more subdued than it formerly was. More effective distribution systems have tended to spread famine more evenly amongst the least affluent in the world, although there is obviously some patchiness still visible.

The awesome prospect and partial realization of world human population growth is shown in *Figure 1*. According to familiar projections, we are on the way to a possible world population of 7.5×10^9 by the year 2000.

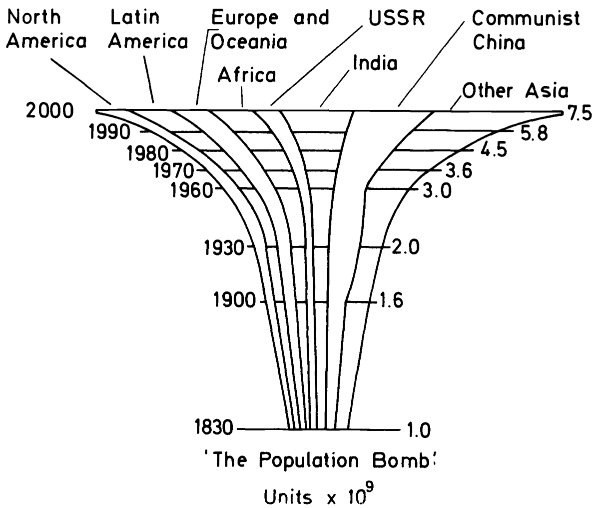

Figure 1.

While some evidence that a population growth rate slowing in some regions of the world may now be occurring, there seems to be nevertheless a relentless expansion along the lines generally indicated in the mushroom cloud shown in the graph.

MAN AND HIS FOOD CONSUMPTION

As an element of survival, certainly food must be rated a key component. World food production both in absolute amounts and in per capita amounts are presented in *Figure 2*. Here, normalized with respect to average production during the period 1961–65, is a plot of both total and per capita food production for the period 1961–72. It should be noted that while totals increased by 25 per cent, the per capita increase has never exceeded 5 per

