FAO Food Control Series No. 5

WHO/HCS/FCM/78.1

GEMS: Global Environmental Monitoring System

# GUIDELINES FOR ESTABLISHING OR STRENGTHENING NATIONAL FOOD CONTAMINATION MONITORING PROGRAMMES

Prepared under the joint sponsorship of the

United Nations Environment Programme, the

Food and Agriculture Organization of the United Nations, and the

World Health Organization

WORLD HEALTH ORGANIZATION, GENEVA, 1979

These Guidelines for Establishing or Strengthening National Food Contamination Monitoring Programmes were prepared by FAO and WHO as part of a project of the United Nations Environment Programme

entitled

"Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme, Phase II"

with

The Food and Agriculture Organization of the United Nations

and

The World Health Organization, as cooperating agencies

FAO and WHO acknowledge the valuable work

of Dr Stuart A. Slorach

in the preparation of this document

CONTENTS

Page

Page

## INTRODUCTION

An adequate supply of safe, wholesome food is essential to the health and well-being of man. Food contamination monitoring, which yields information on the levels of contaminants in food and on time-trends in contamination, is important for ensuring the safety of food supplies and for the management of food and agricultural resources. Monitoring can reveal rising trends in food contamination, thus enabling preventive and control measures to be initiated before contamination becomes so serious or widespread that it threatens human health or causes serious economic losses. When action has been taken to reduce contamination, monitoring provides a means of measuring its success. However, monitoring - the collection over a period of time and evaluation of data on levels of contaminants in food - should not be regarded as an end in itself. The knowledge that food is being monitored for contaminants may have a good psychological effect in that it encourages those who produce and handle food to use good agricultural, manufacturing and handling practices, thus helping to reduce contamination. However, apart from this, monitoring itself does little or nothing to reduce contamination. To do this, the sources of contamination must be identified and eliminated or controlled: at the same time, measures must be taken to prevent contaminated food from reaching the consumer.

### Purpose of the guidelines

These guidelines are intended to assist national authorities wishing to establish or strengthen food contamination monitoring programmes as part of their overall food safety, food control and resource management activities. Furthermore, they aim to show how the information generated by monitoring can be used nationally and, where national authorities agree, internationally and the benefits which can be derived from such work. The assistance that international agencies can provide to countries wishing to start food contamination monitoring is also briefly discussed. The guidelines are primarily intended to meet the needs of those responsible for planning and implementing monitoring programmes. However, it is important that those responsible, at the highest level in government, for the allocation of resources for such activities be made aware of the need for and benefits of monitoring, both in safeguarding human health and from the economic point of view.

### Increased concern about environmental pollution

Human activities inevitably and increasingly bring about a redistribution of material and energy in the environment. When that material or energy endangers or is liable to endanger man's health, his well-being or his resources it is called a pollutant.[a] Environmental pollutants may be chemical substances (e.g. organochlorine compounds, radionuclides), geochemical substances (e.g. dust, sediment), biological agents (e.g. bacteria, viruses, parasites) or physical properties (e.g. noise, waste heat).

During recent decades increasing concern has been voiced about pollution of the human environment. One reason for this is evidence that environmental pollution is increasing and that it can endanger the health and well-being of man or natural resources. Another is that there is increasing awareness that our knowledge of the toxic effects, especially the long-term effects on human health of many environmental contaminants, is inadequate.

Some forms of environmental pollution, for example, pollution of the air with sulfur dioxide, can affect man's health directly. Other forms, for example, pollution of soil and water with cadmium or mercury, can affect health indirectly by contaminating food supplies. In addition to these direct and indirect effects on man's health, air, water and soil pollution may have profound economic effects if it reduces food production by interfering with the

---

[a] According to many dictionary definitions the terms "contaminant" and "pollutant" are synonyms. Almost all contaminants may also be pollutants but not all pollutants are contaminants (e.g. waste heat, noise and some other physical properties).

reproduction, growth or survival of plants and animals. For example, sulfur dioxide emitted from fossil fuel-burning power stations, metal smelters or pulp mills, may be precipitated as sulfuric acid, causing acidification of inland waters and irreversible damage to fish life and to vegetation. Likewise, the use of large quantities of pesticides on non-food crops such as cotton has led to widespread fish kills in polluted waters.

Increased risk of food contamination

Contaminants present in food may arise from industrial pollution of the environment (e.g. mercury, cadmium and polychlorinated biphenyls (PCBs)), from agricultural practices (e.g. pesticides, fertilizers and drugs used in animal husbandry) and from food processing (e.g. nitrosamines and certain polycyclic aromatic hydrocarbons). However, many of the most dangerous food contaminants known occur naturally, for example, pathogenic microorganisms and fungal toxins. In addition, some chemical contaminants may originate from natural geological processes, such as volcanic discharge. If any portion of the food chain becomes contaminated, the contaminant is likely to enter the human food supply, thus presenting a potential hazard to human health as well as an impediment to trade in food. Food contamination is in no way restricted to the industrialized countries - in fact the problems of food contamination of biological origin (parasites, bacteria, mycotoxins, etc.) are often much greater in the developing countries, due to difficulties in securing optimal hygienic practices and the lack of resources for proper handling, storage and marketing.

Food contamination is not a recent problem. However, during the present century awareness of the risk of food becoming contaminated with chemical and biological agents has increased. This is due partly to improvements in methods of detecting contaminants, but there has also been a real increase in contamination, especially with chemical agents, due to, amongst other things, industrialization, urbanization and changes in agricultural practices. For example, the risk of contamination of food by chemical agents has increased enormously during recent decades due to the large-scale production, release and dispersion into the environment of persistent substances, such as DDT, PCBs and heavy metals. The concentration of food processing to fewer and larger units has had many positive effects but it has also increased the potential risk of the spread of food-borne diseases to large populations if contaminants are introduced during processing and/or if processing (e.g. heat-treatment) or handling are unsatisfactory. In addition, it means that many foods, which are especially susceptible to microbiological contamination (e.g. so-called convenience foods containing meat or egg products) and which must be stored and transported under special conditions after processing, are now often transported over long distances, thus increasing the potential risk of food poisoning. The introduction into international commerce of foods from areas in which certain food-borne diseases are endemic can increase the risk of spreading these diseases to distant areas which are otherwise essentially free of them: increased international travel has had the same effect.[1]

What is meant by food contamination monitoring

Food. For the purposes of these guidelines, the term "food" is taken to mean anything which is intended to be consumed by man,[a] with the exception of medicines. It is recognized that in some countries food has been defined in other ways for legislative purposes. In the present guidelines attention has been directed primarily towards investigations on post-harvest or post-slaughter commodities. However, it is important that the results of food monitoring studies be correlated with those from studies carried out at other parts of the food chain (see Chapters 3, 4 and 5).

---

[a] The monitoring of animal feeds for contaminants is an important activity related to the monitoring of food due, amongst other things, to the possibility of transmission of contaminants (e.g. salmonellae, aflatoxins) via animals to food. However, animal feed contamination monitoring will not be dealt with in these guidelines.

Drinking-water is an important food (as defined above) and ensuring the quality of water used in food processing and preparation may play an important role in preventing food contamination. However, since the examination of water for biological and chemical contaminants has already been dealt with in many publications,[a] the monitoring of water *per se* will not be discussed here.

Contaminant. For the purposes of these guidelines, the term "contaminant" is defined as any substance or agent whose presence in or on food, is considered to be undesirable, with the exception of substances normally produced naturally by animals or plants themselves and intentionally added food additives.[b] Some substances, trace amounts of which are essential for human nutrition, and therefore desirable, e.g. selenium, may be regarded as contaminants when present at high concentrations in food.

Contamination may occur at any stage from the initial production of the food to its consumption by man. Most of the contaminants discussed here are either biological agents or reasonably well-defined chemical agents and they usually constitute only an extremely small proportion of the weight of the food. The above definition includes *inter alia* heavy metals, PCBs, vinyl chloride monomer from polyvinyl chloride (PVC) packaging material, nitrosamines and other N-nitroso compounds, residues of pesticides and drugs used in animal husbandry, mycotoxins, bacterial toxins, pathogenic microorganisms and parasites. It does not include substances such as erucic acid, oxalates and certain fish poisons, all of which are produced naturally by plants or animals, or food additives. The definition includes extraneous matter ("filth") such as soil, sand, etc. and also adulterants added intentionally to deceive the consumer, but monitoring for such contaminants will not be discussed in these guidelines.

The monitoring of food for radionuclides requires specialized equipment, personnel and laboratory facilities. It is at present carried out routinely on only a limited number of foods, notably milk (especially for $^{90}Sr$, $^{137}Cs$ and $^{131}I$) and drinking-water. The rapid increase in the use of atomic energy for peaceful purposes, especially the generation of electricity, has led to an increased interest in the monitoring of foods for radionuclides. However, this subject will not be dealt with in these guidelines. Instead, the reader is referred to the publications listed in Appendix 2.

The nature of the contaminants/pollutants giving rise to the greatest concern may vary from country to country and even from place to place within the same country. Furthermore, priorities may change with time as certain sources of pollution are eliminated or controlled and new pollutants are released into the environment or detected. Several international bodies have prepared lists showing what are considered to be the pollutants giving rise to the greatest concern. The agents in the multimedia list of priority pollutants agreed upon by the United Nations Environment Programme (UNEP) Intergovernmental Meeting on Monitoring[2] held in Nairobi in 1974 are shown in Appendix 3. A list of chemical and biological agents which may be of concern as food contaminants is shown in Appendix 4. Although many of the contaminants included in the latter list will be relevant to most countries of the world, in some countries, especially tropical countries and/or developing countries, other contaminants may be of major concern. The criteria for selecting contaminants to monitor in food in national programmes are discussed in Chapter 2.

Monitoring. For the purposes of these guidelines, the term "monitoring" is defined as "a system of repeated observation, measurement and evaluation for a defined purpose, carried out on samples representative of individual foods or the diet in a country, or a given area within a country".

---

[a] See Appendix 1.

[b] This definition does not imply that the use of pesticides or animal drugs in a controlled manner in food production or post-harvest is undesirable, as in this case the benefits of their use outweigh the possible risks. Food legislation in most countries has provisions for regulating the use of such substances so that only safe levels are present at the time the food is sold.

It is preferable to use the term "survey" for studies carried out to determine the extent of food contamination with a particular agent at a particular time, unless the studies are to be repeated several times, in which case they can then be called monitoring.

Because resources are limited, in most countries survey work, rather than monitoring, is carried out. Monitoring is usually limited to situations where experience or a survey indicates a putative health risk, and thus a need for continuing work and to cases where control measures have been introduced and it is desired to measure their impact on contaminant levels.

Purposes and importance of food contamination monitoring

Monitoring may be carried out for a variety of purposes:

(a) To establish a baseline and determine changes in the levels of a contaminant in food with time, thus providing inter alia a means of detecting increasing levels of contaminants in food before they become so high that when ingested they pose a direct threat to human health. This is especially important when the contaminant does not produce ill-health soon after ingestion of the contaminated food but first after an interval of several months or even years. Examples of such contaminants are the heavy metals, lead, cadmium and mercury and the parasites causing taeniasis and fascioliasis. The human intoxications in Minamata and Niigata in Japan caused by the ingestion of fish contaminated with mercury provide a warning of what can happen if food is not monitored to ensure that contamination has not reached dangerous levels. In addition to the suffering they cause, which cannot be measured in monetary terms, intoxications and infections due to food-borne contaminants result in increased costs for medical care and the loss of the productive capacity of the persons affected.

In addition to providing a basis for estimating man's intake of contaminants via food and thus helping to identify groups which may be at risk, levels of contaminants in food often give a good indication of environmental pollution, especially if the plant or animal (food) analysed can concentrate or accumulate contaminants from the environment.

(b) To give an indication of the effectiveness of measures introduced to reduce food contamination. Thus the term "monitoring" can be used to describe studies carried out over a period of several years to see how the levels of mercury in fish taken from a certain lake or river have changed following the introduction of measures designed to prevent or reduce the discharge of mercury into the water. Similarly, long-term studies on the occurrence of a certain parasite in slaughtered animals following the introduction of a parasite eradication programme may be classed as monitoring.

(c) To check that the levels of contaminants in food do not exceed established standards or guidelines, i.e. for what may be termed regulatory or compliance purposes. In this context, "monitoring" is synonymous with "food control" but food control is a broad term and includes many activities in addition to those related to monitoring. The ultimate objectives of both food control and food monitoring are to protect the consumer from acute and chronic intoxications and food-borne infections, to improve the management of food resources and prevent losses in food supplies. However, monitoring is a more long-term activity designed to provide baseline data and to show time-trends in food contamination, whereas food control activities are generally designed with the more immediate objective of preventing food which is unfit for human consumption reaching the consumer. Control activities include regulatory actions, e.g. acceptance/rejection, legal action etc. Some food control activities may satisfy the above definition of monitoring. For example, inspection of meat at slaughter-houses for certain parasites may be regarded both as food control and monitoring; the same may be said of a programme in which imported peanuts or maize are examined for the presence of aflatoxins.

As awareness of the risks associated with contaminated food increases internationally, the demand that food, especially imported food, be monitored for contaminants and controlled is growing. A country which does not have a system for the monitoring and control of imports

for contaminants will find it difficult to prevent itself being used as a dumping ground for substandard food rejected by other countries. In addition, a country without a system to monitor the food it exports to ensure that it meets the requirements of prospective importers runs the risk of having it rejected and suffering economic losses. Thus, besides ensuring the safety of food for domestic consumption, the existence of a well-run monitoring system increases confidence in the quality of the food a country exports and is likely to facilitate international trade and yield better economic returns for the exporting country. Many countries have already introduced import controls to check that certain foods are not contaminated with salmonellae or contain unacceptably high levels of aflatoxins, mercury or pesticide residues. It is likely that import and export control programmes will be introduced in more and more countries and that existing programmes will be expanded. Thus the economic importance of monitoring food for contaminants is likely to increase, especially for countries which derive a major part of their income from the export of food or spend a lot of foreign exchange on food and feed imports.

The Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme

In response to the growing international concern about pollution of the environment and the increasing demand for better information on and control of pollution, the United Nations called a conference on the human environment in Stockholm in 1972.[3] At this conference it was proposed that a United Nations Environment Programme (UNEP) be initiated with a view to concerting international efforts to preserve and improve the human environment.

One recommendation (No. 78) from the above conference was that "internationally co-ordinated programmes of research and monitoring of food contamination by chemical and biological agents be established and developed jointly by the Food and Agriculture Organization of the United Nations and the World Health Organization, taking into account national programmes, and that the results of monitoring be expeditiously assembled, evaluated and made available so as to provide early information on rising trends of contamination and on levels that may be considered undesirable or may lead to unsafe human intakes".

In response to this recommendation and to certain resolutions of the Twenty-fifth[4] and Twenty-sixth[5] World Health Assemblies, the seventeenth session of the FAO conference concerning the assessment and ecological management of resources for food and agriculture[6] and the World Food Conference,[7] a Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme has been developed with funding from the UNEP. This international monitoring programme comes within the framework of the United Nations Global Environmental Monitoring Systems (GEMS) (see Chapter 5). The international monitoring programme and its relation to national programmes is discussed in Chapter 4 of these guidelines.

Food contamination is only one facet of the total environmental pollution problem. The need for and benefits of correlating data on contamination in food and also animal feeds with those on pollution of other media (air, water, soil, the working environment, etc.) and on tissue levels and health effects of contaminants in man are discussed in Chapters 3 and 5.

## CHAPTER 1. THE NEED FOR AND BENEFITS OF FOOD CONTAMINATION MONITORING

The long-term objectives of monitoring are to safeguard health and to improve the management of food and agricultural resources. These two aspects of monitoring are interrelated, in some cases inseparable.

### Safeguarding health

It has long been recognized that the ingestion of food contaminated with chemical or biological agents can give rise to intoxication and food-borne diseases. Among the causative agents of these food-borne diseases, bacteria play an important role. In many countries salmonellae are an important causative agent of food-borne disease. Parasites transmitted via foods can also cause diseases in humans - trichinosis is still a problem in North America and some European countries, cysticercosis is a serious problem in Africa and, to a lesser degree, in Europe and hydatidosis (echinococcosis) is especially prevalent in South America and some Mediterranean countries.

Certain pathogenic organisms transmitted via food to man may be present in living animals or growing crops, i.e. contamination is primary. This is true of most parasitic diseases, for example. In other cases, the contamination is secondary - the organisms are introduced during or after harvesting or slaughter by infected persons handling food or by contaminated equipment, water etc. Staphylococcal food poisoning, for example, is usually the result of secondary contamination.

Some types of food-borne diseases, e.g. salmonellosis and shigellosis, are due to direct contact of the host with the bacteria, while other types, e.g. staphylococcal food poisoning and botulism, are caused by preformed bacteria toxins present in food at the time of its consumption.

If monitoring of biological contaminants is to be of much value, it must be carried out at the relevant parts in the production - processing - distribution chain. In some cases (due, for example, to widespread environmental contamination or the animal disease situation in the country) it may be virtually impossible to prevent initial contamination of raw foods with certain biological agents which might cause a public health hazard, however, contamination can often be controlled by appropriate processing or treatment. In such cases there is little point in routinely monitoring the unprocessed food for contaminants; instead the major effort should be directed towards ensuring that processing is effective.

Many countries accept that there is a definite need to monitor for certain biological contaminants as part of their import controls, meat inspection services and general food control activities. For example, meat inspection regulations in most European countries require that animal carcasses be inspected for certain parasites. Such monitoring improves food safety and also helps to trace the source of any contamination and thus facilitate its control or elimination. Similarly, the import control regulations in many countries require that certain foods (e.g. meat, egg and milk products) be monitored for salmonellae. The need for this type of monitoring has increased with the increase in international trade in foods, especially with the introduction into commerce of foods from areas in which certain food-borne diseases are endemic.

Not all bacterial contamination problems are susceptible to monitoring, for example the hazard posed by *Clostridium botulinum* which is frequently associated with low-acid canned foods. The presence of *Cl. botulinum* spores *per se* is not a basis for rejection of food. However, if coupled with evidence of underprocessing or of some other abuse condition, the presence of these spores is an indication that the product may be hazardous. Thus there is little to be gained by routine monitoring of foods for the presence of such spores or for the toxin. Instead the major effort must be directed towards ensuring adequate processing:

the United States Food and Drug Administration's regulations,[8] covering the production of low-acid canned foods are an example of such control measures.

In recent years, some countries have begun to monitor certain biological contaminants in food and animal feeds as part of investigations of infectious cycles in which, in addition to food and feeds, man, insects, rodents, birds and other living animals, soil, water, etc. may play an important role. This type of monitoring being more of the nature of an investigational study may well increase in importance in the future as it can provide information of great value for programmes designed to reduce the contamination of food with pathogenic microorganisms (e.g. salmonellae in poultry).

Most food-borne bacterial contaminants which produce ill-health do so within a relatively short time after ingestion of the contaminated food (incubation period). On the other hand, the incubation period for certain parasitic diseases, e.g. taeniasis, is usually several months.

During the present century, and especially during the last two decades, it has become increasingly evident that certain chemical contaminants can also produce diseases after a latent period of months or years. This may be because the substance, e.g. cadmium or lead, accumulates in the body over a long period of time and produces ill-health first when the levels in certain tissues reach critical values. Alternatively, it may be due to the fact that there is a long latent period between initial exposure and the appearance of clinically recognizable symptoms of ill-health, without there necessarily being any accumulation in the body. For example, it has been established that there is a usually long latent period (10-20 years) between the initial exposure to certain carcinogens and the appearance of cancer in the exposed persons.

In the light of the above knowledge, it is no longer sufficient to ensure that food does not contain contaminants at such levels that its consumption can lead to acute intoxications or infections, it is also necessary to guard against the possibility of effects appearing after long latent periods. It is in this context that there is a special need for monitoring to protect human health.

One of the most useful parameters for a toxicologist attempting to assess the possible health hazard from a chemical food contaminant which can accumulate in the body is an estimate of its total daily or weekly intake. An estimate of the amount ingested via food can be obtained by analysing samples of individual foods and correlating the results with information on food intake (see p. 31) or by analysing mixed total diet samples. Combined with data on the intake of the contaminant from other sources, such as inhaled air, these data enable the total intake of a specific contaminant to be estimated. Such estimates may reveal areas where the population is at special risk and indicate the need for medical examination/epidemiological studies and/or measures to prevent or reduce their exposure to the contaminant. It is important to remember that although the levels in food may be such that they do not constitute a hazard to the population as a whole, they may do so for certain especially vulnerable groups, e.g. infants, pregnant women, or persons regularly consuming unusually large quantities of certain foods susceptible to contamination.

Monitoring is the only reliable way of determining time-trends in food contamination. The warning of rising trends which can be signalled by monitoring enables corrective action to be taken before contamination reaches dangerous levels. In the case of contaminants producing clinically detectable effects on health only after long latent periods, monitoring is probably the best method of detecting areas where control or better managerial measures must be introduced. Without monitoring, large numbers of people may be exposed for long periods to levels which are in the long term hazardous.

Resource management/economic aspects

As mentioned above (p.10) salmonellosis, parasitic diseases, etc. can be serious health problems even in developed countries. Apart from the suffering they cause, these diseases have very serious economic consequences. For example, salmonellosis results in increasing costs for medical care, loss of the productive capacity of the persons affected, losses to the livestock and poultry industries through death of young animals, decreased egg and milk production, a need for costly testing and control programmes and reduced value of contaminated products. It was estimated[9] in 1969 that the total cost of salmonellosis to the American economy exceeds US$ 300 million annually.[a] Thus the economic importance of monitoring and control measures to reduce such contamination cannot be doubted.

In addition to helping to prevent contaminated food reaching the consumer and providing a warning that a food contamination problem is increasing and/or becoming critical, monitoring is needed to give an indication of the effectiveness of measures introduced to reduce contamination. For example, in Sweden the levels of methylmercury in fish taken from certain rivers and lakes is so high that the fish is considered unfit for human consumption and the water areas are therefore blacklisted. Having taken action to stop or reduce the discharge of mercury from chlorine-alkali factories, the paper industry, etc. the levels of mercury in fish are being monitored to determine when they have fallen to such levels that the fish can again be used for human consumption. Similarly, monitoring can show how the effect of banning the use of a persistent pesticide in a country has led to a decrease in the levels of this pesticide (and its metabolites and degradation products) in various foods.

A survey of lead in food, carried out in the United Kingdom as part of a programme for monitoring heavy metals in foodstuffs, showed undesirably high levels of lead in baby foods packed in cans with lead-soldered seams. The manufacturer went over to using pure tin solder instead and the resultant decrease in lead levels in the baby foods was confirmed at a later stage in the monitoring programme.[10]

Monitoring is needed to assess the impact of the introduction of new substances or practices in agriculture, food processing, food handling, etc. on food contaminant levels. For example, the effects of changes in harvesting, transport and storage practices on the levels of aflatoxins in peanuts and products thereof have been monitored in extensive studies in the United States of America. Feedback of information from these studies provides a basis on which to plan further investigations and action to reduce contamination.