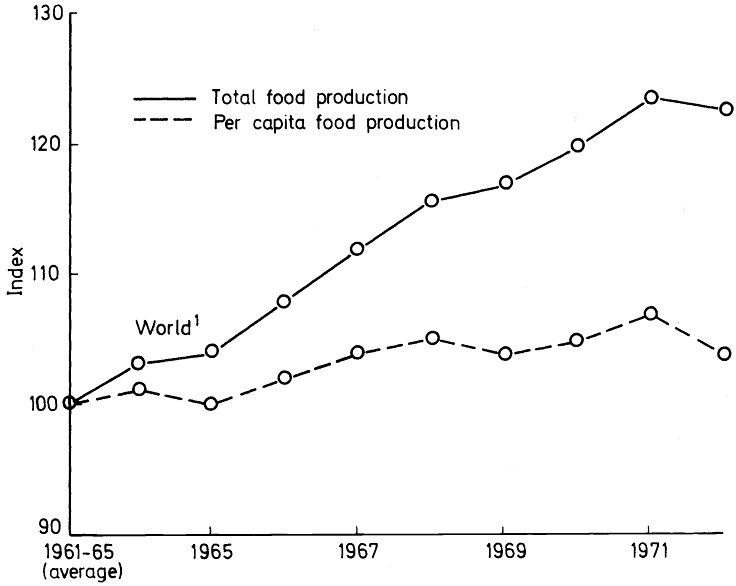

Figure 2. Total and per capita food production, 1961–72

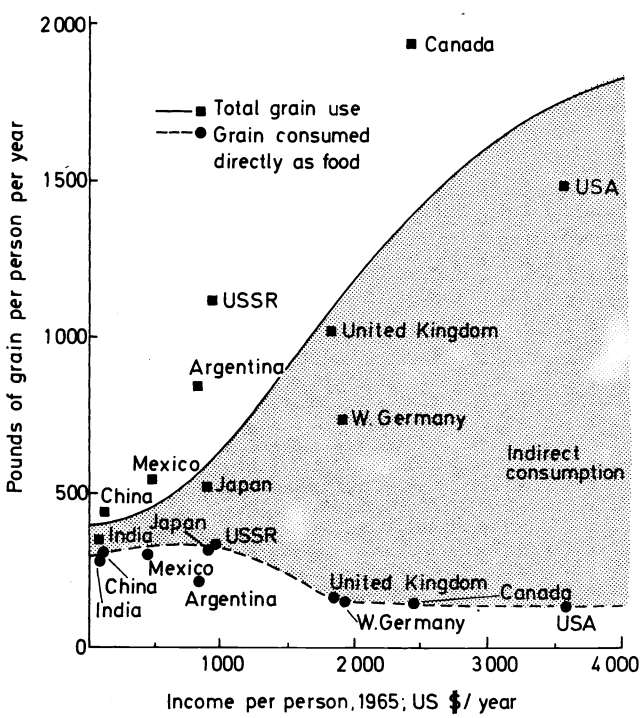

Figure 3. Direct and indirect grain consumption by per capita income, selected countries

cent. Should the droughts that have affected large areas of Africa and Asia be experienced in North America, the effect on grain production will be severe, and the per capita food production could drop even farther than the last point on the curve.

There is a large difference between survival rations and luxuriant food consumption, of course. *Figure 3* depicts grain use as total consumption and as direct food consumption for selected countries and related to average income. Obviously the indirect consumption of grain relates to the 'quality of life' that includes meat, milk, eggs and beer in the diet. At the lower income level, direct grain consumption drops noticeably as average annual income exceeds US $1000.

Protein from the sea may have peaked out, as shown in *Figure 4*. Here are the FAO fishery statistics[1]. Some marine biologists are apprehensive

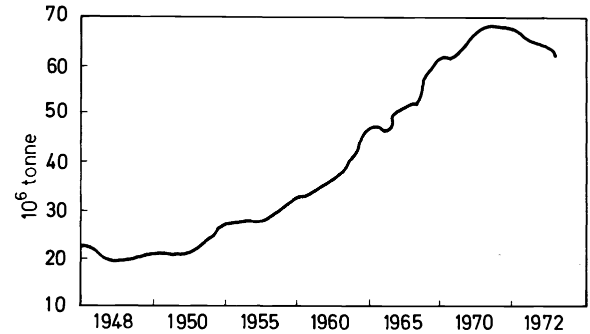

Figure 4. World fish catch: 1948–72 (live weight)

about our ability to go much beyond this point on a sustained basis. Production of fish by culturing in ponds and the like will, of course, be an additional consumption of grains.

A final statistical appraisal entitled by its author 'World Food Security'[2] is shown in *Figure 5*. Very briefly, it shows that, as of 1974, there is no more

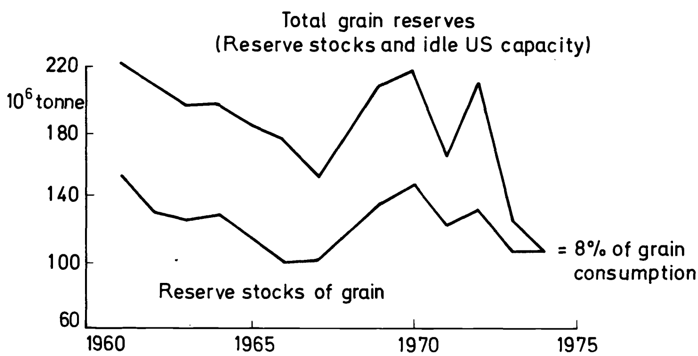

Figure 5. World grain stocks and total grain reserves, 1961–74

than about 8 per cent of present grain consumption in reserve stocks, and that the idle US cropland which previously provided an additional back-up capacity is no longer idle. Should the period of drought that climatologists believe runs in 20-year cycles in North America appear in the remaining years of the 1970's, the world will be in an ominously tight position for grain.

MAN AND HIS FOOD PRODUCTION

In producing food in the amounts required to maintain even the existing per capita level, the capabilities of the lands currently producing at high levels in the advanced countries may not be greatly increased. The aggregate requirements of capital, fertilizer, energy and other inputs may make the cost of incremental higher yields rise sharply. The potential of the poorer countries must be better exploited to satisfy the constantly increasing food requirements. Impressive yield increases have been demonstrated with new grain varieties, but fertilizer, water and other inputs are also required to achieve this.