Monitoring is of undoubted economic importance for countries which depend on the export of food for a large part of their national income. As more and more countries institute control systems to prevent the importation of contaminated food, it becomes increasingly important for the exporting countries to check that their products meet the requirements laid down by the prospective importers. Many countries already insist on evidence that foods presented for import have been tested for salmonellae (e.g. meat and egg products) or aflatoxins (e.g. peanuts) with satisfactory results and that nationally or internationally established tolerances for pesticide residues are not exceeded. If the food does not meet these requirements it is usually refused entry or, after suitable treatment where appropriate, admitted as animal feed only or for industrial purposes, thus commanding a much lower price. This means that any country which does not monitor its exports for contaminants runs a grave risk of having them rejected and suffering heavy economic losses. Furthermore, the existence of a well-run monitoring programme increases confidence in a country's products and quality-controlled food is likely to be easier to sell and thus yield better economic returns. Apart from being necessary for the above reason, monitoring also yields results which can indicate where agricultural or manufacturing practices or control measures must be altered so that the food produced will be acceptable on the world market.

---

[a] Although similar estimates are not available for other countries, these data suggest that considerable economic losses result from salmonellosis elsewhere as well.

On a local level, in addition to reducing the risk of allergic reactions, there are obvious economic benefits to be gained from, for example, monitoring milk intended for cheese or yoghurt production to ensure that it is free from antibiotic residues which may interfere with the growth of the starter culture.

Data from monitoring can be used to estimate the amount of food likely to be rejected if a certain limit for the maximum permitted level of a contaminant were introduced into the national regulations. For example, in a recent publication from the United States Food and Drug Administration[11] estimates of the amount of peanuts which would be rejected if certain specified limits for aflatoxins content were introduced are shown. Likewise, the recent British proposals[12] for changing the regulations on maximum permitted levels for lead in food were made first after monitoring had indicated their probable effects on the food supply.

Monitoring is also necessary to provide some of the facts needed when making difficult decisions on, for example, whether to stop production at a factory which is discharging contaminants into the air or a body of water used for fishing, and thus rendering food unfit for human consumption. Here the long-term economic losses resulting from the contamination of the food must be weighed against inter alia the importance of the factory from the economic point of view and as a source of employment.

Some plants and animals used as food show contaminant levels far above those found in the environment in which they live. Monitoring of such plants and animals (e.g. certain fish species) can thus be a very convenient and sensitive way of following changes in environmental contamination.

In addition to the benefits which have been mentioned above, monitoring can also help to identify research problems in food contamination and related areas, e.g. the need for special studies to show how certain contaminants pass through food chains.

## CHAPTER 2. PLANNING AND IMPLEMENTATION OF NATIONAL FOOD CONTAMINATION MONITORING PROGRAMMES

### 2.1 Planning

#### 2.1.1 Major policy decisions

The results which can be obtained by food contamination monitoring may be of importance to many different government departments, especially those concerned with health, agriculture and fisheries, environmental protection, trade, industry (especially the food industry and any industries which are major contributors to food contamination) and, not least, the national economy. Central government decides the overall policy and allotment of resources to the whole area of food safety, food control and food and agriculture resource management.

Allotment of overall responsibility for food contamination monitoring to a single primary agency

In a country which is starting monitoring or expanding a relatively small monitoring programme, it is advisable to allot responsibility for the overall planning and implementation of monitoring to a single primary agency (e.g. the health or agriculture and fisheries authorities, national food administration or environmental protection agency). This agency could also be responsible for collecting and evaluating the results and, where appropriate, proposing action to prevent or reduce food contamination. In its work this agency should enlist the cooperation of other relevant governmental agencies and non-governmental bodies. The same principle (i.e. allotment of responsibility to a single

primary agency) could also be applied in countries in which extensive monitoring programmes are already in operation. In many such countries different aspects of food contamination monitoring may be the responsibility of one or more of the agencies responsible for health, food, agriculture and fisheries, environmental protection or light industry; this obviously increases the need for coordination.

Policy decisions concerning monitoring may be taken at different levels depending on how activities related to food safety and food control are organized. Many aspects of monitoring are so closely related to food control in general that if direction of the latter rests mainly with central government it is natural to take the major policy decisions on monitoring there. However, if responsibility for food control is largely delegated to state, county, district or municipal authorities, policy decisions may be taken by any of these authorities and the need for coordination in decision-making will thus be greater. Naturally, it is best if all those who have a major responsibility for or interest in monitoring are consulted before any major policy decisions are taken.

2.1.2 Working group to coordinate all monitoring activities, working parties with sectorial responsibility for monitoring

The primary agency with overall responsibility for monitoring should appoint a working group to coordinate the planning, implementation and evaluation of the food contamination monitoring programme. This may consist of government officials and, where appropriate, nongovernment scientists appointed on an ad hoc or permanent basis. The working group should preferably have a government official as its permanent secretary.

If only one or two monitoring projects are to be initiated, it may be most practicable to leave responsibility for their planning, implementation and evaluation in the hands of the working group. However, if a wide variety of projects are to be included in the monitoring programme it is recommended that separate working parties be set up, each with responsibility for a certain sector of the programme. The programme may be divided up in two ways:

(a) by contaminant group - this implies the setting up of separate working parties with responsibility for monitoring various foods and possibly also total diet samples for, for example:

(i) pesticide residues, PCBs, etc.;
(ii) heavy metals;
(iii) biological agents and bacterial toxins;
(iv) mycotoxins;

(b) by food commodity group - this could be done by appointing separate working parties with responsibility for monitoring all relevant contaminants in, for example:

(i) fish and other edible aquatic organisms and produce thereof;
(ii) plant products - cereals, fruit, vegetables, etc.;
(iii) animal products other than (i), i.e. meat, poultry, eggs, milk, etc.

Each of the above approaches has its advantages and disadvantages vis-a-vis the other. In general, the major difference is that when approach (a) is used the working party needs analytical expertise in only a limited area and experts with a knowledge of the production, processing, marketing, etc. of a very wide range of food commodities. On the other hand if approach (b) is used persons with expert knowledge of a wide range of analytical methods must be included in the working party but the need for experts with knowledge of different food commodities is smaller. In order to estimate the total intake via food of a contaminant occurring in a wide range of foods, it will be necessary to collate the results from the different working parties. In general, the approach chosen will largely be governed by the potential problem areas to be covered, the facilities available, on-going activities (if any) and the existing organization of food control activities in the country.

Regardless of which approach is taken, it is essential to make the best possible use of the available expertise when planning the monitoring programme. Thus a working party with responsibility for pesticide residue monitoring should preferably contain persons with a good knowledge of:

(a) the use of pesticides in agriculture, horticulture, silviculture and, where relevant, vector control or other public health programmes. This should include knowledge of which pesticides are used, when they are applied, and in what quantities;

(b) fish life (inter alia food chains, mobility), fisheries and the processing and distribution of fish;

(c) environmental contamination (including water, soil, wild-life, etc.) by pesticides and metabolites and breakdown products thereof, including chemical and other operations which may lead to environmental contamination by chlorinated chemicals and their alteration products;

(d) sampling procedures appropriate to the foods to be studied. Representatives of those responsible for collecting the samples should take part in the planning of projects so that practical difficulties in sampling and the transport of samples to the analytical laboratory, etc. are not overlooked;

(e) methods used and facilities available for analysing pesticide residues in various foods;

(f) the consumption (preferably including data on both average consumption and individual intake) and the economic importance of various food commodities;

(g) pesticide toxicology, if the public health (toxicological) significance of the analytical data generated is to be assessed by the working party;

(h) administration, including budgeting.

### 2.1.3 Allocation of responsibility for sampling, analysis, data-handling, etc.

As has already been mentioned, monitoring should preferably form an integral part of any organized food control system. Thus monitoring should be fitted into the existing food control activities as far as possible, making special arrangements only when absolutely necessary. In some cases, for example in countries which already have in operation extensive programmes for monitoring all carcases at slaughterhouses for parasites, the only extra planning needed may be to adjust the systems for the collection, handling, and evaluation of the data to meet the needs of the monitoring programme. In other cases it may, in addition, be necessary to review existing methods of sampling and analysis.

The working party responsible for a particular monitoring project should allocate responsibility for detailed planning and implementation (including data-handling) of the work and appoint a person(s) to coordinate the whole project. This is especially important if the sampling and analysis are to be carried out by personnel from different administrative units and at many different places. A suggestion for the division of responsibility for planning and implementing food contamination monitoring programmes is presented in Appendix 5.

### 2.1.4 Background information

Regardless of how monitoring is to be organized and implemented, the following information should be collected, as appropriate and where available, when planning such programmes.

(a) Data from surveys or monitoring projects already in operation within the country or in other countries in which the contamination problems are known to be or likely to be similar.

(b) Epidemiological data on actual or potential health problems related to contaminated food, e.g. statistics on the occurrence of food intoxications and food-borne diseases or the frequency of disease carriers found in surveys of food-handling personnel.

(c) Epidemiological data on animal diseases, especially those transmissible to man.

(d) Information on food production and processing, food trade, marketing channels, etc. including any information on rejection of food presented for import or export.

(e) Information from nutrition surveys and food consumption surveys, especially any indicating the existence of vulnerable groups, e.g. malnourished groups and persons regularly consuming unusually large quantities of certain foods which are susceptible to contamination.

(f) Information on the use of pesticides in agriculture, horticulture, silviculture (forestry), vector eradication programmes, etc. and the use of drugs in animal husbandry.

(g) Information on the release of potential food contaminants into the environment (i.e. sources such as factories, mines, centres of population, natural release) or on the levels of contaminants found by monitoring water, soil, air, etc.

(h) Information on the resources available to carry out the work, i.e. finance, personnel, facilities and equipment for sampling, analysis, data processing, etc.

(i) Information from research programmes showing the passage of contaminants through food chains, infectious cycles, etc.

2.1.4.1 Data from nongovernmental sources

In some countries one of the most extensive forms of food contamination monitoring activity carried out are the internal quality control (quality assurance) programmes run by the food industry and trade. For example, many of the major food producing, processing and distributing enterprises run programmes to ensure that the raw materials they buy and the products they produce and/or market are both safe and in other ways acceptable to the consumer. Where necessary, national authorities should provide guidance concerning the establishment and implementation of internal quality control programmes and collate some of the results obtained with those obtained by the authorities themselves to give a better overall picture of the contamination situation.

2.1.5 Objectives and scope

Objectives

The objectives of the monitoring programmes may vary widely from country to country, depending, amongst other things, on the state of the country's development, the extent of the contamination problems and the resources available for monitoring. Countries with very limited resources available for the whole area of food control would be best advised to concentrate on a few projects which are of major public health and/or economic importance. Even nations with larger resources available should concentrate their efforts initially on a modest number of projects and evaluate the results carefully before extending them to a large number of contaminants and/or foods.

It is important to define the objectives of each project clearly and in detail from the very beginning, since they may affect the choice of sampling and analytical methods, etc. and thereby the need for personnel, facilities and equipment. The potential users of the data to be generated must be consulted when a project is being designed. If this is not done, the data may not be of the quality or quantity required and valuable resources will thus be wasted.

It is a good principle to insist that those wishing to start a monitoring project be required to state clearly its objectives and potential benefits and the resources required and that these be subjected to careful scrutiny before the project is approved. For example, the objectives of a project aimed at providing data for the estimation of the daily intake of lead via food may be (a) to ascertain whether the current intake of lead via food constitutes a threat to human health; (b) to find out whether lead levels in certain food are rising and (c) to detect geographical areas (e.g. near smelters, polluted waters) or food products (e.g. canned foods, shellfish) in which lead levels are elevated. The objectives of a project to monitor aflatoxins in nuts in a producer country might be (a) to ensure that no consignments of exported nuts are rejected when subjected to import control examination; (b) to identify areas where control measures should be improved and (c) to protect public health.

Scope

The scope of a monitoring programme will be determined by the resources available, the health and/or economic significance of the programme and by technical constraints, e.g. the absence of reliable analytical methods. For example, toxicologists may be interested in finding out if the levels of cadmium in the human diet constitute a potential health hazard for certain vulnerable groups, e.g. pregnant women, infants, or persons with non-average food habits. Ideally, such an assessment should be based on the analysis of a wide range of foods, coupled with detailed data on food intake. However, because resources are limited it may be necessary to estimate contaminant intake by analysing a limited number of staple foods and coupling the results to available food consumption data.

2.1.6 Priorities

The choice of foods and contaminants to be monitored will vary from country to country, and even from place to place within the same country, and may change with time as dietary habits change and some contamination sources are brought under control and other contamination problems arise or are detected.

The following factors are of importance when deciding priorities.

(a) The potential risk to human health posed by the contaminant. In assessing this, the severity of the possible adverse effects (e.g. neurotoxic, teratogenic, mutagenic and carcinogenic effects) must be taken into account, together with any information on current human exposure or intake and the population at risk.

(b) The frequency with which a food-contaminant combination is implicated in intoxications or food-borne diseases in man.

(c) The prevalence of certain diseases in food-producing animals.

(d) The feasibility of measuring the level of the contaminant in a reliable manner in an adequate number of samples.

(e) The importance of the food in the total diet; staple foods deserve special attention.

(f) The economic importance of the food concerned and the importance the importing/exporting country attaches to contaminant monitoring.

(g) The persistence, ubiquity and abundance of the agent in the environment, its resistance to degradation, the possible conversion to more toxic substances and accumulation in the food chain.

(h) The amount of the pollutant being discharged into the air, rivers, coastal waters, etc. by industry and/or from centres of population and the levels of contaminants found in environmental components other than food.

(i) The nature and amounts of pesticides and other chemicals used in agriculture, horticulture and silviculture (forestry) and of drugs used in animal husbandry.

(j) The hygienic conditions prevailing in connexion with the production, packaging, transport, distribution, storage and preparation of food.

### 2.1.7 Pilot studies

Before starting a large fully-operational monitoring project it is advisable to carry out a pilot study to ensure that most of the practical problems have been ironed out. While the pilot study is being carried out, planning for the fully operational phase can start. The latter may need to be modified in the light of the results of the pilot study. In a large monitoring project there must be several points at which the results can be reviewed and it should be understood that modifications may need to be made during the operation of the project if unforseen circumstances arise which make this desirable.

### 2.1.8 Evaluation of a monitoring project

Provision should be made when planning a monitoring project for an evaluation of the value of the results and the action taken thereon in relation to the resources expended. Data on the resources employed are relatively easy to obtain; the evaluation of the benefits may be more difficult, especially since many of them may be difficult to express in financial terms. However, it may be possible to express the benefits in terms of reductions of economic losses due to rejection of exported food, increases in the prices obtained on the world market for quality controlled food, or reductions in the numbers of new cases of specific food-borne diseases. Other benefits, such as preventing or decreasing the risk of disease due to the accumulation of specific contaminants or increasing the general public's confidence in the food control system are more difficult to express in concrete terms.

## 2.2 Implementation

### 2.2.1 Project descriptions

The body responsible for planning the monitoring programme should aim at producing a project description for each project, outlining the objectives and giving details of the procedures to be used for sampling and analysis and collection, handling and presentation of the results.

### 2.2.2 Sampling[a]

What, where and how to sample are some of the most difficult problems in monitoring and they deserve very careful attention when planning a programme. Unfortunately, although many countries now possess good facilities for analysis, in many of them relatively little attention is paid to the question of sampling. This often means that the analytical facilities are not being put to the best use. Unless well-tried and recommended sampling plans are to be used, it is advisable when planning a monitoring programme to enlist the help of experts in sampling methodology to provide guidance on both the statistical aspects

---

[a] For definitions and explanations of some of the terms used in this section, see Appendix 6.

of sampling and on solutions to the practical problems associated with taking samples in the field. Statistical expertise may in any case be needed to help with other aspects of the planning and implementation of monitoring projects, for example statistical treatment of the analytical results (see 2.2.4: Data-handling and presentation).

The point in the chain from production/harvesting to consumption at which the samples should be taken depends largely on the objectives of the project and on the nature of the contaminant. The number of samples taken and the way in which they are chosen affects the confidence which can be placed in the conclusions drawn from the results of the analysis. Other factors which must be borne in mind when considering methods of sampling include the homogeneity of the material being sampled, precautions required to prevent contamination during sampling, any constraints regarding the number of sample units which can be analysed and practical difficulties in obtaining the desired samples. In the present guidelines it is impossible to give details of sampling for all food/contaminant combinations. Instead, some of the more important general principles will be discussed and references given to sources of more detailed information.

2.2.2.1 What to sample

The choice of the type of food commodity to sample is intimately bound up with the objectives of the monitoring programme (see 2.1.5 and 2.1.6). In most cases the choice is obvious - the carcases of food-producing animals to be examined for parasites known to infect the species, fruit, vegetables to be analysed for pesticides to which they have been exposed during their growth or post-harvest, fish from water areas contaminated with mercury, PCBs, etc. However, in other cases it requires careful thought and a great deal of background information. For example, the results of monitoring contaminants in fish and shellfish can be used to detect possible hazards for the human consumer and they may also show trends in water contamination. When choosing the fish or shellfish species (i.e. the indicator food) to be monitored it is thus necessary to bear in mind, amongst other things, their mobility, their feeding habits, the nature of their life cycle and the extent to which they accumulate/metabolize/eliminate the contaminant concerned. In the case of a monitoring programme designed to show time-trends in the level of methylmercury in fish in a particular body of water, it is desirable to analyse samples of fish which are not only of the same species but also as similar as possible in respect to length/weight/age, etc.

2.2.2.2 At which point in the chain from production to consumption should the sample be taken?

The answer to the above question is usually provided directly by the objectives of the monitoring programme.

Close to harvesting/slaughter/production

When the objectives include determining the extent of contamination occurring during production, for example from the use of pesticides, from animal feeds or from the environment, the sample should be taken at or near production/harvest/slaughter to avoid the complications introduced by contamination during handling and distribution. However, it should be borne in mind that, in contrast to many other contaminants, the levels of some pesticides on fruit and vegetables usually decrease during processing and distribution.

One of the advantages of analysing samples taken close to production is that, since the origin of food and the source of contamination can often be identified, it should be possible to take rapid corrective action to prevent or reduce further contamination. For example, if the analysis of fruit or vegetables indicates unduly high levels of pesticides, feedback of this information to the producer and/or the pest control authorities can lead to corrective action to reduce such contamination. Similarly, the demonstration of antibiotic residues in raw milk received from a particular farm may indicate an improper use of a drug or a failure to observe the specified witholding-time, which again can lead to corrective action.

In the case of fish, shellfish, etc. which are being monitored to provide inter alia data reflecting contamination of a body of water, the geographical origin of the sample must be known fairly exactly if the exercise is to be of much value. When trying to determine the impact of water pollution emanating from a certain factory on levels of contaminants in aquatic organisms the relation of the sampling site to the source of pollution must obviously be recorded.

At points of entry (importation) and at the wholesale level

Many countries have introduced import control systems for food which often include obligatory examination as a condition of entry. It is thus logical and convenient to carry out monitoring at this stage. It is usually possible to identify the origin of the food at this stage, something which often becomes more difficult as one progresses along the distribution chain towards the consumer. As with monitoring of domestically-produced food close to the site of production/harvesting/slaughter, the detection of contamination problems should lead to a feedback of information and to corrective measures, in this case in the exporting country.

Wholesale markets provide a convenient source of samples, often enabling sampling of a large number of products from a wide area. A disadvantage compared to sampling at the site of production is that it may be more difficult to obtain exact information on the origin of the food sampled.

Sampling at the retail level

The results obtained from the analysis of samples taken at the retail level give an indication of the amount of a contaminant which has been introduced during production, processing and handling. Sampling at the retail level is widely used in regulatory programmes to check compliance and especially to reveal faults in food handling. Unfortunately, when samples are drawn at the retail level it is all too common that little attention is given to ensuring that they are representative or to establishing the size and identity of the lot from which they are drawn. Thus, although the analysis of such samples may be valuable in revealing contamination problems, extreme care must be exercised when attempting to estimate time-trends in contamination from them, unless an adequate number of samples has been analysed and it has been established that they are representative of the commodity concerned. For example, the analysis of samples of canned fruit juice taken at the retail level at the same time but originating from a number of different countries and different producers within those countries may show a very wide range of tin and lead levels. Unless adequate numbers of samples of each individual lot are analysed and the results recorded separately, monitoring of the same commodity at a later date may give results which could be interpreted as showing a change in contaminant levels, whereas in fact they may be essentially unchanged, the apparent difference being due to the fact that products of different origin have been sampled on the different occasions, or that the products have been stored at different temperatures or for longer periods.

A further disadvantage of using samples taken at the retail level is that there may be no way of showing if the contaminant has been introduced before, during or after processing. For example, in the case of canned fruit, lead may have been present in the food before canning or it may originate from the container and in the case of poultry products contamination with salmonellae may have occurred during production, at slaughter or during subsequent handling. Thus, although such studies may show that problems exist, and may to some extent protect the customer, since they do not usually in themselves indicate the source of contamination there must be a feedback of results and a correlation with monitoring at earlier stages in the production/distribution chain if they are to be of much value.

Sampling "as eaten"

Chemical contaminants. In studies aimed at estimating the total daily intake via food of specific chemical contaminants, e.g. mixed total diet studies, samples of individual foods are usually collected at the retail level (unless the foods are to a large extent home-grown) and prepared for consumption in a manner similar to that used in the home. In this case specific instructions regarding the composition of the diet or foods to be analysed and the procedure for preparation of the foods must be given (see below under 2.2.3.1: Preparation of sample units from field samples).

Microbiological contaminants. Examination of "as eaten" samples for microbiological contaminants can be of educational value since the variability in practices concerning food storage and preparation in the home greatly affects the microbiological safety of foods. However, it is difficult to obtain samples which can be said to be representative. Such investigations are best carried out either as research projects or as part of food control (if they concern foods served in restaurants, etc.) and not in monitoring programmes.

2.2.2.3 Different approaches to sampling depending on potential hazard

The way in which sampling is carried out in any particular situation depends, amongst other things, on the potential hazard posed by the food-contaminant combination, the number of sample units that are to be analysed (which depends in turn on the availability of analytical facilities, economic factors, etc.) and the objectives of the monitoring programme.

Examination of each individual food unit

Many established procedures for meat inspection include the examination of each carcase for certain parasites, e.g. cattle carcases for Cystericercus bovis and pigs for Trichinella spiralis. In this case the results of examination (assuming it is carried out properly) give a direct measure of the prevalence of the parasite in the slaughtered animals. This type of procedure, i.e. the examination of each individual unit of food (carcase) is only applicable if the method of analysis (examination) is essentially non-destructive. Moreover, for practical and economic reasons it is usually restricted to food-contaminant combinations considered to constitute a severe threat to human health.