PESTICIDES: A VITAL COMPONENT IN FOOD PRODUCTION

It is a fact of life that no matter how many new plant varieties, how much fertilizer, irrigation and other cultural techniques may be brought to bear, the use of pesticides is absolutely vital to achieve respectable yields. The traditional pests which have always affected man's agriculture are the multitude of insects and rodents which attack the growing crops and the harvested yields; the plant diseases which may destroy the crop at any time from planting to harvest and storage; parasites which can sicken, weaken or destroy livestock; and weeds which can engulf the desired crop, drawing off nutrients and water or making the crop unharvestable or unfit for consumption. While improved techniques of pest management may lessen somewhat the intensity of pesticide usage, they are indispensable to an adequate agriculture.

In 1966 a panel of American scientists at the direction of President Johnson studied world food production[3]. One of their observations was the excellent correlation between pesticide use and crop yields and the extremely rapid rate at which pesticide usage increases as agriculture is intensified. Not all the increased crop yield is due exclusively to the use of pesticides, of course, but it is a vital part of the management mix of techniques which has brought about the superior productivity which has been achieved in Japan, Europe and the USA.

ARE THERE SAFETY PROBLEMS ASSOCIATED WITH INCREASED USE OF PESTICIDES THROUGHOUT THE WORLD?

By projecting the knowledge gained in areas where pesticides have been extensively used—Japan, Europe and the USA, for example—it is reasonable to predict that there will not be adverse effects on man and his environment except from misuse or accident. However, we must recognize that within areas of the world that may be candidates for more intensive agriculture there can be circumstances of geography, botany, climate and a host of other ecological variables that are significantly different. Knowledge of pesticide use, diffusion and environmental impact under these conditions will be required to assure safety.

MONITORING

The objectives of pesticide residue monitoring are normally related to assuring safety to man and his environment. Most of us are familiar with the monitoring programmes that are conducted by various national authorities to assure freedom of foodstuffs from harmful levels of pesticide residues. But that is only one aspect of monitoring. The term 'monitoring' carries an inherent concept of successive measurements carried out over a period of time. In the context of pesticide safety assurance, four types of monitoring can be considered:

(1) Modelling data accumulation. The intent is to acquire input data for mathematical models such as those sought to explain or predict the large-scale transport of pesticides from sites of application to adjacent or distant areas.

(2) Reconnaissance monitoring. The intent is to determine trends, levels either increasing or decreasing with time.

(3) Surveillance monitoring. Essentially enforcement in nature, seeking to establish conformity with pre-assigned standards.

(4) Isolated verification. Typically to gain rough knowledge of levels either as a preliminary to a more detailed programme or to deal with a transient episode.

The US Environmental Protection Agency has described the role of environmental monitoring in the following terms[4]:

'Monitoring seeks to determine our total exposure to pollutants. Accurate and reliable monitoring data are essential in every step of pollution control
(a) to establish baselines from which changes can be measured.
(b) to identify pollution problems.
(c) to provide data for defining standards.
(d) to evaluate pollution abatement results.
(e) to provide evidence for enforcement action.
(f) to provide early warning of unforeseen problems.'

That quotation is a fair statement of objectives, which, if achieved, should provide a factual basis for both safety evaluation and safety assurance. Note that the facts determined will do no more than provide a basis for further action. I should like to return to that matter after discussing some aspects of the strategies and tactics of pesticide residue monitoring programmes.

Any monitoring programme should be installed only after its objectives have been carefully defined. While this may seem to be a gratuitously elementary admonition, it is not infrequently violated, commonly for the reason that the information is not essential, but rather is 'interesting to have'.

Those who have dealt with the problem of designing and installing information storage and retrieval systems will recognize the similarity to the naïve first request for an information system that will simply 'handle everything'. The difficulty of defining in detail exactly what information will be needed can be surprisingly agonizing.

While measurements in monitoring programmes can be physical, chemical or biological, the specificity of response is of considerable importance. Bioassay by fish in a stream from a water treatment plant can signal a toxic response, but will give no information concerning identity of the toxicant. If the incidence of episodes is low, however, there may be little point to installing a more elaborate system of continuous chemical analysis.

An additional general comment about information acquired in a monitoring programme is in order. Prompt availability of results to those initially needing the information is assumed. The usefulness to other agencies or parties is not always recognized, however, and delays of years have sometimes occurred before results have been published for general knowledge. Hopefully any monitoring programme will deal explicitly with the matter of prompt dissemination of the information to the maximum audience that may be interested or qualified to use it.

MONITORING STRATEGIES

As indicated previously, four types of pesticide residue monitoring are commonly useful. The where—when—how—what decisions for establish-

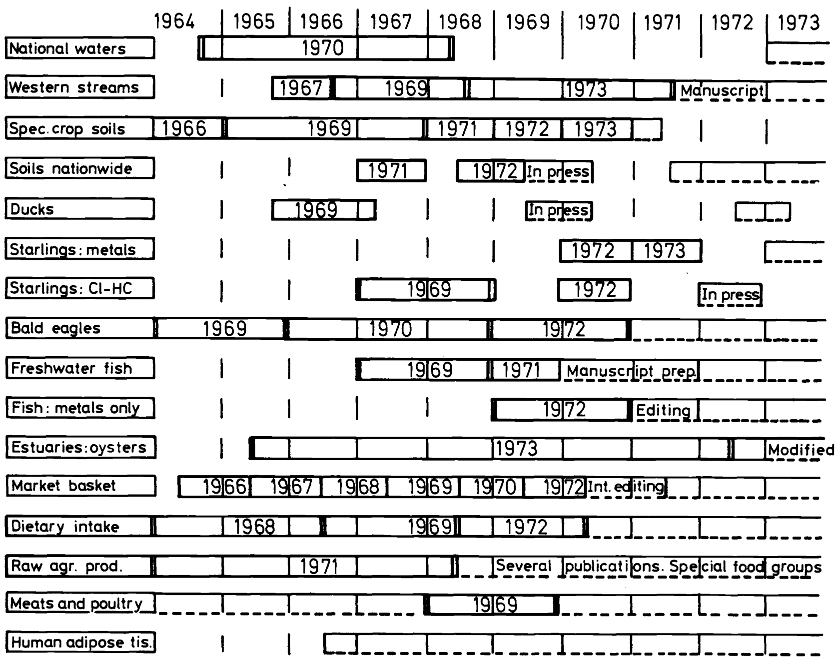

Figure 6. US National Monitoring Program

ing the detailed programme will depend upon the objective. To do a surveillance monitoring of the outfall of a pesticide formulating plant will call for a simple scheme of sample collection, whereas a determination of the trends of DDT accumulation in Arctic seals will require a far different approach.

An ideal objective that has been expressed by many workers is the concept of establishing models that can characterize in a quantitative fashion the flow of materials introduced into the environment. The term 'chemodynamics' has been coined to express this very desirable knowledge. Several years ago a sub-group of the US National Academy of Science's Committee on Oceanography prepared a report[5] in which they proposed a baseline sampling programme to gather in a 1-year period 1000 samples from wind systems, ocean current systems, organisms, rivers, glaciers, rain and sediments. While one may argue with the adequacy of the data from that sampling to achieve a model for global distribution of DDT or anything else, their attempt to make a start draws attention to the magnitude of such an undertaking. As an operating procedure, the stepwise progression of proposing a rough model, to be successively refined with more and more data, until it ultimately matches the observed facts, seems tremendously ambitious. In considering the utility of even a few models that may be accurate enough to gauge problems or solutions stemming from widespread use of a variety of pollutants, however, the benefits are obvious and attractive. Success in this should promise fame to those who succeed.

WHEN TO START—AND STOP—MONITORING

Starting monitoring programmes, once funding is obtained, can be easier than stopping them. Decisions to modify or stop are so dependent upon circumstances that there can be no general rule except to periodically review, asking the question, can the resources invested in this programme be better utilized elsewhere?