Representative samples taken from each lot

If a food-contaminant combination is judged to constitute a potential acute risk to human health and there is a non-uniform distribution of the contaminant, it is frequently decided to subject samples from each lot of food to analysis before allowing the food to be imported or sold. For example, some countries insist that samples chosen according to a predetermined plan from each lot of certain types of meat, egg and milk products presented for importation be examined for the presence of salmonellae (or that each lot is accompanied by evidence that this has already been carried out in an approved manner and shown the lot to be acceptable). This type of sampling is usually associated with regulatory (compliance) programmes but is also used extensively in quality assurance programmes carried out within the food processing industry.

Representative samples taken from lots chosen according to a predetermined plan or at random

When very large quantities of food are involved and/or analytical resources are limited and the contaminant in question is not considered to constitute such a serious threat to health it is often decided to analyse samples taken from lots chosen according to some predetermined plan, or at random. When considering this type of sampling it is important to bear in mind the objectives of the monitoring project. If the project is essentially a control exercise, i.e. the immediate objective is to prevent food which is unfit for consumption being imported or sold, then it is logical to take samples preferentially from lots coming

from producers or processors which have a poor record as far as contamination is concerned or where contamination problems may be expected for various other reasons. On the other hand, if the object of the project is to get an overall picture of the level of a particular contaminant in a commodity then the samples should be drawn from lots chosen with regard to the amount of the commodity originating from various sources. The latter approach should be used when starting a project, unless there are good reasons to suspect that products originating from certain sources are likely to be especially contaminated or if the product is destined for especially sensitive groups, e.g. milk products for infants.

2.2.2.4 Obtaining a representative sample

For practical reasons, it is usually possible to analyse only a relatively small number of sample units[a] representing a very large quantity of food. The only exception to this is cases where it is both desirable and practical to carry out a non-destructive examination of each food unit (see above). In order to be able to draw reliable conclusions from the analytical results obtained, the sample should be as "representative" as possible, i.e. its condition should be as similar as possible to that of the lot from which it is drawn - ideally it should be neither more nor less contaminated than the lot as a whole.

Homogeneity

The more homogeneous the lot to be sampled is, the smaller will be the number of samples necessary to give a reliable picture of the degree of contamination. In some cases it is advantageous to divide a large lot prior to sampling into parts which are known to be more homogeneous within themselves, when this can effectively be done. This concept is called stratification.

Apart from variations in the homogeneity within a lot of food (see below), there may also be wide variations in the range of levels of contaminants in samples of the same food commodity collected in different areas. For example, if commercial sterile baby foods to be analysed for heavy metals are produced at a single factory and distributed throughout a country it makes little difference where the sample is taken geographically. On the other hand, if a food commodity is produced in a very large number of local units (farms, factories) there is a greater chance of finding large differences in contamination levels in samples of the same commodity taken from different areas. In the case of foods where contaminants are likely to be introduced after production, there can of course be wide variations in the level of contamination of the product when it reaches the consumer, even if it originates from the same lot produced in the same factory.

In general, the food supply is more homogeneous in developed countries, where food is often produced and/or processed and packed centrally and widely distributed. Similarly, if a large proportion of food is imported it is often distributed widely from the same points of entry and this gives increased geographical homogeneity. The situation in most of the developing countries is very different since much of the food is not prepacked for sale.

In processed foods manufactured on a large-scale any contaminants present are often fairly evenly distributed throughout each lot and it is not difficult to obtain a representative sample. On the other hand, in a consignment of peanuts the vast majority of the nuts may be free from aflatoxins and the remainder may contain very high levels of these mycotoxins. In this case it is difficult to obtain a representative sample.

Methods of eliminating bias

As has already been stated, the sample drawn from a lot should be no better and no worse than the lot as a whole. Thus the main objective in drawing a sample is to avoid bias.

---

[a] For explanation of terms see Appendix 6.

In this connexion it should be remembered that there are essential differences in objectives between monitoring and certain types of control activity, although the two may overlap. The objective of a control programme may be to ensure that no food containing certain extremely undesirable contaminants, e.g. salmonellae or aflatoxins, reaches the consumer, whereas the objective of a monitoring programme may be to establish the overall frequency or level of contamination. In the former case there is a natural tendency to bias sampling in favour of samples where there is reason to suspect contamination, e.g. parts of a peanut consignment which are obviously mouldy. This type of control activity is obviously of great importance in protecting public health and for food trade but care must be taken to ensure that the results of the analysis of such "suspect" (biased) samples are not interpreted as showing the level of contamination in the food commodity as a whole.

The very least that can be done to avoid bias when sampling is to draw samples from various parts of the lot. However, provided individual sample units can be identified (e.g. in the case of mass-produced prepackaged foods), the best way of choosing a collection of sample units is to use a table of random numbers. In principle, each unit in a lot is assigned a number from 1 to the total number of units in the lot. Random numbers in this range are then read off a table of random numbers[a] until the predetermined number of sample units has been identified. The sample units corresponding to these numbers are then withdrawn from the lot and submitted for analysis.

The principle of "stratification" of heterogeneous lots prior to sampling has already been explained (see p. 22). If it is known or suspected that a consignment is not of uniform quality, e.g. it contains products produced in different factories, on different occasions or packed on different machines, it is advisable to draw random samples from each stratum. This procedure is termed "stratified random sampling".

Another general principle which, if followed, increases the possibility of obtaining a representative sample is that it is better to draw a large number of small units from a lot than to take only a few large units.

Some practical considerations

In most cases the actual numbers of sample units drawn and the way in which they are taken are not "ideal" because of practical constraints imposed by limitations in resources. The number of sample units to be analysed is governed by the availability of resources for analysis and policy decisions concerning the proportion of these resources to be expended on each project or part thereof. A balance must be struck between carrying out in-depth studies using many samples from a few lots or commodities and studies in which a few samples from each of a large number of lots or commodities are analysed.

As has been stated above, a more representative sample of a lot can be obtained by taking a large number of small sample units, rather than a few large sample units. However, sampling itself may be "destructive" if it involves opening sterile or aseptically-filled packs, etc. If each package is large and contains a product which is expensive and/or in short supply such losses caused by sampling must be borne in mind.

2.2.2.5 Carrying out the sampling in the field

Sampling should preferably be carried out by trained personnel who have received detailed instructions regarding their task. Public health inspectors, agricultural or fisheries marketing inspectors, pest control inspectors, customs officials or even specially trained food sampling personnel, if available, are probably most suitable for the job. They must receive clear instructions on how to take the samples, the size of sample required, how to

---

[a] Such tables are to be found in textbooks of statistics and in "Microorganisms in Foods. Volume II. Sampling for Microbiological Analysis: Principles and Specific Applications". University of Toronto Press, 1974. The latter publication also contains detailed instructions on how to use the tables.

record its history and characteristics, how to treat and pack the sample prior to despatch to the analytical laboratory, etc. It is important to record the lot, consignment, etc. from which the samples are drawn. This may be done by referring to some common characteristic, e.g. production site/date, lot number, etc. A list showing some of the details which should be supplied by the person taking the sample is given in Appendix 7. This information should preferably be recorded on a standardized form.

It is convenient to take samples when a large number of individual units of food are readily accessible, for example when they are being moved along a production line, packed, loaded or unloaded at warehouses, ports, wholesale markets, etc. Samples should be drawn in such a way that neither the sample nor the lot from which it is taken becomes contaminated. Samples must be drawn, handled and transported to the analytical laboratory in such a way that their degree of contamination does not change, or at least that any changes are minimized. Depending on the food, the contaminant, the climate, the time required for transportation, etc. it may be necessary to send the sample in the frozen or chilled state. When prepackaged food in consumer packs is sampled it is usually most practicable to send the package unopened to the laboratory: in other cases appropriate containers must be made available to the person taking the samples. Containers or wrapping material should be checked before use for possible interference in the analytical method and at the limit of detection employed in the analysis. Close coordination between the sampling personnel and the analytical laboratories is essential to avoid spoilage of samples due to their arriving at the analytical laboratory when it is closed or in numbers that exceed cold storage capacity, etc. Samples for microbiological examination should preferably not be frozen or if they have been frozen the laboratory should be informed.

In general, the sample (field sample) drawn from a lot should be considerably larger than the sample unit which is to be analysed. This is important, since it may often be difficult or impossible to repeat the sampling if a mishap occurs with the sample unit being analysed or if the analytical results are such that it is thought desirable to repeat the analysis to obtain an unequivocal result. Standardized methods should be used for dividing samples.

Further information on sampling

The International Commission on Microbiological Specifications for Foods (ICMSF) of the International Association of Microbiological Societies has done much valuable work in the field of sampling of foods for microbiological analysis. Amongst other things, ICMSF has produced a handbook entitled "Microorganisms in Foods. Volume II: Sampling for microbiological analysis: principles and specific applications" (University of Toronto Press, 1974). All concerned with the sampling of foods for microbiological analysis are advised to consult this reference work. In addition to explaining the principles behind various types of sampling plan, it contains specific proposals for sampling and sampling plans for most of the important types of foods which are analysed for microbiological contaminants.[a] Although this book is specifically directed towards sampling for microbiological analysis, many of the principles given in it are also applicable to sampling for chemical analysis.

Appendix 8 contains a list of publications containing further information on sampling, including International Organization for Standardization (ISO) international standards and draft standards for sampling, ICMSF methods for sampling of various foodstuffs for microbiological analysis, methods of sampling peanuts for aflatoxin analysis and Codex Alimentarius Committee on Methods of Analysis and Sampling publications on sampling of prepackaged foods.

---

[a] Fish and fishery products, vegetables, dried foods, frozen foods, milk and milk products, raw and processed meats, shelf-staple canned foods, fresh or frozen raw shellfish.

2.2.2.6 Establishment of "Food Sample Banks" for food contamination monitoring purposes

As already mentioned, one of the objectives of food contamination monitoring is to detect time-trends in the levels of contaminants in various foods or in the diet as a whole. Long-term trends in contamination are best studied by periodic analysis of total diets or staple foods or confined to those foods where control measures have been introduced. Many chemical contaminants (e.g. DDT, PCBs and heavy metals) have very long half-lives in the environment and there is little point in monitoring for them at short intervals, if the object is to follow time-trends. The existence of "food sample banks" containing samples of staple foods or of mixed total diets collected over a long period of time would provide samples to enable time-trends in the levels of certain contaminants to be measured at future dates. In addition, countries which do not at present have the facilities to accurately measure low levels of some important contaminants may find it valuable to store samples until such facilities become available. In some countries, samples of grain and seeds are already stored at plant breeding centres.

"Food Sample Banks" should consist of adequately labelled samples of staple foods or mixed total diets taken at various times and stored in a manner which prevents or minimizes deterioration of both the food and the contaminant. In general, whole raw agricultural/fisheries products of major dietary importance, and/or which can be used as indicators of contamination should be stored. The containers used for storage should not themselves add contaminants to the stored samples. Not all foods will be suitable for storage and some contaminants are so unstable that there will be little point in analysing stored food for them. However, by drying, freeze-drying, deep freezing or other physical forms of preservation suitable samples of many foods may be prepared for storage. It is important to record the method used to prepare the samples for storage, since some techniques may reduce the levels of volatile or unstable contaminants.

2.2.3 Analysis

2.2.3.1 Preparing sample units from field samples

The field sample is the material drawn from a lot of food and sent to the laboratory for analysis: the sample unit is the food that is actually used in the analysis. As already mentioned, the field sample should consist of more food than is required for the analysis.

The sample unit should consist of a representative subsample of the whole field sample, or of that portion of the field sample which is to be analysed, as it is received by the laboratory or after appropriate treatment. Care must be taken when drawing the sample unit to avoid contaminating the food being sampled. For example, aseptic technique should be used when preparing sample units for microbiological analysis and contact with metallic equipment and utensils should be avoided when preparing sample units for analysis for metals.

Methods of preparing sample units depend on the nature of the food and the contaminant and the objectives of the monitoring project

Sample units for analysis should be prepared in a manner which is relevant to the food and contaminant concerned and to the objectives of the monitoring project. The way in which sample units of individual foods are prepared depends to some extent on national or local customs concerning food preparation. When planning a monitoring project a standardized method or methods for each of the food-contaminant combinations to be analysed should be agreed upon and the method used should be reported together with the analytical results. It is meaningless to report levels of pesticides in oranges or bananas without stating whether the levels refer to the peeled or unpeeled fruit. Likewise, it is insufficient to report lead levels in potatoes without indicating if they have been washed, peeled, cooked, etc. or not before analysis. Similarly, levels of contaminants in fish should relate to specified edible portion(s) of the fish concerned.

Sample units for chemical analysis

(a) Regulatory (compliance) projects

If the main objective is to check that the food commodity complies with an established standard or guideline then the way in which the regulations are framed will dictate how the sample unit is to be prepared. For example, if the tolerance for a certain pesticide in or on oranges refers to the fruit as sold, the sample unit should be prepared by taking a subsample of the field sample of the whole fruit. On the other hand, if the tolerance refers to the edible portion of fish or to fish muscle then the sample unit should be prepared by taking a subsample of the appropriate portion of the field sample of fish.

(b) Projects aimed at showing time-trends in contaminant levels in specific commodities

When the main object of the monitoring project is to obtain information on time-trends in contaminant levels in a particular commodity, it is important that the preparation of the sample units is the same on different occasions. In general, the sample unit should consist of a subsample of the whole of the raw field sample. However, when parts of the commodity are generally agreed to be inedible, sample units may be prepared from the raw edible portion only. In some special cases it may be worth while analysing sample units prepared from portions of a commodity which are rarely consumed and/or which constitute only a small part of the weight of the commodity. An example of this is the liver of certain fish which, because of its high fat content, may contain several hundred times higher concentrations of PCBs, DDT, etc. than the muscle of the same fish and thus be a more sensitive indicator of contamination trends.

(c) Projects aimed at estimating the intake of a contaminant via food

When the main objective of the project is to obtain data to enable the human intake of the contaminant via food to be estimated, it is logical to analyse sample units which are subsamples of the field samples prepared "as eaten". This presents considerable problems, since there can be wide variations in the levels of certain contaminants (especially those concentrated on the surface) in foods depending on whether they are analysed washed or unwashed, with or without outer leaves or peel, raw or cooked, etc. Even within the same country, there can be wide differences in the ways in which food is prepared for eating, depending on ethnic, tribal or religious customs, etc. Some methods of preparing sample units in mixed total diet studies - used to provide data to enable the intake of contaminants via food to be estimated - are given below. Appendix 9 contains a few practical examples of the problems to be faced when preparing a sample unit from a field sample. In general, if there is any doubt about whether or not consumers usually wash or peel a commodity, reject inferior parts of it, etc., the "worst case" principle should be followed, i.e. the sample unit should be prepared from the whole field sample in such a way that the maximum degree of contamination of the food as eaten likely to be encountered in practice is measured.

Sample units for microbiological analysis

Guidelines for preparing sample units for microbiological analysis are given in the ICMSF handbook "Microorganisms in foods, Volume I. Their significance and methods of enumeration", Second edition, (University of Toronto Press, 1978), to which the reader is referred.

Obtaining a representative sample unit

In general, in order to obtain a representative subsample of the field sample, it is advisable to make the latter as homogeneous as possible before withdrawing the sample units by thorough mixing, by agitating the container before opening it, (liquids, suspensions, free-flowing powders) or by comminuting and/or homogenizing the sample, using appropriate vehicles where necessary. Directions for preparing and diluting food homogenates for microbiological analysis are given in the above-mentioned ICMSF handbook.

The reserve portion of the field sample should be stored under appropriate conditions in case replicate analyses are required.

Total diet studies

Various attempts, based on somewhat different approaches, have been made to estimate the total daily or weekly intake via food of certain chemical contaminants (e.g. lead, mercury, DDT). One such approach involves the analysis of so-called "total diet" samples.

Using food intake data[13] obtained for example from food balance sheets ("food disappearance" data) or household food consumption surveys, the average diet for the whole or a particular age-group in the population in a country or an area of a country can be estimated. In Australia, Canada and the United States of America it has been assumed that the person having the highest energy intake is also likely to have the largest intake of contaminants. Accordingly, in the United States of America, estimates of the total intake via food of contaminants[14] are based on the analysis of total diet samples representing the two-week diet of a 16-19-year-old male. In the United Kingdom the total diet samples analysed reflect the food intake of a person consuming a "typical" diet.[15]

Samples of the foods constituting the chosen total diet are then purchased at the retail level in the specified town or area under investigation and prepared for eating in a manner representative of that used in the home. In practice, it is necessary to limit the number of foods included and emphasis is placed on major foods and on items which are thought likely to be contaminated. If the diet for a two-week period is to be analysed, this means that the same raw foods may have to be prepared for eating in several different ways, e.g. vegetables, meat and fish may be boiled, fried or prepared in other ways. Thus, when so carried out, total diet studies should reflect local differences in food consumption and preparation habits. The prepared foods are then combined into groups (e.g. fats, fish, root vegetables, green vegetables) to facilitate analysis and to enable food groups in which the contaminant may be concentrated to be revealed.

When studies are carried out on groups of the population with fairly homogeneous food consumption and preparation patterns, the intake of contaminants may be estimated by analysing duplicate samples of the meals prepared ready for eating. This type of approach is usually of only limited value at the national level but may be used in cases where institutional catering provides a major part of the diet.

Initiating a mixed total diet ("market basket") study to estimate the intake of a specific contaminant via food requires very large resources. Therefore, it is recommended that, in the first instance, estimates of contaminant intake be made by analysing staple foods and correlating the results with the best available data on food intake. In some countries the results of the analysis of individual foods have been correlated with food intake data for up to 80 different groups within the population, e.g. infants, schoolchildren of different ages, etc.

2.2.3.2 Methods of analysis

The analysis (examination) of sample units is the most important part of any monitoring programme. For this reason, it is essential that adequate facilities be provided and that the work is carried out conscientiously by well-trained personnel under adequate supervision. It should be emphasized that it is the skill of the analyst, and not only the method used, which in the end determines the confidence which can be placed in the results. Assistants carrying out the analysis should be provided with clear, preferably written, instructions.

The methods used should have a sensitivity which is adequate for the objectives of the monitoring programme and be as rapid, simple and cheap as is consistent with the achievement of reliable results. In many cases, and especially in countries with very limited analytical resources, it is advisable to use simple, cheap and rapid methods to detect relatively high levels of contaminants in a large number of samples, rather than to use more complicated,

and sensitive methods and analyse fewer samples. An example of this is the analysis of peanut consignments for aflatoxins - it is better to use a rapid screening method, capable of demonstrating the presence of ca 10 µg of aflatoxins per kg, and examine a large number of samples than to use methods which have a greater sensitivity but are much slower and more expensive.

Analytical methodology is undergoing constant development - methods based on completely new techniques are being elaborated and improvements to existing methods are being made. For this reason, in these guidelines, instead of giving details of analytical methods, which may soon be superseded, reference will be made to some currently recommended methods of analysis for contaminants of major concern and details of sources of information on analytical methodology will be given. Those responsible at the national level for the analysis of food for contaminants should attempt to keep abreast of developments within the field and introduce improved methods if and when practicable. Before new methods are introduced or existing methods modified, studies should be carried out in the individual laboratory to confirm the accuracy, limit of detection, repeatability, reproducibility and specificity of the method in the hands of the analyst responsible. Even when well-established methods are used routinely, quality control is still essential.

Quality Control

The objective of a quality control programme is to achieve precise and accurate results at all times. Analysis of the same food sample in different laboratories within a country should, of course, give essentially the same results, especially if results from different laboratories are to be combined in contamination monitoring studies. This can best be achieved by:

(a) where possible, using the same methods of analysis throughout the country. If this is not possible, for example because certain expensive items of equipment are available at only one or two laboratories, the different methods used must be checked against each other;

(b) providing adequate instruction for the personnel carrying out the analysis. This should take the form of detailed written information on how to carry out the analysis and also courses of practical instruction in the relevant techniques;

(c) organizing inter-laboratory collaborative studies in which check samples are sent out from a central laboratory organizing the study and the results obtained collected, collated and evaluated;

(d) restricting analysis to (approved) laboratories which have adequate equipment and well-trained personnel and have produced satisfactory results in collaborative studies; and

(e) periodic inspection of approved laboratories to ensure that operating standards are maintained and periodic refresher courses for the supervisory analysts.

Many countries already use analytical methods which have been tested in collaborative studies and which are recommended by one or more international bodies (in some cases general methods have been slightly modified at the national level when they are used for specific foods). Other countries wishing to start analysing foods for various contaminants are strongly advised to choose such internationally-recommended methods.

A list of some[a] of the major organizations concerned with the development, testing and/or evaluation of methods of analysis for contaminants in food and information on how to contact them is given in Appendix 10. The organizations are not listed in any particular order of importance.

---

[a] A more complete list is to be found in a paper (CX/MAS 75/9) prepared for the Ninth Session of the Codex Committee on Methods of Analysis and Sampling, Budapest, 27-31 October 1975.

Chemical contaminants

Methods of analysing various foods for certain chemical contaminants of major importance have recently been reviewed by inter alia The Codex Committee on Pesticide Residues (CCPR),[16] the Codex Committee on Methods of Analysis and Sampling (CCMAS),[17] two Joint FAO/WHO Expert Consultations[18,19] on sampling and analytical methodology, by Schuller & Egan[20] and by Schuller.[21] The methods of analysis recommended here are mainly based on the recommendations made by these reviewing bodies. Recommendations on methods of analysis for lead, cadmium, mercury and arsenic are given in Appendix 11, those for pesticide residues and PCBs in Appendix 12 and those for aflatoxins in Appendix 13 of these guidelines.

Biological contaminants

The standardization of methods of analysis (examination) for biological contaminants is under rapid development, both as regards pathogens, such as Salmonella, and indicator and spoilage organisms. Methods of analysing various foods for important biological contaminants have recently been dealt with by three Joint FAO/WHO Expert Consultations[18,22,23] a WHO Study Group[24] and a WHO Expert Committee.[1] The two Joint FAO/WHO Expert Consultations on Microbiological Specifications for Foods have made specific recommendations for a number of foods and contaminants, including sampling plans, methods of examination and microbiological limits. A recent review of the current position as regards methodology by Christian is presented as Appendix 24.

Parasites

Food-borne parasites may be divided into two categories:

(a) Parasites that are present in the tissues of food animals, where they may or may not undergo cyclic development, and that persist in the food, e.g. meat, fish, shellfish, in a form that is infective to man; and

(b) Parasites that are derived from the environment (soil or water), from animals, or from food handlers, the infective stages of which are transmitted in food.

Parasites in the first category, the infective stages of which are found in food animals, call for methods of detection in the living animal or in certain of its tissues after slaughter. With larger food animals and their meat every animal should be examined in organized meat inspection programmes. For practical purposes, with smaller food animals, especially fish and other aquatic animals, only randomly selected samples are usually examined for those infections that may survive subsequent processing.

Monitoring of food for parasitic infections derived from the environment (soil, water) and food handlers is usually indirect and takes the form of monitoring sources. Such monitoring should be limited to infectious organisms likely to survive subsequent processing, as complete monitoring is likely to prove expensive in relation to the results achieved. Procedures for examining soil, water, etc. for parasites are described in common textbooks of parasitology. In some cases (e.g. tapeworm segments and the metacercariae of Fasciola) the parasites are visible to the naked eye and their identity can be confirmed by microscopy.