SPECIFIC EXAMPLES OF MONITORING PROGRAMMES

In *Figure 6* a chart of the US National Pesticide Monitoring Program is shown[6]. As an example of what can be achieved by various groups working together but not under a common agency or enjoying a common budget, it is suggestive of what can be accomplished on a world wide basis. The National Monitoring Program was launched in 1964 only on the basis of mutual interests of various federal agencies, with each agency funding its own programmes. Not until 1972 was this cooperative programme consolidated into one federal programme under the Environmental Protection Agency.

The chart indicates periods of operation, varying publication status of the results, and the programme titles. It demonstrates the widely varying nature of the investigations. Briefly, the environmental compartments examined are waters and streams; soils of both cropped and uncropped land; wildfowl, reflecting both aquatic and terrestrial exposure; starlings for widespread terrestrial avian exposure; bald eagles as a special predator atop food chains; fresh water fish; shellfish in more than 100 estuaries around the entire US perimeter; ready-to-eat foodstuffs; raw agricultural crops; meats and poultry: and, on a lesser scale, human adipose tissue.

In other countries programmes have operated at various scales to fit the individual needs. In Australia, for example meat and dairy products are carefully examined for pesticide residues as part of quality control. The examination of foodstuffs in various European and Scandinavian countries is regularly done. Recently the FAO/WHO joint conference on Food Additives and Contaminants indicated its interest in developing an internationally coordinated programme for monitoring contaminants, including pesticides, in food. Presumably such a programme would consolidate data from ongoing national programmes and assist those nations who may wish to initiate or strengthen their food monitoring programmes.

A few months ago the United Nations Environmental Program, with permanent staff in Nairobi, Kenya, conducted a meeting attended by representatives of 67 nations. It is my understanding that recommendations of the working party have been made concerning a pollutants priority list, and that funds of US $100 million will be expended during the next five years, chiefly in developing countries, to develop environmental monitoring capabilities. DDT and other organochlorine compounds in biota are included in the priority list.

CONTAMINATION VERSUS POLLUTION

I referred earlier to the point that monitoring provides only a factual basis for action, and it is this matter that I would now like to discuss. The regulation of pesticides is practised to varying degrees throughout the world. Generally where there is little use, regulations are minimal; where usage is intense, regulations are more extensive. The entire purpose of regulation is to protect the user, the public and the environment. When there is sound knowledge that this mission is being accomplished, regulatory measures can be adjusted to a minimum level, consistent with sensible objectives. By this I mean that objectives such as total elimination of contamination are neither realistic nor sensible. But a great deal of knowledge is required to establish suitable limits. A useful distinction between 'contamination' and 'pollution' can be made: contamination is the presence of a material in an environment, while pollution is its presence at a level that will harm something that man values. Monitoring of pesticide residues provides knowledge of detectable levels, interpretation is required to determine if the levels measured represent contamination or pollution. The safety factor that may be employed in establishing allowable or tolerable levels in environmental compartments may be variable, depending on local needs and situation. The benefit of having a total view of the levels encountered in other areas of the same continent and in other parts of the world is obvious.

The availability of knowledge concerning the diffusion of pesticides in the environment and the realization that the consequences of greater or modified pesticide usage can be measured should relieve much of the anxiety concerning these necessary changes. While local ecological systems are of first importance, the world community has a justifiable concern that the tail should not wag the dog, and that there is a legitimate concern regarding the diffusion of pesticides beyond national boundaries. The Nordic Convention is an interesting example of that concept. Very recently—within the past few months, I believe—the signatory nations of Finland, Sweden. Norway and Denmark formalized an agreement whereby an individual of nation 'A' can take legal action in the court of adjacent nation 'B' to recover compensation for damages caused by release of harmful agents by an individual in nation 'B' and to force suspension of that activity. This is a remarkable agreement, and the use of monitoring information as evidence in such cases will be extremely interesting.