A list of methods of sampling and examination of food and food animals for food-borne parasitic infections is given in Appendix 14.

Bacteria

Methods of examining foods for the presence of bacterial contaminants are listed in Appendix 15. Methods are listed for important pathogens such as Salmonella, and also for spoilage and indicator organisms such as coliforms. However, it should be emphasized that not all bacterial contamination problems are susceptible to monitoring (see p. 10).

Viruses

At present there are no physical or chemical tests capable of detecting minute amounts of viral constituents (protein, nucleic acid, lipids) against a background of similar compounds in the food itself and serological procedures are generally not sensitive enough for the direct detection of viral antigens in foodstuffs. It is therefore essential to isolate viruses in living host systems, such as laboratory animals, chick embryos or tissue cultures. Although general schemes for the examination of food samples for viruses have been published,[24] standardized methods for the examination of food samples for specific viruses cannot be given in the present guidelines. However, information on viruses in food, including methods of examining foods for viruses, is being collected in the WHO Food Virology Programme. Further details are available from the Food Hygienist, Veterinary Public Health, World Health Organization, CH-1211 Geneva 27, Switzerland.

Yeast and moulds

The analysis of food for aflatoxins is dealt with under the section on chemical contaminants.

Standardized methods for the enumeration of yeasts and moulds have been published by the ICMSF (Microorganisms in foods: their significance and methods of enumeration, Second edition, University of Toronto Press, 1978). In addition, the AOAC has published a method for the enumeration of fungi in eggs and egg products (Official Methods of Analysis of the AOAC, Twelfth edition, 1975, 46.011).

2.2.3.3 Presentation of results

The results of the analysis (examination) of foods for chemical and biological contaminants should be reported in a standardized manner: this can be facilitated by preparing standard forms for reporting results and issuing clear instructions for their completion. The report should contain the following information:

Identification of the sample. The report should contain all details necessary for complete identification of the sample. In many cases this requirement can conveniently be met by attaching the information supplied on a standardized form by the person who has taken the sample (see p.21 and Appendix 7). If this is not done, then at least the basic information on the nature and origin of the sample, the nature of the container, any identification marks, the date and place of sampling and the name of the person submitting the sample should be recorded. As has already been pointed out, samples for monitoring purposes should be representative. If for any reason the sample is not representative, i.e. is a "suspect" sample, this must be clearly indicated.

Analysis, etc. The way in which the sample unit for analysis has been prepared from the field sample (i.e. portion of sample analysed and sample preparation) should be recorded. The analytical method used should be reported either in detail or, if a standardized published method is used, by giving a reference to the relevant publication (e.g. AOAC, ISO, ICMSF, the United States FDA's Pesticide Analytical Manual, etc.).

The date and place of analysis should be recorded, together with the name of the supervising analyst.

Levels of contaminants. The concentrations of chemical contaminants should be expressed as micrograms or milligrams per kilogram (μg/kg) wet weight or dry weight of the food. In the case of certain pesticides which accumulate in fat, it may be appropriate to express the results on a fat basis. The levels of contaminants which are chemically closely related (e.g. DDT and its metabolites, aflatoxins $B_1$, $B_2$, $G_1$, $G_2$, PCBs) may be expressed in terms of the individual compounds or as the sum of the related compounds. For recommendations on how to express the results of analysis for PCBs see Appendix 12.

In the case of biological contaminants, the method of reporting the results varies with the organism involved, the type of analysis and the food. In some cases, it is sufficient to report that the organism has been detected/not been detected in a carcass or a certain weight of food when examined by the method specified. In other cases, the number of organisms found in a certain quantity of food under the conditions of test should be reported (see below). In order to obtain reliable data on the incidence of contamination, with for example parasites, it is important that the total number of carcasses, etc. examined be reported together with the number of positive/negative findings.

When more than one enrichment and/or selective medium is used in an analysis for bacterial contaminants (e.g. in the ISO-method for the detection of salmonellae in meat and meat products, ISO 3565-1975) the media from which the organisms were detected should be reported. If the strains of organisms, such as salmonellae, have been identified, the name of the centre which has helped with the identification should be recorded.

The international standards issued by ISO specify how the results of the examination are to be reported. For example, the result of an aerobic count at 30°C on meat or meat products (see ISO 2293-1976) should be expressed as a number between 1.0 and 9.9 multiplied by the appropriate power of 10 (for example an average count of 15 000 per gram would be reported as $1.5 \times 10^4$ per gram). This method of expressing quantitative results of microbiological analysis is to be recommended.

Statistical parameters

When many similar samples of the same commodity are analysed for the same contaminant the results should be presented in summary form. The statistical parameters which should be applied vary somewhat according to the food and the nature of the contaminant. Which measure of dispersion is appropriate depends on the form of statistical distribution of the results - the standard deviation, variance and standard error of the mean become less appropriate as the distribution deviates from "normal".

In general, the statistical parameters that are of greatest interest are the following: number of samples analysed, median or arithmetical mean; 90th percentile; overall range; and number or percentage of samples in a number (up to 10) of defined ranges of contamination.

Other parameters which may be valuable in some cases are: standard deviation; standard error of the mean; and geometric mean.

The term "not detectable" has little meaning unless the detection limit is specified. When calculating mean levels of environmental chemical contaminants, it should be assumed that samples in which the contaminant could not be detected contain a level corresponding to half the limit of detection, and not zero.

2.2.4 Data handling and presentation

The system for handling and presenting data from a national monitoring programme should be designed to fulfil two main functions:

(a) to collect, appraise, process, store and retrieve data generated in the monitoring programme and present it to the user(s) in an appropriate manner; and

(b) to facilitate the management of the programme by providing a means of following progress in its implementation;

The way in which the data is handled depends on its nature and volume and on the resources (trained personnel, hardware[a] and software for electronic data processing, etc.) available.

[a] Hardware refers to the computer facility and related equipment. Software means the programmes and instructions necessary to operate or use the computer.

Countries starting monitoring or having relatively small programmes should concentrate initially on establishing efficient manual systems. Only when considerable experience has been gained with such systems and the volume of data becomes so large that it is cumbersome to handle manually should computer-based systems be considered.

Detailed data on sampling and analysis should be stored at the place where the analysis/examination is carried out. When several laboratories are taking part in the same project, the data should be collected, appraised, processed and stored at a single centre (hereafter called the "Project Data Handling Centre"). Within a national food contamination monitoring programme there may be several such centres, each with responsibility for one more project (see 2.1.3 and Appendix 5). The centre should present the data in the manner requested by the user(s).

The data generated in monitoring may be classified into two types - that calling for immediate action to protect human health and other data.

(a) Data indicating a need for immediate action

Although monitoring is not primarily designed to protect human health from acute intoxications and infections, the results obtained may sometimes call for immediate action. Such data should be handled independently of the routine data collecting system. Two approaches may be adopted:

(i) all results can be transmitted rapidly to a national centre where they are screened and any alarming levels of contaminants recognized and appropriate action taken; or

(ii) high levels of contaminants indicating a need for immediate action can be recognized at the place where the food is analysed/examined and the appropriate authority responsible for instituting preventative and corrective measures be alerted quickly from there, for example by telephone or telex. In such cases the amount of data to be transmitted rapidly will usually be quite small, the vast bulk of the data being submitted to the data handling centre at a slower rate. In order to make this approach workable, the laboratories carrying out food analysis/examination must be given guidelines showing the threshold of contamination above which immediate action is warranted (in the case of certain biological contaminants, e.g. Salmonella in baby food, any positive findings may warrant immediate action).

(b) Other data

A suggested overall system for handling the remainder of the data in a national monitoring programme is outlined below and also presented schematically in Appendix 16.

When designing a system for the handling and presentation of data in a programme the principal needs for and uses of conceivable outputs should first be identified. In other words, the users or potential users of the data should be asked to state as clearly as possible which data they require and the form in which they would like them to be presented. When these user needs have been identified, the system output requirements can be developed. This in turn leads to the development of system input requirements and the processing steps necessary to produce the requested outputs.

Collection and handling of data on sampling and analysis

The person taking the sample in the field should fill in the sampling data on a standard form according to written instructions supplied by the programme management. If electronic data processing systems are being used or are contemplated, the form should be designed with

this in mind. The completed form should then be sent together with the sample to the analytical laboratory. A copy of the completed form is retained at the sampling site and, if required by the project management to enable the progress of a project to be followed (see below), a copy is sent direct to the Project Data Handling Centre.

The person carrying out the analysis/examination of the food fills in the results on a standardized form, following written instructions issued by the project management. Simple statistical treatment of the results (sums, means, measures of dispersion) may also be carried out at this stage.

These data, i.e. sampling and analysis data including any simple statistical parameters, are then forwarded from the various individual laboratories to the Project Data Handling Centre. At the Centre, the data are first checked to see that they are complete and that they meet the agreed criteria as regards sampling and analysis. Results relating to "suspect" (i.e. non-representative) samples should on no account be combined with results relating to representative samples. If such results are combined, this may give a false picture of the contamination situation. For example, if there is a problem with mercury contamination of fish due to industrial pollution of inland or coastal waters it is logical to make an effort to define the size of the problem by taking a relatively large number of samples of fish from polluted waters and few from waters which are not or are unlikely to be polluted. However, fish from polluted waters may constitute only a small fraction of the total consumed. If a large number of results relating to fish (showing high mercury levels) from polluted waters are combined with the few results relating to fish from unpolluted waters and the mean level of contamination is calculated, this will give a false picture of the level of mercury in the fish supply as a whole.

If results from different laboratories are to be combined, a careful check must be carried out to ensure that the same portion of the food in question has been analysed and that the methods of preparation prior to analysis are the same. Furthermore, it must be established (by the use of check samples, etc.) that analysis of the same sample in the different laboratories gives essentially the same results; this is especially important when different methods of analysis are used. Before data received from different sources is further processed, any statistical analyses which have been performed should be checked.

The data which satisfy the agreed criteria are then entered into the central data file(s).

The data outputs from the Project Data Handling Centre will be of essentially two types:

(a) Standard summaries of the findings, including some basic descriptive statistics (such as sums, means and measures of dispersion) with several different forms of summarization, e.g. by sampling location, by lot (when several samples are taken from the same lot), by laboratory. In general, the preparation of such summaries involves the use of relatively simple statistical manipulations and, if a computer is used, standard programmes. Such summaries should also meet the needs of the programme management for following progress in the implementation of various projects.

(b) Specially tailored compilations of data necessitating a more complete or more sophisticated statistical analysis of the data than that carried out to produce standard summaries will be required in some cases. In addition to analysis of the data generated within the programme, there may be a need to associate the data with that from other sources, e.g. data on the production or consumption of the food, levels of contaminants in other media, outbreaks of food-borne disease, epidemiology of certain animal diseases, climatic conditions, etc. This latter data may also be stored in the central data file(s).

The type of statistical work envisaged here should be carried out under the supervision of an expert statistician. If a computer is available, many of the operations can be carried out using available statistical packages, in other cases special programming will be required.

The need for standardized terminology

The data to be collected will probably vary from project to project depending on the nature of the food commodity, the contaminant studied, the way in which the commodity is produced, processed and distributed, etc. However, certain basic information will probably be required in each project, e.g. sample identification, project identification, location of sampling, contaminant identification and level, method of analysis/examination, product identification (including container type, physical condition of product, preservation technique, etc.), etc. It is important that standardized nomenclature is used where possible and that classification, nomenclature, coding, etc. be agreed upon at an early stage in the project before large amounts of data have been collected. Before deciding on a system of nomenclature the existing systems of nomenclature for food commodities, contaminants, etc. should be examined for suitability. In this connexion, FAO has already developed classification and nomenclature systems for some foods as part of the FAO Interlinked Computer Storage and Processing System of Food and Agricultural Data.[25] A more detailed classification which could be used for pesticide residue data has been prepared by Duggan[16] for the Codex Committee on Pesticide Residues.

Storage and retrieval

Data from the monitoring system should be stored in a readily accessible fashion. When the volume of data is small this can be achieved using card-index and similar filing systems, when the volume becomes larger it may be worth while microfilming the data to reduce its bulk for storage and when very large volumes are involved some kind of computer storage will be required. Interpretation of the data stored in the central file may require detailed information on the nature of the sampling plans and the methods of analysis used. Such detailed information should be stored in hard copy form at the Project Data Handling Centre. When summaries or compilations of data are issued, references should be given to the source of detailed information on sampling and analysis.

Publication

Many countries carrying out food contamination monitoring have adopted the practice of publishing their results in the open literature or in the form of official reports.[a] It is to be hoped that other countries will follow their example since, in addition to providing information on the levels of contaminants in food, these reports often provide valuable information on the organization and implementation of monitoring programmes.

Use of computers

A review of all the various options available for computer handling of monitoring data is outside the scope of these guidelines. However, some general considerations concerning the use of computers in this connexion are given in Appendix 17. In practice the facilities available for computer processing and the feasibility of using remote terminals, etc. will usually dictate how the data handling system can be designed.

Progress reporting to improve project management

When several independent organizations are involved in carrying out sampling and analysis, it is important that those responsible for managing the project are able to keep track of its progress. This can be achieved by requiring progress reports at various stages. For example, when sampling has been completed, the person who has taken the samples sends a copy of the sampling data (which accompanies the samples to the analytical laboratory) to the project manager or to the Project Data Handling Centre. The management can then check that the project is being carried out as planned and on schedule, detect and rectify mistakes and omissions at an early stage and modify the project where necessary to ensure its smooth running. The way in which the data is transmitted will depend on the way in which the rest of the data handling system is constructed, e.g. hard copies by post or data via telephone lines from remote terminals to the Project Data Handling Centre.

[a] See, for example, reports in Pesticides Monitoring Journal, Residue Reviews and the Journal of the Association of Official Analytical Chemists and the reports of the United Kingdom Working Party on the Monitoring of Foodstuffs for Heavy Metals (HMSO, London).

# CHAPTER 3. USE OF DATA AT THE NATIONAL LEVEL

## 3.1 Preventing contaminated food from reaching the consumer

Monitoring will sometimes reveal the presence of contaminants at such levels that they clearly constitute an acute or long-term hazard to human health. Examples of contaminants producing acute health effects are salmonellae and tin (high concentrations). The heavy metals lead, cadmium and mercury and PCBs and aflatoxins and various food-borne parasites may constitute health hazards in the long term. Whenever such health hazards are revealed, the analytical laboratory must report its findings to the appropriate authority immediately so that action can be taken to prevent the food reaching the consumer or being eaten. In some cases (e.g. some types of import control, slaughterhouse meat inspection, some forms of production control) this will be fairly easy because the food is not released for sale until the results of the analysis/examination are known. However, in other cases the food may already be on sale to the public before the analysis results are known. An effective system should be developed to stop the sale of contaminated food, remove it from the distribution channels and, when necessary, warn the public. If it is thought that the contaminated products might also be on sale in other countries these should be alerted to the risk.

## 3.2 Estimating the intake of contaminants via food

Certain contaminants (e.g. lead, cadmium, PCBs) accumulate in the human body and may produce ill health first after a long latent period when the concentrations in certain tissues reach critical levels. However, the ingestion of such substances with food rarely gives rise to acute health effects. An estimate of the total daily (or weekly) intake of such a contaminant via food, together with data on the intake from other sources, is valuable when trying to assess if current levels of food contamination constitute a long-term threat to health. The estimated intake of the contaminants should be compared with the intake which international (e.g. the Joint FAO/WHO Expert Committee on Food Additives[26] or Joint Meetings on Pesticide Residues[27]) or national expert bodies consider tolerable or acceptable. It should be borne in mind that, as far as possible, the levels of contaminants in food should be kept so low that the food can safely be consumed by all sections of the populat on. This implies that it is not sufficient to estimate only the average intake for the whole population. Estimates should also be made of the intake by population groups which may be especially vulnerable for biological reasons (e.g. infants, pregnant women and old people) or because they consume abnormally large amounts of certain foods which may be subject to contamination (e.g. fishermen and their families often eat much more fish than the population in general).

The daily or weekly intake of a specific contaminant via food can be estimated using several different approaches - for example, by the analysis of mixed total diet samples (see p. 21) or by analysing individual foods and coupling the results to data on food consumption. In either case data on food consumption and levels of contaminants should relate to the same area. As mentioned earlier, methods based on the analysis of staple foods are recommended in the first instance. However, if resources are available mixed total diet studies provide a conventient method of estimating the intakes via food of a wide range of both contaminants and nutrients. Once the mixed total diet samples have been prepared and analysed estimating the intake of contaminants is relatively simple. The concentration of the contaminants in each composite sample (e.g. the cereals, fats or meat composite) is multiplied by its weight to give the amount of contaminant in each composite sample. The amount of the contaminant in the total diet is the sum of the amounts in all the composite samples.

In the second method of estimating the intake of a contaminant individual foods are analysed and the results are then coupled to data on the consumption of these foods by the population as a whole or by specific groups within the population. From this type of study it is possible to identify the several contributions of the individual dietary items to the total contaminant intake via food. In many countries the use of this method of estimating

contaminant intake is hampered by the inadequacy of available data on food intake. However, some estimate of food intake can usually be made from food balance sheets, household food intake surveys etc., e.g. data available from the FAO Interlinked Computer Storage and Processing System of Food and Agricultural Data, as discussed by Buss & Lörstad.[13] To assist countries wishing to obtain better data on food intake, guidelines for estimation of food contaminants intake are being prepared as part of the Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme (see Chapter 4).

If adequate data on the intake of various foods are not available, it is possible to make a gross estimate of the maximum intake of a contaminant on the basis of known physiological requirements for energy and fluids. (The daily energy and fluid requirements usually lie between certain defined limits but vary with age, climatic conditions, physical activity, etc.). Using this approach, it is possible to estimate the maximum intake of the contaminant by assuming that the carbohydrate, fat, protein and fluid sources with the highest levels of contamination constitute the sole sources of carbohydrate, fat, protein and fluid and by assuming a high energy and fluid intake. If the intake of the contaminant calculated in this way is less than the acceptable daily intake (ADI) or tolerable weekly intake proposed by the Joint FAO/WHO Expert Committee on Food Additives (JECFA) or the Joint Meetings on Pesticide Residues, is not likely to constitute a health hazard. If the estimated intake is much higher than the ADI, a more accurate estimate of the actual intake should be made, based on food intake data for vulnerable groups.

When assessing the potential threat to human health the intake of a contaminant via food should not be considered in isolation but should be correlated with data showing the intake of the contaminant by other routes, e.g. via the lungs. In addition, since the toxicity of some contaminants is markedly affected by nutritional status and especially by the intake of specific nutrients (e.g. calcium affects lead toxicity, selenium affects mercury toxicity) information may be extremely important in assessing risk. Although for many contaminants food is by far the most important source for the population as a whole occupational exposure may be important for workers in certain industries. In the latter case it should be borne in mind that in calculating the tolerable weekly intake of lead, cadmium and mercury via food the Joint Expert Committee on Food Additives[26] has assumed that the intake from other sources does not exceed certain limits. If these limits are exceeded, for example due to excessive atmospheric pollution or air pollution at the working place, the tolerable intake of the contaminant via food will be correspondingly reduced.

### 3.3 Indicating the need for and effects of measures designed to reduce food contamination

Monitoring provides the best way of evaluating the success of regulatory measures introduced with a view to reducing food contamination and preventing contaminated food from reaching the consumer. Since no country has the resources to monitor all foods for all contaminants (even if this were realistic), there is always a need to make the best possible use of the available resources for food control. Monitoring data will indicate where control efforts should be intensified or redirected.

#### 3.3.1 Control of pesticide use

The results of monitoring may indicate that the levels of pesticides in some foods are higher than is acceptable from a health point of view or higher than the levels expected if "Good Agricultural Practice" is used. In such cases, the authorities responsible for supervising the use of pesticides should be informed and requested to take measures to ensure that the pesticide is used in the correct manner and at the recommended time (e.g. that it is not used too close to the time of harvesting). When measures are introduced with a view to reducing residues levels subsequent monitoring shows how effective they are.

#### 3.3.2 Control of the use of drugs in animal husbandry

Monitoring of animal tissues (e.g. liver or kidney) or animal products (milk, eggs etc.) may show the presence of undesirably high levels of drugs used to treat animal diseases or

added to animal feeds as growth promotants. Such data indicate a need for stricter measures to control the use of such drugs, for example by restricting their availability to veterinarians and/or by ensuring that recommended withholding times are observed. When such measures are introduced subsequent monitoring will indicate if they are adequate.

3.3.3 Diseases in food-producing animals

Pre- and postmortem monitoring at farms/slaughter-houses may reveal the presence of certain biological contaminants, e.g. parasites, salmonellae etc., which constitute a health hazard. In such cases it is important to trace the origin of the animal concerned and, where appropriate, take steps to eradicate the infection. When eradication programmes are put into operation monitoring is a reliable way of measuring their success. Data from monitoring carried out at slaughter-houses may also be valuable in studies of infectious cycles in which food animals play a significant role.

3.3.4 Hygienic practices in food production, processing and handling and personnel hygiene

Monitoring data may show that biological contaminants (usually bacteria) are being introduced into food during its production, processing or handling due to poor hygiene and/or that the food is not being adequately treated to render such contaminants harmless. Such problems may be tackled by improving processing and handling techniques and by introducing medical examinations (either because of epidemiological considerations, the nature of the food handled in a particular establishment or the medical history of the prospective employee) to check that personnel engaged in certain food handling activities are not carriers of diseases which are transmissible by food. When such measures are introduced, further monitoring will provide a guide to their success in reducing contamination. Monitoring may also reveal undesirable changes in the microflora of some foods produced by changes of production or processing techniques.

3.3.5 Chemical contamination during processing and handling

Monitoring of processed and/or prepackaged foods may show that chemical contaminants have been introduced during processing (e.g. polycyclic aromatic hydrocarbons or nitrosamines) or from the packaging material (e.g. tin, lead, vinyl chloride). When processing techniques are changed or improvements are made in packaging materials (e.g. the use of lead-free solder is made mandatory, or the vinyl chloride level in polyvinyl chloride packaging material is reduced) monitoring will show how the levels of contaminants in food have changed.

3.3.6 Environmental pollution

Monitoring may show that the levels of a contaminant in certain foods (e.g. mercury in fish) are rising or are already so high that the food is unfit for human consumption. If the source(s) of contamination can be traced it may be possible to reduce or eliminate it. If this can be done then, in time, monitoring will show how the level of the contaminant decreases and when the food from a given area is again fit for human consumption. Data from such monitoring is needed to estimate both the size of the threat to human health and also the economic consequences of continuing discharge of pollutants into the environment. These consequences must then be weighed against the benefits of allowing such pollution to continue and the costs of reducing or eliminating discharge of the pollutant.

3.4 Import controls

Monitoring data may reveal a need to introduce a system (import controls) to check certain imported foods for the presence of specific contaminants. This need arises especially when the exporting country has no monitoring programme of its own and thus cannot guarantee the quality of its products. When an import control system is established samples may be taken at random from some or all consignments of the commodity presented for importation. More intensive monitoring carried out at later dates can be used to examine the success of the control system employed. When unacceptable levels of contamination are revealed by monitoring of imports, the authorities and/or producers in the exporting country should be informed and requested to rectify the situation.

### 3.5 Export controls

The data obtained from monitoring food which is partly or wholly intended for export can be used as evidence that the food meets certain standards regarding levels of contaminants. In many cases, certificates showing that the food has been sampled and analysed with acceptable results can, by bi- or multilateral agreements, be accepted by the importing country. This avoids the necessity of duplicating control activities in two countries. Evidence that the food to be exported has been monitored for contaminants increases the purchaser's confidence in its quality and should lead to increased trade and better economic returns for the producer.

### 3.6 Measuring the impact of the introduction of new substances or practices in agriculture, food processing, food handling etc. on food contaminant levels

When new pesticides or new techniques for producing, processing and handling food are introduced monitoring data shows the impact they have had on food contaminant levels.

New methods of processing and distributing food are often not primarily designed to reduce contamination but are introduced for purely commercial reasons, for example to reduce costs and/or to concentrate manufacturing to fewer and larger units. The latter may imply that the food must then be transported over longer distances before reaching the consumer. Similarly, the tendency in some countries to reduce the salt content in processed meat and fish products may imply increased risks for the growth of certain pathogenic bacteria in these foods.

A potential source of food contaminants which deserves special attention is activated sludge which is being used in agriculture as a fertilizer in increasing amounts as facilities for treating urban sewage are introduced or extended: problems may arise when such sludge is contaminated with heavy metals, pathogenic microorganisms or other contaminants discharged into the sewage system.

### 3.7 Localizing sources of food contaminants and measuring the impact of industrial discharges etc. on food contaminant levels

Data from the analysis of samples taken from geographically well-defined areas may help to localize sources of food contaminants. For example, monitoring data on fish samples taken upstream and downstream of a factory, or on crops at certain distances down-wind from it if the contaminant is spread via the atmosphere, are valuable in establishing the role of the factory as a source of contaminants in fish. When new factories or mines which are likely to pollute the air, water or soil are opened monitoring of food produced in their vicinity provides a measure of their impact on food contaminant levels there. Studies carried out in various countries have shown the influence of industrial pollution from lead smelters and other metal producing industries on contaminant levels in foods grown in the vicinity. Likewise, monitoring of foods grown in the vicinity of fossil fuel-burning power stations for heavy metals etc. can give a measure of their impact on food contaminant levels.

### 3.8 Establishing maximum limits (tolerances) for contaminants in national food standards

Data on the actual levels of contaminants in different foods enables legislators at the national level to evaluate the effect of establishing a certain legal tolerance (maximum limit) or "action guideline" for a contaminant in a food in terms of the amount of food likely to be rejected. This must then be weighed against the health risks involved in setting a higher limit. Unless there are urgent toxicological reasons for doing so, it is generally inadvisable to establish legal limits for contaminants in foods before their impact on the food supply has been ascertained by monitoring or at least a survey.

### 3.9 Correlation with contaminant levels in other media and in body tissues and with outbreaks of human and animal diseases

The data generated in food monitoring programmes can be used together with data on contaminant levels in other media to obtain an overall picture of contamination of the environment. Data on the levels of contaminants in fish and other aquatic animals should be correlated with data on levels in water and in other parts of the food chain. Data on the levels of some contaminants in foods of animal origin can be correlated with levels of the same contaminant in animal feeds.

Data on the intake of contaminants via food should be correlated with estimates of intake from other sources and the total intake should, if possible, be correlated to the levels of the contaminant in tissues or body fluids (e.g. blood levels of lead and organochlorine compounds in human milk). In the case of certain biological contaminants the level (or frequency of positive findings) should be correlated with epidemiological data on relevant diseases in man, or animals.

### 3.10 Identification of research problems

The data generated in monitoring programmes may show areas where there is a need for further research work. Furthermore, an examination of the monitoring data should enable priorities to be established both with regard to research concerned with monitoring itself (better methods of sampling and analysis) and with the problem of food contamination as a whole.

## CHAPTER 4. THE JOINT FAO/WHO FOOD AND ANIMAL FEED CONTAMINATION MONITORING PROGRAMME AND ITS RELATION TO NATIONAL PROGRAMMES

The background to the development of the Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme has been given in the introduction to the present guidelines (see p. 9). The internationally coordinated programme will utilize data from national monitoring studies and encourage and assist investigations in countries where such studies have not yet been initiated. The Third Joint FAO/WHO Conference on Food Additives and Contaminants (Geneva, 22-26 October 1973) recommended that Member Governments cooperate to the fullest possible extent with the two agencies in the implementation of the Programme.

### 4.1 Objectives

The objectives of the internationally-coordinated monitoring programme may be summarized as follows:

(a) To assist governments, where necessary, in establishing or strengthening food and animal feed contamination monitoring programmes in order to strengthen the national services responsible for the control and prevention of food and animal feed contamination.

(b) To provide an internationally coordinated mechanism for the collection and storage of data from national monitoring programmes on the chemical and biological contamination of foods and animal feeds.

(c) To strengthen current national food consumption surveys so as to meet the needs of the food contaminant monitoring programme.

(d) To provide information which will facilitate the evaluation of the risk of food contamination to human health.

(e) To review, evaluate and disseminate the monitoring data at an international level and make available the results of such evaluations of potential public health and economic significance.

(f) To identify, coordinate and promote research on the problems of food and animal feed contamination, with particular reference to sampling and analytical methodology, food safety and the movement of contaminants through food chains.

(g) To provide the Joint FAO/WHO Codex Alimentarius Commission with information on the levels of contaminants in food to support and accelerate its work on international standards for contaminants in food.

(h) To enable concerted worldwide planning for international action programmes to reduce or eliminate health and economic risks from food and animal feed contamination.

## 4.2 Benefits

The potential benefits to be derived from the internationally coordinated programme may be summarized as follows (some benefits are the same as those expected from national programmes but there are others which accrue from international coordination):

(a) Improved safety of foods and animal feeds.

(b) Warning of actual and potential food and animal feed contamination problems, both local and international.

(c) Provision of data on the intake of contaminants via food which contribute to toxicological evaluations of possible human health hazards and to epidemiological studies.

(d) Improved economic prospects, especially for developing countries through better management and optimal utilization of natural resources, and improved returns from the export of quality-controlled food and animal feeds.

(e) Continuing information on levels of environmental pollution throughout the world, hence providing data that can contribute to eventual reduction in pollution and to the overall improvement of the human environment.

(f) Identification of relevant research problems.

(g) Provision of reliable information to the world public on the safety of foods.

(h) Development of technological expertise in monitoring and survey methodology for personnel, especially in developing countries.

(i) Provision of a means of checking the effectiveness of established regulatory mechanisms and a means of planning suitable technological developments.

## 4.3 Development of the International Programme

As mentioned above, the International Programme will be based on data obtained in national food and animal feed contamination monitoring programmes. It is envisaged that eventually a large number of countries will contribute data, but initially selected data has been requested from 15-20 countries, including some developing countries, with existing food and animal feed contamination monitoring programmes. A major feature of the programme is the provision of financial and technical assistance to those Member States who wish to establish or strengthen their national monitoring programmes with a view to enabling them to participate in the International Programme. Such assistance will be provided by FAO and WHO and other international and national organizations.

A flow diagram showing the steps involved in starting the International Programme is given in Appendix 18. Brief comments on the various steps are given here.

4.3.1 Studies on existing national programmes

Reports on existing national food contamination monitoring programmes in thirteen countries[a] were prepared by FAO/WHO staff members, consultants or temporary advisers following visits to the respective countries during the period November 1973 to September 1974. These reports were reviewed by an Expert Consultation (see 4.3.2). Further countries were visited in 1977-1978.

4.3.2 Selection of contaminants and foods to be studied and methods of sampling and analysis

An Expert Consultation was held in Rome in October 1974 to select the contaminants and foods to be included in Phase II of the International Programme and to recommend methods of sampling and analysis. The recommendations of the consultation are summarized in Appendix 19. It should be noted that, in addition to selecting contaminants, foods and methods of sampling and analysis the Consultation emphasized the need for quality control of the data collected from the various countries participating in the International Programme.

4.3.3 Development of a system for processing, appraisal and storage of data

An Expert Consultation was held in Geneva in March 1975 to develop a system for processing, appraising and storing the data to be collected in the Programme. The recommendations of the Consultation are summarized in Appendix 20.

4.3.4 National participation

Having completed the above pre-programme activities (Phase I), FAO/WHO invited 15 countries with existing food and animal feed monitoring programmes to participate in Phase II of the Programme by supplying selected data on certain contaminants. It should be noted that not all the data generated in national programmes are to be included in, or are indeed relevant to, the International Programme. The conditions of governmental participation, the contaminants and foods for which data are to be collected and the roles of the Collaborating Centres (see 4.3.5) were discussed with the participating governments at a Consultation in Geneva in June 1977. The capabilities of further countries with poorly-developed monitoring systems to participate in the programme will be assessed and, where possible, they will be provided with financial and technical assistance to strengthen their monitoring activities. The contaminants and foods on which data are to be collected in Phase II are shown in Appendix 25.

4.3.5 FAO/WHO Collaborating Centres

After consultation with the governments concerned, FAO/WHO have designated a Collaborating Centre in each of the 19 countries[b] which has agreed to participate in the International Programme by supplying data on selected contaminants. These centres will serve as a focal point in each country and will be responsible for collecting the relevant data and forwarding it to the Central Unit at WHO in Geneva. The designation of Collaborating Centres in further countries is contemplated.

4.3.6 Collation and processing of the data and preparation of reviews, reports, etc.

The selected data supplied by individual countries will be collated and further processed by consultants recruited by FAO/WHO on an ad hoc basis and reports containing summaries and evaluations of the data on specific contaminants will be produced. Furthermore, the consultants will be asked to make recommendations for improving the International Programme.

---

As of May 1978 the following countries:

[a] Austria, Canada, Denmark, Federal Republic of Germany, German Democratic Republic, Hungary, Ireland, Japan, Netherlands, Poland, Sweden, United Kingdom and the United States of America.

[b] Austria, Brazil, Canada, Denmark, Egypt, Federal Republic of Germany, Guatemala, Hungary, Ireland, Kenya, Japan, Netherlands, New Zealand, Poland, Sweden, Switzerland, United Kingdom, United States of America, USSR.

4.3.7 Central data bank

The selected data on food and animal feed contamination received from the Collaborating Centres will be stored at the FAO/WHO Central Unit located at WHO headquarters in Geneva.

4.3.8 Guidelines

In addition to the present guidelines, guidelines for estimation of food contaminants intake are being prepared.

4.3.9 Technical Advisory Committee Meetings

A committee including technical experts from those countries that are currently involved in the International Programme will discuss any problems arising in the running of the International Programme and, in the light of experience at the national and international levels, suggest ways of improving it. The first session of the Technical Advisory Committee was held in Rome, 13-17 March 1978.

The progress of the International Programme will be reviewed at regular intervals by an inter-secretariat (FAO, UNEP, WHO) meeting. In addition such meetings will plan the future development of the Programme (including such aspects as financial and technical support to the developing countries) and review the relation of the project to other elements of the Global Environmental Monitoring System (GEMS) programme of UNEP (see p. 43).

4.4 The fully-operational programme

The development of the International Programme towards the fully operational stage has been described under 4.3. The flow diagram in Appendix 21 shows schematically how the fully operational programme is envisaged.

The use of data from the International Programme in related programmes of United Nations and other international agencies is discussed in Chapter 5. An outline of the type of assistance which United Nations agencies, especially FAO and WHO, can provide to countries wishing to establish or strengthen food and animal feed contamination monitoring programmes is discussed in Chapter 6.

4.5 Relation to national programmes

4.5.1 Inputs from national programmes

As is evident from the earlier parts of this chapter, the input envisaged from national monitoring programmes to the International Programme consists primarily of selected data on levels of contaminants in food and animal feeds. These data will be channelled via the Collaborating Centres to the FAO/WHO Central Unit at WHO headquarters, Geneva. In addition, it is envisaged that countries with well-developed monitoring systems will provide some assistance to the agencies in training personnel from countries with poorly-developed monitoring systems.

4.5.2 Outputs from the International Programme

The outputs envisaged from the International Programme include (a) periodic reports, compilations, summaries etc. on contaminant levels and time-trends in contamination in various foods of particular significance; (b) technical publications giving recommendations on various aspects of monitoring (e.g. planning, sampling, analysis, data handling); (c) evaluations and assessments of problems posed by food contaminants, e.g. reports from the Joint Expert Committee on Food Additives and Criteria Documents from WHO. (These reports/documents also include data derived from many other sources and are not a direct output of the International Programme); and (d) recommendations from the Codex Alimentarius Commission on maximum permissible levels of contaminants in various food commodities. (Data from the International Programme will assist the Commission in its work; the Codex recommendations are not a direct output of the Programme).

In addition, within the framework of the Programme assistance, in the form of equipment, training courses, study tours etc., will be provided to countries wishing to strengthen their food contamination programmes with a view to participating in the International Programme (see Chapter 6).

## CHAPTER 5. RELATED PROGRAMMES OF UNITED NATIONS AND OTHER INTERNATIONAL AGENCIES

Several international programmes concerned with increasing our knowledge of levels of various contaminants in the environment and of their impact on man's health and wellbeing and on natural resources have been initiated or are at the planning stage. Data on levels of contaminants in food and animal feeds and on the intake via food of contaminants by man will form an essential part of several such programmes. Some aspects of the major programmes which are related to food and animal feed monitoring are discussed below.

### 5.1 Other monitoring systems

#### 5.1.1 United Nations Environment Programme (UNEP)

At the United Nations Conference on the Human Environment held in Stockholm in 1972[3] it was proposed that a United Nations Environment Programme (UNEP) be started with a view to concerting international efforts to preserve and improve the human environment. The Conference adopted 109 specific recommendations for action. Two of these (Nos. 78[a] and 82[b]) have a direct bearing on food and animal feed contamination monitoring: the present monitoring programme is being developed in response to recommendation 78.

The UNEP consists of three main components - environmental assessment, environmental management and supporting measures.

Environmental assessment, codenamed "Earthwatch", consists of the following sub-components: (a) monitoring, (b) evaluation, (c) research and (d) exchange of information on the state of the environment as a basis for rational environmental management decisions.

Under Earthwatch, monitoring activities form part of the Global Environment Monitoring System (GEMS) - a collective international effort to collect systematically data describing the state of the environment and the changes it undergoes in space and time. UNEP through its GEMS Programme Activity Centre ensures the coordination of monitoring activities by channelling to some of them the resources of the Environment Fund.

The GEMS programmes supported by the Environment Fund fall into the following major categories:

1) Health-related monitoring deals with the monitoring of air pollution, water quality, food contamination and the assessment of both the exposure to air pollutants and (through measurements of pollutants in body tissues and fluids) the exposure of pollutants deposited in the human body. These activities involve primarily the WHO;

2) Climate-related monitoring, concerned with background levels of atmospheric pollutants and, in the near future, with measurements of earth's reflectance, changes in the cryosphere, ocean surface temperature and other variables that either reflect or may determine climatic changes. Most of these activities are the responsibility of WMO;

---

[a] See p. 9 of these Guidelines.

[b] Recommendation 82: "It is recommended that increased support be given to the Codex Alimentarius Commission to develop international standards for pollutants in food and a Code of Ethics for international food trade, and that the capabilities of the Food and Agriculture Organization in the field of food control be increased."

3) Monitoring of the long-range transport of pollutants, particularly across borders, aims at providing data on deposition of pollutants (particularly sulphur oxide and their transformation products) in relation to the movement of air masses from pollutant sources to distant targets (ECE and WMO);

4) Natural renewable resource monitoring aims at assessing the state and trend of resources (e.g. forests, grasslands) particularly in the tropics where current information is scanty (FAO);

5) Ocean monitoring is mostly concerned with such pollutants as heavy metals and organochlorine compounds in marine living resources as well as with petroleum hydrocarbons in ocean waters. Several agencies including FAO, IAEA, IOC/UNESCO, WHO and WMO are involved in ocean monitoring.

A number of other internationally coordinated activities, though contributing to GEMS, are not financed by the Environment Fund. Major examples are the majority of the activities of the World Weather Watch of the WHO, the Wildlife Sampling Programme of OECD and the activities in marine pollution monitoring carried out in the Baltic, the North Sea and the North Atlantic by ICES.

### 5.1.2 FAO Fisheries Contamination Information System

A system for monitoring pollution of the aquatic environment for its harmful effects on living organisms and the presence of contaminants in fishery products is being developed. This system will provide a coordinated mechanism for the inventory of data from national monitoring programmes on contaminants in fish and other edible aquatic organisms. There will be a close link between this programme and the projected FAO Fishery Data Centre. The Fishery Data Centre is a permanent specialized centre which is responsible for collecting, storing and analysing fishery data from international cooperative investigations, especially those sponsored by the Intergovernmental Oceanographic Commission, data from FAO-executed fishery field projects financed by UNEP and such other data of national or international origin as may be deposited from bilateral aid programmes, FAO trust fund projects and activities of regional fisheries councils and commissions, whereas the Information System is dependent on UNEP funding. The fishery data does not include data on the level of contaminants from ongoing national food contamination monitoring programmes.

One aspect of the work of the Fishery Data Centre includes the implementation of the UNEP project "Data on Contaminants in Aquatic Organisms". The centre has produced a "Directory of Institutes Engaged in Pollution Investigations - Contaminants in Aquatic Organisms".[28]

### 5.1.3 FAO programme on impact monitoring of residues from the use of agricultural pesticides in developing countries

This project, which is supported by UNEP, is designed to assist developing countries to undertake any kind of physical, chemical or biological measurements in connexion with known uses of pesticides with a view to obtaining information on the distribution of the chemical and/or its effects in the environment. The objectives therefore are basically aimed at avoiding or minimizing environmental problems arising from their use of agricultural pesticides. It will cover such problems as build-up of residues in soil, transport through food chains and any potential hazards to man and other nontarget organisms. The development of this project was discussed at a FAO/UNEP Consultation in 1975.[29]

The project entitled "The Ecological Assessment of Pest Management and Fertilizer Use on Terrestrial and Aquatic Ecosystems" which is being developed, with assistance from FAO, as part of UNESCO's "Man and the Biosphere" programme will also cover this problem area. This project is an intergovernmental and interdisciplinary programme of ecological research into the broad environmental consequences of widespread use of chemical pesticides.

### 5.1.4 WHO Environmental Health Monitoring Programme

The aim of environmental health monitoring is to provide information for the assessment of human exposure to environmental agents and the associated effects on human health, make possible the assessment of progress made towards defined environmental health goals, indicate the compliance with the relevant regulations and serve as an alert warning system. The principal objectives of the WHO Environmental Health Monitoring Programme are (a) assistance to Member States in their efforts to establish and develop environmental health monitoring systems which they need for their programmes to protect human health from adverse environmental influences, and (b) the international exchange of information on levels and trends of environmental pollution and other hazards, the resulting human exposure and the associated effects on man's health; and the use of this information for the assessment and improvement of environmental conditions of relevance to public health. The programme will be based upon current and established monitoring activities in Member States and is intended to be the major health component of GEMS.

Since man may be exposed to pollutants through inhaled air and ingested food and water or through contact with the skin, it is necessary to use integrated monitoring when attempting to assess total exposure to a pollutant. Thus the data obtained from food monitoring programmes on the intake of a contaminant via food will be correlated with data on the intake of the same contaminant from other sources, e.g. inhaled air. For some contaminants, the levels of the contaminant in certain tissues or body fluids or certain biochemical indicators will be used as an index of exposure. For example, it is proposed[30] to monitor lead levels in blood, mercury in blood and hair and certain organochlorine compounds in human milk to assess human exposure to these compounds.

The data on human exposure to various pollutants will then be correlated with information obtained by monitoring health effects, e.g. health statistics and registers for specific morbidity, and data from occupational health studies.

## 5.2 Other users of the data at the international level

### 5.2.1 Joint FAO/WHO Food Standards Programme - Codex Alimentarius Commission

The United Nations Conference on the Human Environment recommended that increased support be given to the Codex Alimentarius Commission (CAC) to develop international standards for contaminants in foods. Data from food monitoring programmes would be of considerable value to the CAC and its subsidiary bodies when developing standards for contaminants in food. Such data should allow an estimate to be made of the proportion of food which is likely to be rejected if a certain standard for the maximum permissible level of a contaminant in a food commodity is adopted.

This potential loss of food must then be weighed against the risk to human health which may arise if higher levels of the contaminant are permitted. The international food standards which have so far been elaborated or are in preparation include, in appropriate cases, recommendations on tolerable levels of contaminants such as heavy metals, pesticide residues and certain microorganisms.

### 5.2.2 Joint FAO/WHO Expert Committee on Food Additives (JECFA), Joint Meetings of the FAO Working Party of Experts and the WHO Expert Committee on Pesticide Residues (JMPR), and Joint FAO/WHO Expert Consultations on Microbiological Standards for Foods (JECMSF)

The JECFA is mainly concerned with toxicological evaluations of food additives but has also evaluated certain contaminants[26] which may pose a threat to human health when present at certain levels in food, e.g. lead, cadmium, mercury. More reliable and extensive data on the levels of chemical contaminants in food would be of great value to JECFA in evaluating tolerable intakes of such contaminants via food.

The JMPR produce recommendations concerning the levels of various pesticide residues which may be tolerated in certain food commodities. At the Joint Meetings two groups of experts, one on the use of pesticides and the other on their toxicology, produce recommendations for maximum residue limits which are consistent with the use of various pesticides according to "Good Agricultural Practice", whilst at the same time providing adequate protection for the health of the consumer. Data provided from food monitoring programmes on the levels of pesticide residues in various commodities in normal commercial channels would be of great value to JMPR in elaborating their recommendations for maximum residue limits.

The JECMSF makes recommendations to Codex Alimentarius Committees on methodology for sampling and analysis for microbiological contamination in foods and for limits for microbiological contaminants. The work of the JECMSF would be facilitated by information from monitoring programmes on the frequency and levels of microbiological contamination in foods.

### 5.2.3 WHO Environmental Health Criteria Programme

Under WHO's Environmental Health Criteria Programme, documents are prepared which are critical reviews of existing knowledge on the relationships between the exposure to a pollutant (and certain physical factors) and its effects, both acute and long-term, on man's health. In many cases these criteria documents contain guidance regarding levels or concentrations of exposure consistent with the protection of the health and wellbeing of exposed populations. A list of criteria documents already prepared and those planned or in preparation is given in Appendix 23. For some pollutants the major route of human exposure is via food. In such cases information on levels of the contaminant in various foods and on the intake of the contaminant via food will be of paramount importance for the elaboration of the criteria document.