VALIDITY OF SAMPLING AND ANALYSIS

The validity of monitoring data and their interpretation is limited by the quality of the programme. This includes the adequacy of sampling and the validity of analyses. Computer users have invented the acronym 'GIGO' (Garbage In—Garbage Out) to express their awareness that the computer cannot magically produce good results from bad data. It is outside the scope of my presentation to deal in any detail with the subject of quality control in environmental pesticide residue analysis, but the value of any monitoring system, worldwide or local, is not only collapsed, but turned into a negative quantity, by faulty analytical methodology. As recently expressed by Dr Donald Crosby, University of California, analytical determinations in environmental samples suffer not from lack of sensitivity, but rather from inadequate specificity. We need verification for exact identification, so that phthalate plasticizers, for example, are not mistakenly identified as DDT. The complaint is sometimes made that the cost of verifying identifications by such means as three different determinations (e.g. by GLC, TLC and chemical derivative formation) is excessive. While some compromise may be acceptable in the interest of reducing costs, the costs of mistaken identity can be severe. I can only caution that the curse of the ultrasensitive methods is the pain of verification.

An international cooperative effort to measure the concordance of results of various laboratories analysing shared environmental samples from marine and wildlife sources was undertaken in 1967. Dr A. V. Holden[7] has reported his assessment of results to the effect that for the DDT–Dieldrin analyses, coefficients of variation between laboratories of $\pm$ 30–60 per cent were observed. Subsequent investigations[8] to assess the feasibility of international monitoring were reported to demonstrate that the problem of biological sampling and assessment of ecological changes falls far short of that necessary for an effective programme'.

MONITORING DATA INTERPRETATION

In interpretation of monitoring data, the temptation to substitute the reasoning of association for more rigorous proof of cause-and-effect relationship must be resisted. The credibility of the scientific world is tarnished by premature, sometimes sensational pronouncements that are ultimately found to be wrong. I find myself uncomfortable to hear loudly trumpeted discoveries that the demise of certain avian species by egg shell thinning is the fault of DDT, later PCBs. later still mercury and who knows what by next month. Aside from the problems of mistaken identification in analysis that I alluded to earlier, there may be further complications in determining who causes what effect. For example, we are now informed of evidence that DDT can be formed from PCBs in the environment. So the finding, verified in triplicate, of DDT and DDE, in an ocean sample may be a result of agricultural use of DDT, or it may be from PCBs, or it may be from a shipboard use in controlling bedbugs. I can only caution that hard proof is difficult to achieve, and circumstantial evidence, like a trout in the milk, can be very persuasive.

RECOMMENDATIONS

In listing some suggestions for achieving value from worldwide pesticide monitoring systems, I would include the following:

(1) Exploit fully the information and experience from various national programmes. This would require the assembly of a catalogue of past and current programmes; a clearing-house for prompt dissemination of data; clear-cut quality criteria for data should be established, and unqualified data rejected.

(2) In establishing new monitoring programmes, don't overlook the merits of the obvious for the romance of the exotic. Examine estuaries before oceans, rivers before estuaries. The problems associated with extremely low detection limits are acute.

(3) Look to the problems of both data acquisition *and* data interpretation before launching extensive programmes of environmental monitoring. The procedures of the Organization for Economic Cooperation (OECD) reported by Dr A. V. Holden are illuminating and exemplary in this respect.

SUMMARY

In summary, I have reviewed the basis for a belief that greatly expanded agriculture in less developed parts of the world is in the not-distant future. As a necessary part of that intensified agriculture, the expanded use of pesticides of all kinds is inevitable. Some principles and strategy of monitoring were briefly described, and illustrative examples of actual programmes were presented. Some problems in data acquisition, data quality, and interpretation also exist, but careful investigation is defining these limitations especially in the area of environmental monitoring.

Finally, the chief value of a monitoring system lies in making it possible to know what you are talking about. Decisions on important regulatory matters are made on a political basis, but the quality of the scientific input contributing to those decisions is crucial. The politics of a hungry world can be overwhelming. By providing the knowledge necessary to distinguish between contamination and pollution, it is possible to tailor regulatory actions concerning the use of agricultural pesticides to the minimum required, consistent with human and environmental safety. Hopefully this will allow an expanded world agriculture to keep pace with the intensive food production requirements that are now facing us. And therein lies the value of worldwide pesticide residue monitoring systems.

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