## CHAPTER 6. ASSISTANCE FROM UNITED NATIONS AGENCIES TO NATIONS WISHING TO ESTABLISH OR STRENGTHEN FOOD AND ANIMAL FEED CONTAMINATION MONITORING PROGRAMMES

Some countries wishing to establish or strengthen food contamination monitoring programmes as part of their food safety and food control activities are hampered by the lack of trained personnel, equipment or other facilities. Providing the country concerned can demonstrate a real need for and interest in monitoring, FAO and WHO may be able to offer some of the technical assistance required. As mentioned in Chapter 4, the International Programme has some provision for supporting or assisting developing countries in launching national programmes. Other sources of funding are available to the two agencies from within the United Nations system or outside. Any such assistance, however, can only be of limited nature and the countries have to depend by and large on their own resources which one imagines would bring enough returns to make the efforts worthwhile from health and economic points of view. Four types of technical assistance may be provided by international agencies, like FAO and WHO, in regard to such monitoring activities: (a) expert guidance and planning in implementing and evaluating monitoring programmes; (b) strengthening of national institutions and infrastructure; (c) personnel training; (d) publications and other information on various aspects of monitoring.

### 6.1 Expert guidance in planning, implementing and evaluating monitoring programmes

FAO and WHO already have extensive programmes to provide developing countries with guidance and assistance on some aspects of food control and food safety as part of their regular programmes. To the extent that resources, facilities and other commitments permit, FAO and WHO are prepared, upon request, to provide experts to assist countries in the planning, implementation and evaluation of food contamination monitoring programmes. Such assistance may be for relatively short periods, when guidance in planning or evaluation is sought, or for periods of months or even years when assistance with various operational aspects of a programme, e.g. analysis using sophisticated techniques, is sought. Before any assistance is

provided, an assessment of the resources available in the country itself and of the need for assistance must be made and the scope and terms of reference must be agreed upon. It should be borne in mind that unless the nation concerned is prepared to act upon the recommendations of the expert(s) such assistance may prove a waste of money and skilled manpower.

### 6.2 Strengthening national institutions

In some developing countries FAO and WHO are already helping to strengthen national institutions concerned with various aspects of food control and resource management by providing funds and experts to establish laboratories for food analysis and centres to train local personnel in food hygiene, pest control techniques, food processing etc. The agencies may increase this assistance in cases where this is requested and where it would accelerate the introduction of food contamination monitoring programmes.

### 6.3 Personnel training

A major barrier to the establishment of monitoring systems in some countries is the lack of suitably trained personnel, e.g. well-qualified analysts. Some countries have neither the trained personnel nor the facilities to train them. FAO and WHO have extensive programmes to help developing countries to train food analysts, food inspectors etc. Such training is provided through individual fellowships, by organizing training courses or by setting up training centres on a more long-term basis. The provision of fellowships enables individuals with suitable basic education to obtain specialized training in other countries or to visit a number of countries to study various aspects of the monitoring programmes in operation there. The above training activities may be financed by FAO, WHO or UNEP or through other funding arrangements. In some cases individual governments bear the cost of training specialists from other countries.

### 6.4 Publications, reports and other information of relevance to food contamination monitoring

FAO, WHO and a number of other international organizations, e.g., ISO, ICMSF, produce publications relevant to various aspects of monitoring; many of them have already been mentioned in these guidelines. Publications which may be of special interest include the FAO/WHO "Guidelines for developing an effective national food control system" (1976), the reports of the Joint Meetings on Pesticide Residues and the Joint Expert Committee on Food Additives (see p. 45), and WHO Environmental Health Criteria documents (see p. 46). Lists of current FAO and WHO publications are available from the headquarters of the agencies in Rome and Geneva respectively. The Codex Alimentarius Commission and its subsidiary bodies produce a large number of valuable publications and reports on recommended international standards for various food commodities, methods of sampling and analysis, pesticide residues, food hygiene, etc. These can be obtained via the national Codex Contact Points.

Appendices 8 and 10 contain lists of sources of information on sampling and analysis.

APPENDIX 1

## SOME SOURCES OF INFORMATION ON METHODS OF SAMPLING AND ANALYSIS OF AND STANDARDS FOR DRINKING-WATER

International Standards for Drinking-Water, Third Edition, World Health Organization, Geneva, 1971.

European Standards for Drinking-Water, Second Edition, World Health Organization, Geneva, 1970.

Surveillance of Drinking-Water Quality, World Health Organization, Geneva, 1976.

Standard Methods for the Examination of Water and Waste-water, 14th edition, 1976, prepared and published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation. Publication office: American Public Health Association, 1740 Broadway, New York, N.Y. 10019.

Approved Methods for the Physical and Chemical Examination of Water, Third Edition, The Institution of Water Engineers, The Royal Institute of Chemistry, and the Society for Analytical Chemistry, London, 1960.

Standard Methods for the Water Quality Examination for the Member Countries of the Council for Mutual Economic Assistance, The Ministry of Forestry and Water Management in cooperation with the Hydraulic Research Institute Prague, Prague, 1968.

The Chemical Analysis of Water, General Principles and Techniques, A. L. Wilson, Published by The Society for Analytical Chemistry, London, 1974.

Simplified Procedures for Water Examination, Laboratory Manual, Revised 1975. American Water Works Association, 6666 W. Quincy Ave., Denver, Colo. 80235, United States of America (Portuguese - see below - Spanish and French translations available or in preparation).

Processos Simplificados para Exame e Analise da Agua. Traduçao do Manual Simplificado, para Laboratorio, da American Water Works Association (M-12). Faculdade de Saude Publica Universidade de São Paulo, 1970.

Deutsche Einheitsverfahren zur Wasser-, Abwasser- und Schlamm-Untersuchung. Physikalische, chemische und bakteriologische Verfahren. Herausgegeben von der Fachgruppe Wasserchemie in der Gesellschaft Deutscher Chemiker. Dritte, völlig neubearbeitete Auflage, Verlag Chemie, GmbH, Weinheim/Bergstr., 1960.

Water Treatment and Examination. A successor to "The Examination of Waters and Water Supplies" by Thresh, Beale and Suckling. Edited for The Society for Water Treatment and Examination by W. S. Holden, J. & A. Churchill, London, 1970.

Methods for Chemical Analysis of Water and Wastes, Environmental Protection Agency, Cincinatti, Ohio, 1971.

APPENDIX 2

## SOME SOURCES OF INFORMATION ON MONITORING OF FOODS FOR RADIONUCLIDES

International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection: Report of Committee II on permissible dose for internal radiation (Publication 2). Pergamon Press, Oxford, 1960.

Routine Surveillance for Radionuclides in Air and Water, World Health Organization, Geneva, 1968.

Environmental Contamination by Radioactive Materials. Proceedings of a Seminar on Agricultural and Public Health Aspects of Environmental Contamination by Radioactive Materials, jointly organized by the IAEA, FAO and WHO, Vienna, 24-28 March 1968. International Atomic Energy Agency, Vienna, 1969.

European Standards for Drinking Water, Second Edition, World Health Organization, Geneva, 1970.

The Environmental Radiation Surveillance Laboratory. A Guide to Design, Layout, Staff and Equipment Requirements, P. R. Kamath, WHO, Geneva, 1970.

International Standards for Drinking-Water, Third Edition, World Health Organization, Geneva, 1971.

Assessment of Radioactive Contamination in Man. Proceedings of a Symposium on the Assessment of Radioactive Organ and Body Burdens organized by IAEA and WHO, Stockholm, 22-26 November 1971. International Atomic Energy Agency, Vienna, 1972.

Environmental Radioactivity Surveillance Guide, U.S. Environmental Protection Agency, Office of Radiation Programs, Surveillance and Inspection Division, Washington D.C., 1972.

Objectives and Design of Environmental Monitoring Programmes for Radioactive Contaminants, Sponsored by IAEA and WHO, International Atomic Energy Agency, Vienna, 1975.

Organization of surveys for radionuclides in food and agriculture. FAO Atomic Energy Series No. 4, 1962.

APPENDIX 3

MULTIMEDIA LIST OF PRIORITY POLLUTANTS AGREED UPON BY THE INTERGOVERNMENTAL MEETING ON MONITORING, ORGANIZED BY UNEP IN NAIROBI, 1974

| Pollutant | Medium |
|---|---|
| Arsenic | Drinking-water |
| Asbestos | Air |
| Cadmium and compounds thereof | Food,[a] man, water |
| Carbon dioxide | Air |
| Carbon monoxide | Air |
| DDT and other organochlorine compounds | Biota,[b] man |
| Fluorides | Freshwater |
| Lead | Air, food[a] |
| Mercury and compounds thereof | Food,[a] water |
| Microbial contaminants | Food[a] |
| Mycotoxins | Food[a] |
| Petroleum hydrocarbons | Sea |
| Nitrates, nitrites | Drinking-water, food[a] |
| Nitrogen dioxide, nitric oxide | Air |
| Ozone | Air |
| Radionuclides ($^{90}Sr$, $^{137}Cs$) | Food[a] |
| Reactive hydrocarbons | Air |
| Sulfur dioxide and suspended particulates | Air |

[a] Food includes animal feed.

[b] Programme should include food monitoring.

APPENDIX 4

## LIST OF CHEMICAL AND BIOLOGICAL AGENTS WHICH MAY BE OF CONCERN AS FOOD CONTAMINANTS

The agents are not listed in order of priority and other agents not included here may be important in some countries. Not all the agents listed lend themselves to monitoring.

### Chemical contaminants

#### Metals

Antimony
Arsenic
Cadmium[a]
Chromium
Cobalt
Lead[a]
Mercury[a]
Nickel
Tin

#### Pesticides and metabolites and breakdown products thereof

Dithiocarbamates
Methyl bromide
Organochlorine insecticides[a]
Organophorphorus insecticides

#### Radionuclides

$^{137}Cs$
$^{90}Sr$
$^{131}I$

#### Other substances

Asbestos
Fluorides
Nitrates
Nitrites
N-Nitroso compounds (including nitrosamines)
Polycyclic aromatic hydrocarbons
Polyhalogenated bi-and terphenyls (including PCBs)[a]
Substances used in animal husbandry, e.g. antibiotics and hormones
Selenium
Vinyl chloride monomer and other organic compounds migrating from packaging materials

---

[a] Selected as a priority contaminant by the Expert Consultation to Identify the Contaminants to be Monitored and Recommend Methods of Sampling and Analysis for the Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme, Rome, 1974, see p. 41.

## Contaminants of biological origin

### Bacteria and bacterial toxins

- *Bacillus cereus*
- *Clostridium botulinum* toxin
- *Clostridium perfringens*
- Salmonellae[a]
- Shigellae
- Staphylococcal enterotoxin
- *Vibrio parahemolyticus*

### Mycotoxins

- Aflatoxins[a]
- Citrinin
- *Fusaria* toxins
- Ochratoxin A
- Patulin
- Sterigmatocystin

### Parasites

- *Cysticercus bovis*[a]
- *Echinococcus granulosus*[a]
- *Fasciola hepatica*, *F. gigantica*
- *Paragonimus westermani*
- *Taenia saginata*
- *Taenia solium*
- *Trichinella spiralis*[a]

### Viruses

- Hepatitis A virus

---

[a] Selected as a priority contaminant by the Expert Consultation to Identify the Contaminants to be Monitored and Recommend Methods of Sampling and Analysis for the Joint FAO/WHO Food and Animal Feed Contamination Monitoring Programme, Rome, 1974, see p. 41.

APPENDIX 5

## SUGGESTED DIVISION OF RESPONSIBILITY FOR PLANNING, IMPLEMENTING AND EVALUATING NATIONAL FOOD CONTAMINATION MONITORING PROGRAMMES

CENTRAL GOVERNMENT gives A SINGLE PRIMARY AGENCY overall responsibility for the monitoring programme, e.g. National Food Administration, Ministry of Health's Division of Environmental Health, Environmental Protection Agency, etc.

The primary agency, after consultation with other government agencies and other competent bodies (e.g. academic institutions, food industry and trade), appoints a WORKING GROUP ON MONITORING responsible for coordinating the various projects in the programme and for evaluating the whole programme.

The Working Group[a] appoints several WORKING PARTIES each with responsibility for the detailed planning and implementation of a specific project in the monitoring programme. Each Working Party is responsible for all phases of the planning and implementation of a project and should appoint a Project Coordinator to coordinate the activities of the sampling personnel, analysts, data processors, etc. Separate Working Parties could be set up for, for example, the monitoring of heavy metals, pesticide residues, PCBs and related organic compounds (possibly including mycotoxins), selected bacterial contaminants (e.g. Salmonellae) and parasites.

At each analytical laboratory, etc. a person is given responsibility for directing the work connected with monitoring and acts as a contact point with other institutions involved in the same project.

---

[a] The Working Group may assume the responsibilities allotted to the Working Parties if the programme is restricted to one or two projects.

APPENDIX 6

## DEFINITIONS[a] AND EXPLANATIONS OF SOME OF THE TERMS USED IN THE SECTION ON SAMPLING (2.2.2)

Batch see Lot.

Consignment. A quantity of food destined in commerce to a particular recipient, usually consisting of multiple containers of food from one or more lots.

Field sample. A sample drawn from a lot of food and sent to the laboratory for analysis.

Lot (= batch). A defined quantity of food produced under conditions which are presumed to be uniform.

Package. A unit of food within a specific container - sack, bag, can, box, bottle, etc.

Population. The total number of sample units about which an inference is to be made from the analytical results obtained.

Random sample. A collection of sample units chosen from the material of interest in such a manner that each sample unit had an equal chance of being selected, hence excluding bias.

Sample. Part of the whole (population) from which the properties of the whole are to be estimated by analysis or examination. Note that only part of the field sample (see above) may actually be analysed (see under Sample unit).

Sample unit. The individual portion or container of food randomly taken as part of the field sample and to which the analytical test will be applied.

Stratification. A technique for controlling known sources of variation. It may be used where it is known that the consignment is potentially not of uniform quality (see p. 22).

---

[a] Based mainly on the definitions used in "Microorganisms in Foods. 2. Sampling for microbiological analysis: principles and specific applications". ICMSF (University of Toronto Press, 1974) and the International Organization for Standardization ISO/TC 34 - Agricultural Food Products - Working Group 1. Sampling Vocabulary of Sampling Terms and Definitions.

APPENDIX 7

SOME OF THE MORE IMPORTANT DATA[a] TO BE RECORDED WHEN TAKING SAMPLES IN THE FIELD AND SENT WITH THE SAMPLE TO THE ANALYTICAL LABORATORY

1. Name and address of the person collecting the samples.

2. Date, place and time of sampling.

3. Reason(s) for sampling - if part of a specific monitoring project, project reference number.

4. Nature of the food.

5. Name of the manufacturer, importer, wholesaler, retailer, etc. as appropriate.

6. Number and size of units constituting the lot.

7. Number and marking of the lot.

8. Origin of lot.

9. Destination of lot.

10. Method of sampling (random throughout the lot, random throughout accessible units, etc.).

11. Size, number and reference number of field samples.

12. Date of despatch and means of transportation to analytical laboratory.

13. Name and address of analytical laboratory.

14. Analysis to be performed.

15. Any other relevant information regarding the condition of the lot or the field sample, e.g. details of processing.

---

[a] Not all data may be relevant in all cases. Unless the monitoring project is also a food control exercise, it may not be necessary to record all the data given below.

APPENDIX 8

## SOME SOURCES OF FURTHER INFORMATION ON SAMPLING

### Biological contaminants

International Commission on Microbiological Specifications for Foods. Microorganisms in Foods. 2. Sampling for microbiological analysis: principles and specific applications, Toronto, University of Toronto Press, 1974.

Food-borne Disease: Methods of Sampling and Examination in Surveillance Programmes. World Health Organization Technical Report Series No. 543. WHO, Geneva, 1974.

An Evaluation of the Salmonella Problem, National Academy of Sciences, Washington D.C., 1969.

### Pesticide residues

Guidelines on Sampling and Statistical Methodologies for Ambient Pesticide Monitoring. Federal Working Group on Pest Management, Washington D.C., United States of America, October 1974.

Feltz, H. R. & Cuthbertson, J. K. (1972) Sampling procedures and problems in determining pesticide residues in the hydrologic environment, Pesticide Monitoring J., 6 (3), 171-178.

Lykken, L. (1963) Important considerations in collecting and preparing crop samples for residue analysis, Residue Rev., 3, 1934.

Report of the Codex Committee on Pesticides Residues, Ninth Session.

### Aflatoxins

Whitaker, T. B. & Dickens, J. W. (1974) J. Am. Oil Chem. Soc., 51, 214.

International Union of Pure and Applied Chemistry, Technical Report No. 10 (1974).

### General

Documents Relating to Sampling (Revised Edition). Joint FAO/WHO Food Standards Programme. Codex Committee on Methods of Analysis and Sampling CX/MAS/73/13/Rev, CS/MAS/73/14 Rev. May 1974.

The International Organization for Standardization (ISO) has issued international standards or draft standards on sampling for the following foodstuffs: cocoa beans, oilseeds, fresh and processed fruits and vegetables, cereals (as grain), pulses, milk and milk products, meat and meat products, spices and condiments. These standards can be obtained direct from ISO (for address see Appendix 10) or via the national standardization organizations.

APPENDIX 9

SOME EXAMPLES OF PROBLEMS ASSOCIATED WITH THE PREPARATION OF SAMPLE UNITS FROM FIELD SAMPLES AND SOME SUGGESTIONS FOR SOLVING THEM

1. Fresh fruits. In most cases sample units of fresh fruits are prepared from the whole, unwashed fruit (after removing large inedible stones where appropriate, e.g. peaches). In some cases, e.g. bananas, sample units may also be prepared from the peeled or skinned fruit. In the case of oranges, which may contain much higher levels of antifungal agents in the peel than in the fruit flesh, it is usual to prepare the sample unit from the whole fruit since, although it is usually discarded, the peel may sometimes be used to prepare preserves, fruit syrups, candied peel, etc.

2. Root vegetables are often contaminated with soil when sold. Prior to consumption they are usually washed or peeled and often cooked. For most purposes it seems appropriate to wash them with distilled water and analyse sample units of the raw vegetable before and/or after peeling. It is suggested that the skins should be left on except the outer sheaths for onions or garlic.

3. Leafy vegetables, especially the outer leaves, may be contaminated with soil and dust and other airborne contaminants. It seems appropriate to remove gross contamination by rinsing with distilled water and prepare sample units from the whole of the vegetable. It seems unreasonable to discard the outer leaves unless the consumer is certain to do so. If possible, the outer leaves could be analysed separately.

4. Fish. Some fish are consumed whole whereas in other cases only the flesh, liver and roe or the flesh alone are commonly eaten. It seems appropriate to prepare the sample unit either from the whole, raw fish or to prepare separate sample units from the flesh, liver, roe, etc. Since fish liver has often a high fat content and may contain a several hundred times higher concentration of fat-soluble contaminants (e.g. DDT, PCBs) than the fish flesh, it can be a valuable indicator of contamination when the levels of the contaminant in fish flesh are below the limit of detection.

5. Meat. Since the levels of a contaminant in various tissues and organs in an animal may vary considerably, it is preferable to prepare separate sample units for muscle tissue, fat, liver, kidney, etc. In most cases it seems reasonable to remove bone.

6. Nuts. Field samples of in-shell nuts often contain a proportion of grossly defective nut kernels (meats) which would in all probability be rejected by the consumer after shelling. It seems reasonable to exclude these before drawing the sample units but, if this is done, criteria must be established to enable the exclusion to be as objective as possible. However, kernels which are only seen to be defective on close inspection under a magnifying glass or after sectioning should not be excluded, since there is a reasonable chance that a normal consumer may have eaten them.

This problem is not restricted to nuts, it applies generally to cases where the field sample contains obviously inedible or dubiously edible units, e.g. partly mouldy fruit and vegetables, blown cans, packages with defective seals, etc.

7. Concentrates, dry mixes, etc. should preferably be diluted or prepared ready for consumption according to the instructions provided by the manufacturer before taking the sample unit.

8. Canned products and other products in which a significant proportion of the contaminant may arise from the packaging material present a special problem since, unless the food is a mobile liquid or free-flowing solid, the concentration of contaminant may be highest in the part in contact with the container. To obtain a representative sample unit it is advisable to homogenize the whole of the content of the package, adding a suitable vehicle where appropriate.

9. Dried products, such as dried fruit and vegetables, can be analysed on a dry weight basis or after reconstitution according to a standardized procedure.

10. Frozen products should be thawed, drained and equilibrated at room temperature before analysis if it is the custom to do so before cooking and consumption.

11. Products packed in syrups, water, etc., e.g. canned fruit and vegetables should either be homogenized before taking the sample units or drained and homogenized, depending on whether it is customary to consume the fluid or not.

SOURCES OF INFORMATION ON ANALYTICAL METHODOLOGY

The International Organization for Standardization (ISO): Central Secretariat, 1, rue de Varembé, Case postale 56, 1211 Genève 20, Switzerland. Information on ISO methods can also be obtained via the national standardization committees which exist in many countries.

The Association of Official Analytical Chemists (AOAC), P.O. Box 540, Benjamin Franklin Station, Washington, DC 20044, United States of America.

The International Commission on Microbiological Specifications for Foods (ICMSF) of the International Association of Microbiological Societies. Information can be obtained from Dr S. Clark, Food Technology Section, Division of Biological Sciences, National Research Council of Canada, Ottawa, Ontario, Canada KIA ORG.

The International Union of Pure and Applied Chemistry (IUPAC): Secretariat, Bank Court Chambers, 2/3 Pound Way, Cowley Centre, Oxford, England.

The Codex Alimentarius Committee on Pesticide Residues, The Codex Alimentarius Committee on Food Hygiene and the Codex Alimentarius Committee on Methods of Analysis and Sampling: information on the work of these Committees can be obtained via the national Codex Contact Points.

The Nordic Committee on Food Analysis: Secretariat, c/o Swedish National Food Administration, Box 622, S-751 26 Uppsala, Sweden.

The International Commission for Uniform Methods of Sugar Analysis (ICUMSA). Information can be obtained via Mr D. Hibbert, British Sugar Corporation Ltd, Central Laboratory, P.O. Box 35, Whart Road, Peterborough PE2 9PU, United Kingdom.

The International Dairy Federation (IDF): Secretary-general: P. Staal, 41 sq Vergote, 1040 Brussels, Belgium.

The International Federation of Fruit Juice Producers (IFJU), 10, rue de Liège, F-75009, Paris 9e, France.

The International Vine and Wine Office (IWO): Director R. Protin, 11, rue Roquépine, 75-Paris 8e, France.

The International Office of Cocoa and Chocolate (OICC): Dr H. W. Buser, Chocolat Tobler AG., Länggess-Strasse 51, Postfach, CH-3001 Berne, Switzerland.

Pesticide Analytical Manual (Volumes I and II), Food and Drug Administration, Office of the Associate Commissioner for Compliance, 5600 Fishers Ave., Rockville, Maryland 20852, United States of America.

SOME RECOMMENDED METHODS OF ANALYSIS FOR LEAD, CADMIUM, MERCURY AND ARSENIC IN FOODSTUFFS

Lead

For reviews of current methods of determining lead in foods see the Report of the Ninth Session of the Codex Committee on Methods of Analysis and Sampling (ALINORM 76/23), the Report of the Expert Consultation on the Joint FAO/WHO Food Contamination Monitoring Programme - Identification of Contaminants to be Monitored and Recommendations on Sampling Plans and Methodology, Rome, 7-11 October 1974. FAO-ESN: MON/74.21 Report WHO-FAD/FCM/74.21 and the Report of a Joint FAO/WHO Expert Consultation on Methods of Sampling and Analysis of Contaminants in Food, Rome, 12-16 January, 1976. FAO Food Control Series No. 3, WHO Food Control No. 3, or, preferably, Schuller, P. L. & Egan, H. (1976) Cadmium, lead, mercury and methylmercury compounds. A review of methods of trace analysis and sampling with special reference to food, FAO, Rome.

Instrumental methods, polargraphy and atomic absorption spectrophotometry (AAS) are generally more reliable than colorimetric methods at lower concentrations. If facilities for AAS are available it is recommended that such methods be used, if not a procedure based on the colorimetric determination of lead as the dithizone complex should be used.

The following methods are recommended:

1. The Association of Official Analytical Chemists (AOAC) method based on AAS after wet oxidation or dry ashing (Official Methods of Analysis of the AOAC 1975, 12th edition 25.060-25.064 - general method and 25.065-25-086 - special method for evaporated milk and fish).

2. If equipment for AAS is not available, the following procedures based on colorimetric determination of lead as the dithizone complex, after suitable pretreatment, are recommended: Official Methods of Analysis of the AOAC 1975, 12th edition 25-088-25.101. A number of alternative pretreatment procedures are given for use with foods containing bismuth, tin, etc.

3. The International Federation of Fruit Juice Producers (IFJU) Method No. 14, based on wet ashing of the sample with nitric then sulfuric acid, extraction of lead as the dithizone complex with chloroform and, after acidification with dilute nitric acid, determination of the lead as the lead-dithizone complex, is recommended for fruit juices.

4. The International Commission for Uniform Methods of Sugar Analysis - Methods of Sugar Analysis 1964 - p. 48(c) method, based on wet ashing with perchloric acid, with sulfuric acid or nitric acid when calcium is present, followed by a procedure involving colorimetric determination as the lead-dithizone complex, is recommended for sugars.

5. The Nordic Committee on Food Analysis (NMKL) method (Method 46), based on colorimetric determination of lead as the dithizone complex.

Cadmium

For reviews of current methods of determining cadmium in foods see the publications cited above under "lead".

The following methods are recommended:

1. The Association of Official Analytical Chemists (AOAC) method based on AAS after digestion with nitric acid, sulfuric acid and hydrogen peroxide and extraction with dithizone (Official Methods of Analysis of the AOAC 1975, 12th edition 25.026-25.030).

2. If facilities for the above AAS method are not available, the AOAC procedure (Official Methods of Analysis of the AOAC 1975, 12th edition 25.021-25.025), based on the colorimetric determination of cadmium as the dithizone complex is recommended for levels of 1 mg/kg or more.

3. The Nordic Committee for Food Analysis method (Method 51) based on colorimetric determination of cadmium as the dithizone complex is also recommended for levels of 1 mg/kg or more, if AAS facilities are not available.

Mercury

For reviews of current methods of determining mercury in foods see the publications cited above under "lead".

It has been established that mercury found as a contaminant in fish is almost exclusively present in the form of methylmercury. However, for most food contamination monitoring studies it is quite adequate to measure total mercury and not carry out the more complicated procedures needed to measure methylmercury. If facilities for AAS are available, it is recommended that such methods be used. If not, a procedure based on the colorimetric determination of mercury as the dithizone complex can be used.

The following methods are recommended:

1. The Association of Official Analytical Chemists (AOAC) method based on AAS after wet oxidation (Official Methods of Analysis of the AOAC 1975, 12th edition 25.102-25.107) or the corresponding wet combustion method of Krinitz & Holak (J. Assoc. Off. Anal. Chem., 1972, 55, 741).

2. If facilities for AAS are not available the AOAC dithizone colorimetric method (Official Methods of Analysis of the AOAC, 12th edition 1975, 25.108-25.115) is an acceptable alternative.

Arsenic

For review of current methods of determining arsenic in foods see the Report of the Ninth Session of the Codex Committee on Methods of Analysis and Sampling (ALINORM 76/23).

The following method is recommended:

The Association of Official Analytical Chemists (AOAC) colorimetric silver diethyldithiocarbamate method (Official Methods of Analysis of the AOAC 1975, 12th edition 25.006-25.009, 25.012-013).

Standard reference materials. At present samples of orchard leaves, bovine liver and spinach containing certified levels of mercury, lead, zinc and certain other trace elements are available from the US National Bureau of Standards. Standard wheat flour reference material will soon be available from the same source.

Note: Dry ash-anodic stripping voltammetry methods for lead and hydride-AAS methods for arsenic and selenium are under development and should offer improvements over the currently recommended methods.

## SOME RECOMMENDED METHODS OF ANALYSIS FOR PESTICIDE RESIDUES AND PCBS IN FOODSTUFFS

For reviews of current methods of determining pesticide residues and PCBs in foods see the Report of the Expert Consultation on the Joint FAO/WHO Food Contamination Monitoring Programme - Identification of Contaminants to be Monitored and Recommendations on Sampling Plans and Methodology, Rome, 7-11 October 1974, FAO/ESN: MON/74.21 Report, WHO-FAD/FCM/74.21 and the Report of a Joint FAO/WHO Expert Consultation on Methods of Sampling and Analysis of Contaminants in Food, Rome, 12-16 January, 1976, FAO Food Control Series No. 3, WHO Food Control No. 3. The Report of the Ninth Session of the Codex Committee on Pesticide Residues (CCPR) contains a list of suitable methods of analysis prepared by a CCPR Ad-hoc Working Group.

Multiresidue techniques based on the Mills extraction and clean-up procedure (Mills et al., J. Assoc. Off. Anal. Chem., 1972, 55, 39) followed by gas-liquid, paper or thin-layer chromatography have gained wide acceptance. The AOAC methods based on this procedure (Official Methods of Analysis of the AOAC 1975, 12th edition 29.001-29.032) are recommended. These methods enable the estimation of residues of i.a. DDT and its metabolites, BHC isomers, endrin, heptachlor and its epoxide, dieldrin and aldrin, methoxychlor and HCH.

The US Food and Drug Administration's Pesticide Analytical Manual Vol. I contains further information on the behaviour of pesticides in multiresidue schemes of analysis.

ISO has published a draft international standard for the determination of organochlorine pesticide residues in milk and milk products (ISO/DIS 3890) based on the multiresidue technique.

The AOAC multiresidue technique has been validated for the following food-pesticide combinations:

| Compound | Foods |
|---|---|
| Dieldrin<br>Heptachlor epoxide | Group I, nonfatty foods,[a] dairy products, fish, vegetable oils |
| BHC<br>p,p' -DDE<br>p,p' -DDT<br>p,p' -TDE (DDD) | Group I, nonfatty foods,[a] dairy products, fish |
| Lindane<br>Methoxychlor<br>Perthane | Group I, nonfatty foods,[a] dairy products |
| Aldrin<br>Endrin<br>Heptachlor<br>Mirex | Group I, nonfatty foods[a] |
| o,p' -DDT | Dairy products |

[a] Group I, nonfatty foods: apples, apricots, barley, beets, bell peppers, broccoli, cabbage, cantaloupes, cauliflower, celery collard greens, corn meal and silage, cucumbers, eggplant, endive, grapes, green beans, hay, kale, mustard greens, oats, peaches, pears, peas, plums, popcorn, potatoes, radish tops, spinach, squash, strawberries, sugar beets, sweet potatoes, tomatoes, turnips, turnip greens, wheat.

| Compound | Foods |
|---|---|
| Diazinon<br>Ethion<br>Malathion<br>Me parathion<br>Parathion<br>Ronnel | Group II, nonfatty foods[a] |

PCBs can be detected by modifications of the above method, for example the procedures reported in the following papers:

Armour, J. A. & Burke, J. A. (1970) Methods of separating PCBs from DDT and its analogues, JAOAC, 53, 761-768

Westöö, C. & Norén, K. (1970) Determination of organochlorine pesticides and PCBs in animal foods, Acta chem. scand., 24, 1639-1644

Jensen, S., Johnels, A. G., Olsson, M. & Otterlind, G. (1972) DDT and PCB in herring and cod from the Baltic, the Kattegat and the Skagerrak, Ambio Special Report No. 1, 71-85, Royal Swedish Academy of Sciences

Quantitation of PCBs should be effected by comparing the size of the chromatographic detector response for the sample with that for the commercial PCB with the most similar GLC pattern or by using pp' -DDE as reference standard.

For other methods of analysis the reader is referred to the references given by the CCPR Ad hoc Working Group (see above). Further valuable sources of information on pesticide residue analysis are the US Food and Drug Administration's Pesticide Analytical Manual (Vol. I, multiresidue methods as noted above and Vol. II, single compound methods available for enforcement of United States tolerances for residues in foods), the "Guidelines on Analytical Methodology for Pesticide Residue Monitoring" published by the Federal Working Group on Pest Management, Washington, D.C. 20460, United States of America and the Canadian Department of National Health and Welfare publication "Analytical Methods for Pesticide Residues in Foods".

It is important to report the recovery factor together with the analytical results and, in the case of PCBs, to state which analytical reference standard has been used, e.g. an individual commercial PCB preparation or pp'-DDE. The limit of quantitation of the method as applied to the study should also be reported.

The identity of pesticide and PCB residues should be confirmed, when appropriate, by comparing their behaviour in various chromatographic systems, before and/or after treatment with appropriate chemical agents, with that of reference standards.

Reference standards of good quality are not readily available for many pesticides and the situation is even worse for many metabolites. Reference standards of some pesticides are available from the following sources: Division of Chemical Standards, National Physical Laboratory, Teddington, Middlesex TW 11 OLW, England.

Pesticides Reference Standard Section, Chemistry Branch, Registration Division, Room 5175 South Agriculture Building, Environmental Protection Agency, Washington, D.C. 20460, United States of America.

National Environmental Research Center, Chemistry Branch, Pesticides and Toxic Substances Effect Laboratory, Research Triangle Park, North Carolina, 2711, United States of America.

---

[a] Group II, nonfatty foods: Group I, nonfatty foods marked with an asterisk (*) plus carrots, green peppers, and lettuce.

## SOME RECOMMENDED METHODS OF ANALYSIS FOR AFLATOXINS IN FOODSTUFFS

The aflatoxins constitute a closely related group of toxic secondary metabolites of certain moulds belonging to the Aspergillus flavus group. From a food safety point of view, five toxins are of concern: aflatoxins $B_1$, $B_2$, $G_1$, $G_2$ and $M_1$.

For reviews of current methods of determining aflatoxins in foods see the Report of the Expert Consultation on the Joint FAO/WHO Food Contamination Monitoring Programme - Identification of Contaminants to be Monitored and Recommendations on Sampling Plans and Methodology, Rome, 7-11 October 1974, FAO-ESN: MON/74.21 Report WHO-FAD/FCM/74.21 and the Report of a Joint FAO/WHO Expert Consultation on Methods of Sampling and Analysis of Contaminants in Food, Rome, 12-16 January 1976, FAO Food Control Series No. 3, WHO Food Control No. 3. The methods recommended below are those recommended by these expert consultations.

The aflatoxins are intensely fluorescent when exposed to long-wave UV-illumination and as little as 5-10 g can be detected on thin-layer chromatograms in this way. This forms the basis for practically all the chemical methods for their detection. Quantitative TLC methods designed specifically for each commodity have been developed and tested in collaborative studies. The identity of the mycotoxin estimated by quantitative TLC methods should be confirmed by a suitable technique devised for this purpose.

More recently, minicolumn chromatography methods for qualitative detection which are less time-consuming and can be used at the field level where sophisticated equipment is not available, have been developed. One such procedure, the "Romer method" is applicable to a wide range of commodities and is most valuable as a rapid screening method. Samples giving a positive result in this test should then be analysed by a quantitative TLC method.

The following methods are recommended:

### Screening method

The Romer method (Romer, T. R. (1975) J. Assoc. Off. Anal. Chem., 58, 500) has been studied collaboratively (Romer, T. R. & Campbell, A. D. J. (1976) J. Assoc. Off. Anal. Chem., 59, 110) and adopted by the AOAC /Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.A01-26, A08 (Changes in Methods)/. This method is recommended as a screening method for total aflatoxins in food in general at levels of 10 or more µg/kg.

### Quantitative TLC methods

The CB method (Official Methods of Analysis of the AOAC, 12th edition, 1975 26.014-26.019) and the BF method (Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.020-26.024) are more or less equivalent except at the lower limit of detection and are recommended at levels down to 5 µg total (B + G) aflatoxins/kg.

The confirmatory method of Przybylski (J. Assoc. Off. Anal. Chem., 1975, 58, 163), which has been studied collaboratively for peanut butter /Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.A17 (Changes in Methods)/, is recommended for use in conjunction with either method.

### Cottonseed and cottonseed products

The Rapid Cottonseed Method /Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.A09 26.A16 (Changes in Methods)/, also adopted by the American Oil Chemists' Society, is recommended at levels down to 10 µg total (B + G) aflatoxins/kg in nonammoniated cottonseed products.

Corn (maize), soyabeans

The CB method (Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.037-26.039), also adopted by the American Association of Cereal Chemists, is recommended at levels down to 20 µg total (B + G) aflatoxins/kg.

Copra, copra meal, coconut

The CB method (Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.032-26.036), also endorsed by IUPAC and the American Oil Chemists' Society, is recommended at levels down to 35 µg aflatoxin $B_1$/kg.

Tree nuts

The CB and BF methods (Official Methods of Analysis of the AOAC, 12th edition 1975, 26.014-26.019 and 26.020-26.024 respectively) are recommended.

Milk

The Stubblefield modification of the Jacobson method (IUPAC Information Bulletin - Technical Report No. 11, 1974 or Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.084-26.087) is recommended for levels down to 0.1 µg of aflatoxin $M_1$/l of fluid milk.

The Purchase and Steyn method, as published by IUPAC and adopted by the AOAC (Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.088-26.089) is recommended for levels down to 0.5 µg of aflatoxin $M_1$/kg in dried milk.

The confirmation test for aflatoxin $M_1$ based on the formation of a hemiacetal derivative (Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.090) is recommended for amounts of aflatoxin $M_1$ of one or more nanograms.

Cocoa beans

The Scott method adopted by the AOAC (Official Methods of Analysis of the AOAC, 12th edition, 1975, 26.025-26.031) and also accepted by IUPAC is recommended at levels of 45 or more µg/kg.

Aflatoxin reference standards

Aflatoxin standards are available from inter alia: Rijksinstituut voor Volkgezondheit, P.O. Box 1, Bilthoven, The Netherlands, Makor Chemicals Ltd, Box 6570, Jerusalem, Israel, Senn Chemicals, CH-8157 Dielsdorf, Switzerland.

IARC aflatoxin check sample programme

The International Agency for Research on Cancer in Lyon, France, is running an aflatoxin check sample programme.

METHODS OF SAMPLING AND EXAMINATION OF FOOD AND FOOD ANIMALS FOR FOOD-BORNE PARASITIC INFECTIONS[a]

| Parasite | Food involved | Sampling and examination methods for food and food animals |
|---|---|---|
| A. INFECTIVE STAGE IN FOOD ANIMALS | | |
| Taenia saginata | Beef | Individual inspection: (1) direct examination of predilection site of cysticercus; (2) latex test with fractionated antigen; (3) indirect haemagglutination test. |
| Taenia solium | Pork | |
| Diphyllobothrium latum | Fish | Random sampling: direct examination of fish for plerocercoid. |
| Clonorchis sinensis | Fish | |
| Opisthorchis felineus and Opisthorchis viverrini | Fish | |
| Paragonimus westermani | Crayfish and crab | Random sampling: microscopic examination for metacercariae |
| Echinostoma iliocanum | Snail | |
| Heterophyes heterophyes | Fish | |
| Trichinella spiralis | Pork, bear meat, and meat of some sea mammals | Individual inspection: (1) direct microscopic examination of samples from diaphragma: (2) digestion method (microscopic examination of muscle digested by pepsin and hydrochloric acid) |
| Fasciola hepatica and F. gigantea | Aquatic plants, watercress | (1) Visual and microscopic examination for metacercariae and eggs; (2) visual examination of liver and lungs of food animals. |
| Dicrocoelium lanceolatum | Vegetables | (1) Visual examination of vegetables for ants; (2) visual examination of liver and lungs of food animals. |
| Fasciolopsis buski | Aquatic plants | Microscopic examination of plants for metacercariae |
| Ascaris lumbricoides | Raw vegetables, fruit, and water | Microscopic examination of the food. |
| Toxocara cati and T. canis | Vegetables and water | Microscopic examination of the food. |

METHODS OF SAMPLING AND EXAMINATION OF FOOD AND FOOD ANIMALS FOR FOOD-BORNE PARASITIC INFECTIONS[a] (continued)

| Parasite | Food involved | Sampling and examination methods for food and food animals |
|---|---|---|
| Dracunculus medinensis | Water | (1) Visual examination for cyclops; (2) microscopic examination for microfilaria in cyclops. |
| Capillaria hepatica | Liver | Microscopic examination of liver. |
| Trichostrongylus spp. | Vegetables and water | Microscopic examination. |
| Trichuris trichiura | Any foods contaminated with soil | Microscopic examination. |
| Moniliformis moniliformis | Various foods | Visual examination of food for cockroaches |
| Diptera, e.g., Piophila casei | Various foods | Microscopic examination of food for larvae |
| Musca domestica | | |
| Stomoxys calcitrans | | |
| Anisakis spp. | Fish | Random sampling: (1) direct microscopic and microscopic examination; (2) digestion method. |
| Dicotophyme renale | Fish | Random sampling: visual examination of fish for larvae |
| Gnathostoma spinigerum | Fish, flesh of snake and birds | Random sampling: visual examination. |
| Angiostrongylus cantonensis | Molluscs and snails | Random sampling: microscopic examination. |
| Toxoplasma gondii | Meat and uncooked food contaminated with oocysts from cat faeces | Random sampling: (1) dye test; (2) indirect complement fixation test; (3) indirect haemagglutination test. |
| Sarcocystis spp. | Muscle of sheep and other herbivores | Microscopic examination. |
| Linguatula serrata | Liver | Individual inspection: visual examination of liver and lymph nodes. |

METHODS OF SAMPLING AND EXAMINATION OF FOOD AND FOOD ANIMALS FOR FOOD-BORNE PARASITIC INFECTIONS[a] (continued)

| Parasite | Food involved | Sampling and examination methods for food and food animals |
|---|---|---|
| B. INFECTIVE STAGE IN THE ENVIRONMENT (PASTURES, FOOD PLANTS, AQUATIC FOODS, WATER, ETC.) AND IN FOOD HANDLERS | | |
| Echinococcus granulosus | Any contaminated raw food | (1) Microscopic examination of contaminated foods; (2) visual examination of carcasses and organs of food animals (not directly infective for man). |
| Echinococcus multilocularis | Raw fruit and vegetables | (1) microscopic examination of contaminated foods; (2) visual examination of carcasses and organs of food animals. |
| Multiceps spp. | Vegetables | Random sampling: microscopic examination of vegetables for eggs. |
| Hymenolepis diminuta | Grain and cereals | Random sampling: microscopic examination for eggs. |

[a] Based on Annex 2 to the Report of a WHO Study Group. Food-Borne Disease: Methods of sampling and examination in surveillance programmes, Wld Hlth Org. techn. Rep. Ser. No. 543, Geneva, 1974.

SOME RECOMMENDED METHODS OF ANALYSIS FOR BACTERIAL CONTAMINANTS IN FOODSTUFFS

For reviews of methods of analysis for bacterial contaminants, especially Salmonella, in foodstuffs the reader is referred to the Report of the Joint FAO/WHO Expert Consultation on Microbiological Specifications for Foods held in Geneva from 7 to 11 April 1975 (EC, Microbiol/75/Report 1, FAO, Rome, 1975). The ICMSF publication "Microorganisms in Foods. I. Their significance and methods of enumeration", second edition, Toronto University Press, 1978 and the compendium of Methods for the Microbiological Examination of Foods, APHA Intersociety/Agency Committee on Microbiological Methods for Foods, American Public Health Association, Washington, D.C. 20036 (1976) are valuable reference works for methodology for bacterial contaminants.

Food-borne disease bacteria

Salmonella

(a) The ICMSF methods[a] for the isolation and identification of Salmonella are recommended.

(b) For meat and meat products the International Organization for Standardization method (ISO International Standard 3565 - 1975) is recommended. Modifications of this method can be used for other foods.

(c) For eggs and egg products, the reference method for the detection of salmonellae given in Annex 5 to the above-mentioned report of the Joint FAO/WHO Expert Consultation on Microbiological Specifications for Foods, or the AOAC method (Official Methods of Analysis of the AOAC, 12th ed., 1975, 46.013-46.026) is recommended. The former method is a modification of the above-mentioned ISO method for meat and meat products.

(d) For dried milk products the AOAC method (Official Methods of Analysis of the AOAC, 12th ed., 1975, 46.013-46.026) is recommended.

Other food-borne disease bacteria

The ICMSF methods for examination of foods for the following bacteria (and in some cases their toxins) are recommended:

(a) Shigella: isolation and biochemical and serological screening for.

(b) Enteropathogenic escherichea coli: enrichment, isolation and identification of.

(c) Vibrio parahaemolyticus: isolation, enumeration and identification of.

(d) Vibrio cholerae: isolation, serological screening and biochemical screening and confirmation for.

(e) Staphylococcus aureus: enumeration of coagulase-positive staphylococci, testing for coagulase production, testing for thermostable nuclease production. Staphylococcal enterotoxins: serological detection, production of enterotoxin by staphylococcal isolates, extraction and detection of enterotoxin in foods.

(f) Clostridium botulinum: screening test for detection, direct cultural procedure for detection, isolation of causative organism in implicated foods.

---

[a] All the ICMSF methods are to be found in "Microorganisms in Foods. I. Their significance and methods of enumeration", second edition, Toronto University Press, 1978.

(g) Clostridium perfringens: enumeration, isolation and identification of.

(h) Bacillus cereus: enumeration of presumptive B. cereus, confirmation.

(i) Enterococci: enumeration of presumptive enterococci, confirmation.

(j) Faecal streptococci: enumeration of presumptive faecal streptococci, confirmation.

(k) Haemolytic streptococci: examination for.

The following AOAC methods for the examination of foods for certain food-borne disease bacteria are recommended (these have been published in the Official Methods of Analysis of the AOAC, 12th ed., 1975):

(a) Clostridium perfringens: chilled, frozen, precooked or prepared foods.

(b) Haemolytic staphylococci: eggs and egg products.

(c) Coagulase-positive Staphylococcus aureus: chilled, frozen, precooked or prepared foods.

(d) Streptococci: eggs and egg products.

The Nordic Committee on Food Analysis has published methods for, amongst others, the following food-borne disease bacteria:

(a) Pathogenic haemolytic streptococci: milk and milk products.

(b) Sulfite - reducing clostridia: enumeration.

(c) Staphylococcus aureus: enumeration.

(d) Bacillus cereus: enumeration.

(e) Faecal streptococci: enumeration.

(f) Clostridium botulinum (and toxin) detection and determination.

The International Dairy Federation has published a method for coagulase-positive staphylococci in dried milk.

Indicator organisms

The following ICMSF methods for examining food for indicator organisms are recommended:

(a) Coliform bacteria: enumeration (determination of the most probable number), determination of coliforms of faecal origin, identification test for coliforms.

(b) Enterobacteriaceae: presence or absence test, enumeration by agar plate count method, confirmation tests.

(c) Enterococci: enumeration of presumptive enterococci, confirmation.

(d) Viable spores: enumeration.

The following AOAC methods for examining foods for indicator organisms (see Official Methods of Analysis of the AOAC, 12th ed., 1975) are recommended:

(a) Coliform organisms: eggs and egg products, chilled, frozen, precooked or prepared foods and tree nut meats.

(b) Escherichia coli: chilled, frozen, precooked or prepared foods and tree nut meats.

The International Organization for Standardization has published a number of international standards and draft international standards for methods of examining foods for indicator organisms:

(a) Aerobic count at 30°C - meat and meat products. International Standard ISO 2293 - 1976.

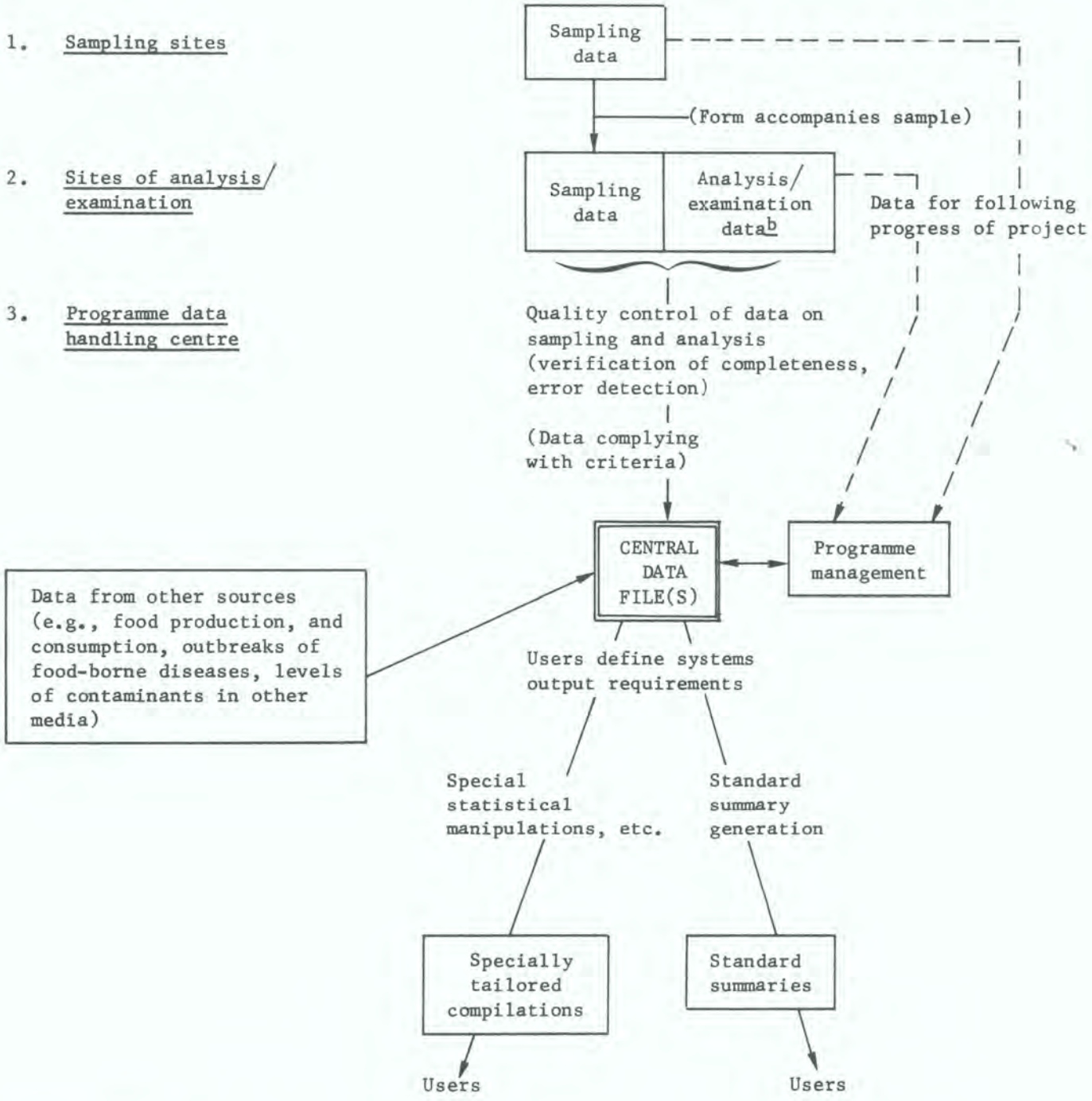
(b) General guidelines for enumeration of coliforms - most probable number technique. Draft International Standard ISO/DIS 4831.

(c) General guidelines for enumeration of coliforms - colony count technique. Draft International Standard ISO/DES 4832.

The Nordic Committee on Food Analysis has published methods for coliforms, thermotolerant coliforms, total bacteria (milk, cream, ice cream products and meat and certain meat products).

The International Dairy Federation has published methods for colony counts and coliform counts in milk and various milk products.

SUGGESTED GENERAL OUTLINES OF A SYSTEM FOR HANDLING DATA[a] IN A NATIONAL MONITORING PROGRAMME




[a] Concerning data indicating a need for immediate action see p. 32.

[b] Including simple statistical manipulations (e.g., calculation of means and dispersion).

GENERAL CONSIDERATIONS ON THE USE OF COMPUTERS FOR DATA HANDLING AND STORAGE IN FOOD CONTAMINATION MONITORING PROGRAMMES

1. If computers are to be used, adequate provisions for trained personnel and hardware and software must be made well in advance so that the computer can be operational and the staff adequately trained before large volumes of data require processing.

2. The development of a computer-based system for data handling should be entrusted to experts in the field of systems analysis, computer technology and programming. A user's manual must be developed if data is to be transmitted from several remote terminals.

3. High level, standard programming languages such as FORTRAN, COBOL, etc. should be used in implementing the system.

4. Full systems and programming documentation should be insisted upon. This reduces the impact of turnover of systems personnel and facilitates modifications and transfer from one computer to another.

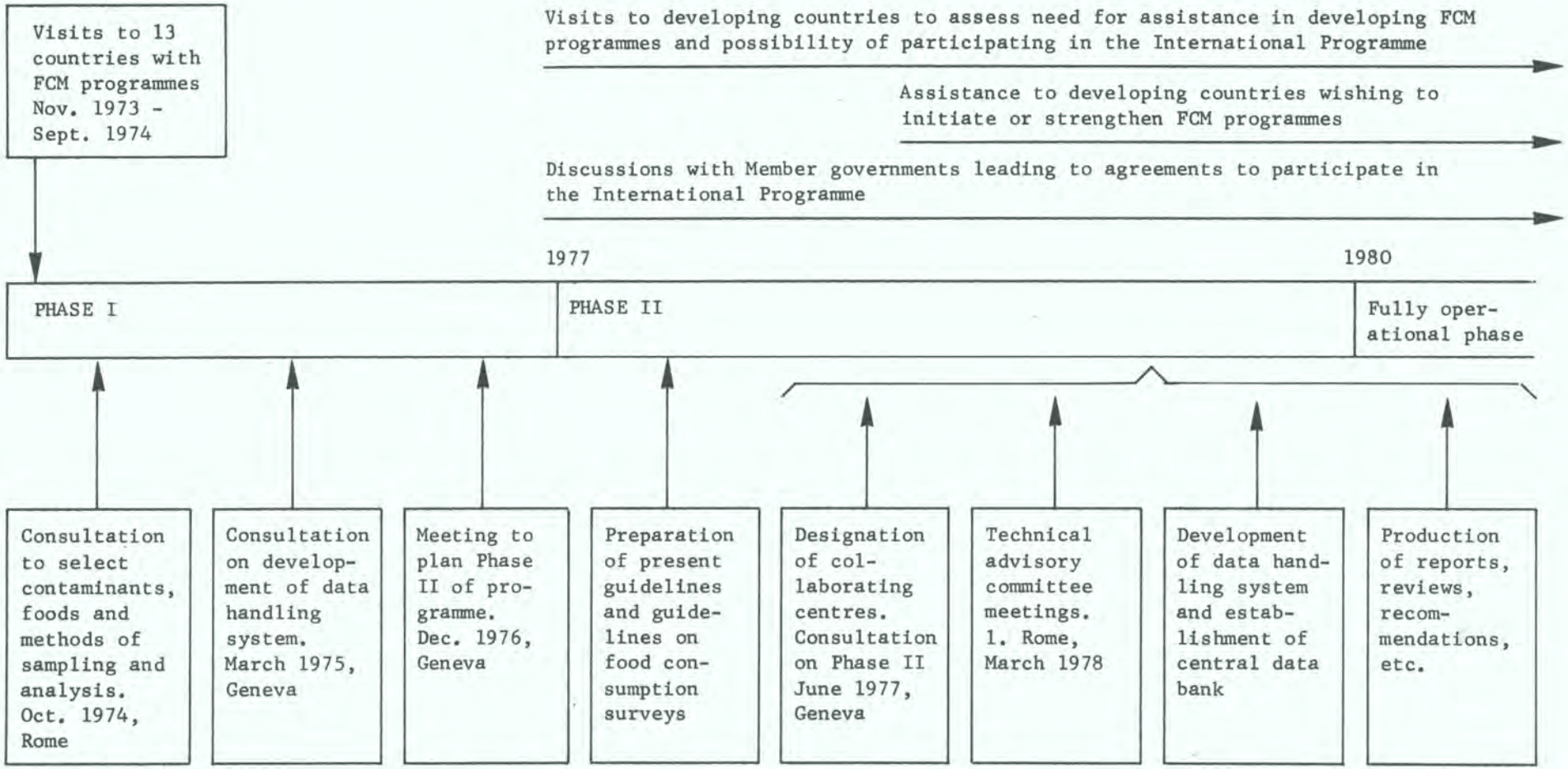
5. If a small capacity computer is to be used initially it should be such that conversion to a larger system can proceed smoothly with the minimum of programme modifications. Furthermore, growth should entail the addition, but very little replacement, of hardware.

6. The need for editing of the data before it enters the main data file is even more important when computers are used than in manual systems. The techniques available for this range from simple human verifications of complete listing of values, range and symbol checks, etc. to sophisticated statistical routines to detect outliers. In addition, since some errors will inevitably find their way into the file in spite of editing, a full set of file change procedures must therefore be part of the system. These include the capability to add, delete or change individual data records.

7. In addition to the computer data file(s), a hard copy file containing all the detailed data on sampling and analysis should be maintained at the Programme Data Handling Centre.

8. If the necessary resources are available, the best computer-based system would probably involve data entry from a network of remote interactive terminals situated at various strategic locations around the country, especially in the laboratories taking part in the programme. However, there will always be a need for data entry capability at the Programme Data Handling Centre. This type of system should be ideal for programme management purposes. The computer system to which these terminals are connected should accept data in a conversational mode, i.e. when the terminal operator has identified him/herself the computer will stepwise instruct him/her as to the data which is required next. In addition to speed of transmission of data, such an arrangement has the important advantage that it permits on-line editing: all errors which are detectable by computer (e.g., a contaminant name not on the standard list of such names) may be identified immediately at the time of entry.

FOOD AND ANIMAL FEED CONTAMINATION MONITORING (FCM) PROGRAMME
NETWORK PLAN FOR DEVELOPMENT ACTIVITIES



# SUMMARY OF THE MAIN CONCLUSIONS AND RECOMMENDATIONS OF THE EXPERT CONSULTATION TO IDENTIFY THE CONTAMINANTS TO BE MONITORED AND RECOMMEND METHODS OF SAMPLING AND ANALYSIS[a] FOR THE JOINT FAO/WHO FOOD CONTAMINATION MONITORING PROGRAMME HELD IN ROME, 7-11 OCTOBER 1974

## 1. SELECTION OF CONTAMINANTS AND FOODS FOR THE INITIAL PHASE OF THE PROGRAMME

### 1.1 Chemical contaminants

The meeting reviewed the GEMS food pollutant priorities list (UNEP Governing Council, March 1974) and in the light of national activities recommended that the Programme should include selected chemical contaminants belonging to the categories of heavy metals, agricultural and industrial contaminants and mycotoxins. One important criterion for selection of a contaminant should be the knowledge that it is monitored in on-going national monitoring programmes. Other criteria considered include feasibility of monitoring, likelihood of national or institutional collaboration, possibility of control of hazard from the contaminant, and socioeconomic and technological impact.

Having regard to the above criteria, the following contaminants were selected from existing on-going monitoring programmes in the countries considered:

Heavy metals

(a) Mercury in fish and other edible aquatic organisms. The meeting decided that fish was the only commodity for which data need be included in the Programme since mercury has not been found in any other staple food in significant amounts. It was of the opinion that according to current evidence in almost all cases, about 90% of trace mercury in samples of aquatic origin is in the form of methyl mercury compounds. However, as the methodology for methyl mercury compounds is more complicated than the basic atomic absorption spectrophotometric methods for total mercury, the meeting agreed that the objectives of the Programme will be served by monitoring total mercury.

(b) Lead and cadmium in canned foods (especially lead in foods preserved in cans with soldered side seams), in grains or cereal products according to dietary habits, in edible aquatic organisms, in potatoes and other staple carbohydrate products of local importance and in apples.

In the case of canned foods, the meeting recognized the problem of deciding whether the whole contents of the can should be used or merely the drained produce. It agreed that a decision should be based upon the portion usually eaten. Similarly, for other products analysis should be based on the raw commodity as prepared for cooking or consumption.

The meeting also discussed the question of monitoring milk and milk products for lead, cadmium and mercury. Although it recognized this as especially important for infants, the results of surveys have shown that milk is not generally contaminated with these metals. The meeting did not therefore consider it suitable for the Programme.

Organochlorine compounds

Organochlorine compounds in milk and dairy products, eggs, meat, cereals, fish, fruit and vegetables, all as in retail trade, but prepared for cooking or consumption. The meeting considered that human milk should also be included in the Programme.

---

[a] Copies of the complete report of the Consultation (reference FAO-ESN:MON/74.21: WHO-FAD/FCM 74.21) can be obtained from WHO (Environmental Health Criteria and Standards) or FAO (Food Policy and Nutrition Division).

The individual compounds to be monitored include pp'-DDT and dieldrin when measured by the multi-detection methods (see 2.2). These methods will also estimate metabolites of DDT, BHC isomers, endrin, heptachlor and its epoxide, aldrin, methoxychlor, HCB and HCH, as well as other organochlorine compounds, including PCBs.

Mycotoxins

Aflatoxins $B_1$, $B_2$, $G_1$ and $G_2$ in nuts and nut products, and cereals, particularly maize.

It was recognized that sampling was a particular problem for monitoring of aflatoxins. The meeting recommended the use of the United States sampling method for peanuts, though sampling procedures need to be studied in much more detail for other commodities. Monitoring for aflatoxins in food of animal origin (milk and meat) was not recommended because the selected method is not satisfactory for these commodities.

Comments on other contaminants

The meeting stressed that contaminants not included in the initial phase may nonetheless be of high priority from the health point of view and that research programmes relating to these should continue. In addition, other contaminants such as other mycotoxins (ochratoxins, sterigmatoxystin, zearalenone), selenium, polynuclear aromatic hydrocarbons, nitrates and nitrites and nitrosamines may be of importance and be considered for inclusion in the Programme at a later stage. Nitrosamines are being studied by the International Agency for Cancer Research. The methodology for nitrosamines, while well advanced, is still being examined and the full significance of the occurrence of trace amounts of these compounds is being evaluated. Nitrates and nitrites, though on the GEMS priority list, were not selected by the meeting for inclusion in the Programme at this stage since the latter is primarily based on existing national programmes. This matter might be brought to the attention of national governments.

1.2 Biological contaminants

Since the Programme is to be restricted to those contaminants of direct public health concern which are monitored in on-going national programmes, it is necessary to give first priority to those microorganisms causing food-borne diseases. By using these criteria the number suitable for inclusion in the Programme is greatly restricted. Members of the genus Salmonella and three parasitic species, namely, Trichinella spiralis, Cysticercus bovis and Echinococcus granulosus have been selected.

Salmonella

The degree of hazard presented by foods containing salmonellae will depend upon several factors, such as the type of food and the level of awareness of food hygiene among food handlers. Raw products such as raw meats, poultry, frog legs are often contaminated with salmonellae. Handling and processing practices have been established which are applicable for the protection of consumers against infection, even when such contaminated foods are brought directly to the homes. The important consideration is that those involved are aware of these measures. Accordingly, only processed foods likely to be consumed without further treatment designed to provide reasonable assurance of destroying any salmonellae present are considered appropriate for inclusion in the Programme. Universal agreement on the list of selected foods is not to be expected. The following food commodities were selected for inclusion - the list will be updated in the future in light of new developments:

(a) meat and meat products excluding shelf-staple cured or uncured meats; perishable cured canned meats; sausages cooked, uncooked or fermented, dried or semi-dried;

(b) poultry and poultry products, excluding canned products;

(c) liquid eggs and dried egg products;

(d) dried milks and dried whey;

(e) shellfish.

In addition, animal and marine rendered products and pelletized feeds might be considered for inclusion at a future date.

Parasitic infections in food-animals have been monitored since the end of the last century. Special emphasis throughout the world has been given to Trichinella spiralis, Cysticercus bovis and Echinococcus granulosus. Trichinosis is still a disease problem in North America and in some European countries, cysticercosis is a serious problem in Africa and to a lesser degree in Europe, and echinococcosis is especially prevalent in South America and some Mediterranean areas. Monitoring for such parasites is performed daily in slaughter houses in many countries. Examination for trichina is confined to pigs and for C. bovis to cattle, whereas various slaughtered animals are examined for E. granulosus. The nature and extent of monitoring depends largely upon the type and extent of infection in any particular country. Due to increasing trade in meat, monitoring programmes for these infections would give important information and might even be helpful in disease control. Since these infections pose a public health problem and are being monitored in many countries, the above parasites should be included in the Programme.

Comments on other contaminants

Microbial indicator species and groups, e.g. aerobic plate counts, coliforms, moulds and yeasts, are usefully monitored in supporting programmes designed to assess hygienic food manufacturing and handling practices, but little would be accomplished by their inclusion in the Programme.

Clostridium perfringens, Staphylococcus aureus, Bacillus cereus, Clostridium botulinum and Vibrio parahaemolyticus are microbiological contaminants to be excluded from the Programme. These species are ubiquitous in many environments and foods. None of them when found in food constitutes an imminent danger to health, although there is a potential danger provided a certain quantitative level is attained. Such large populations of these agents are a prerequisite either because of the relatively low virulence of infectious species or for the formation of toxins. In foods handled under normal conditions, the presence of such large populations is not likely.

Monitoring for certain mycotoxins has been discussed in section 1.1. To monitor appropriate foods for other microbial toxins, such as enterotoxins, would serve a useful purpose; however, methods presently available are much too difficult and time consuming to be applicable.

Foods have not been clearly shown to be important vehicles for transmission of viral diseases other than infectious hepatitis. Methods for detecting hepatitis virus in suspect foods, such as shellfish, are not available. Accordingly viruses are not included at this stage in the Programme.

It would seem that programmes designed to identify health hazards due to contamination of food with the above-mentioned specific organisms more properly fit into food-borne disease surveillance programmes, such as the WHO Programme of Surveillance of Food Infections and Food Poisoning of Biological Origin and the food hygiene programmes, the latter being developed within the framework of the Joint FAO/WHO Food Standards Programme.

1.3 Additional comments on foods and total diet

The meeting gave consideration to details for individual types of foods - including total diet studies, staple food, indicator food and food significant in international and regional trade - in the light of the working paper "Sampling of Food and Total Diet Studies for Food Contaminants Monitoring" prepared by A. W. Hubbard.

It was agreed that analyses should be based on items purchased on the retail market. The analyses should be conducted on samples which have been prepared for consumption and separated into logical composite groups for analytical convenience.

Total diet

The meeting noted that the total diet studies included in the national programmes reviewed related only to certain countries and represented at least two different systems of approach, based respectively on food intake and on food disappearance statistics, with dissimilar criteria for a "standard subject". It recognized the need for further dietary information, particularly from developing countries, based on well-established principles of nutritional surveys. The meeting also considered the relative value of dietary residues studies related to "average intake" and "greatest risk" and recommended that full dietary information should be collected on the basis of average intake figures. Total diet studies should thus be based on local nutritional surveys which should take full account of ethnic and other dietary variations.

Individual foods

The meeting considered in particular the selection of staple foods, which for monitoring of chemical contaminants were taken to include cereals, root crops, legumes, milk, potatoes, bread, meat and fish.

Indicator foods

Indicator foods, the analysis of which can give warning of food contamination problems, were considered to include edible marine and other aquatic organisms. Several foods selected for monitoring may be considered as indicator foods. The meeting agreed that no other foods in this category be included in the Programme at this stage. The meeting noted with interest that the FAO-GFCM (General Fisheries Council for the Mediterranean) with the support of UNEP, had included such marine and other aquatic organisms in its "Co-ordinated Mediterranean Pilot Project on Base-line Studies and Monitoring".

Foods significant in international and regional trade

Having proposed the inclusion of a number of staple food commodities in the initial phase of the Programme - many of which are of direct significance for international and regional trade - the meeting concluded that no other foods need be considered in this category at this stage.

2. RECOMMENDATIONS ON SAMPLING AND METHODS OF ANALYSIS OF CONTAMINANTS INCLUDING COMPARABILITY AND QUALITY CONTROL OF DATA

2.1 Sampling

The meeting recognized the importance of sampling operations, both as to the selection of food to be analysed and sampling of this for analysis. Special sampling requirements for aflatoxin studies and total diet surveys have been discussed in sections 1.1 and 1.3 respectively. Such special sampling requirements may in some cases be identical with those of other national programmes. For example, similar samples may be required for dietary food surveys, but not for regulatory purposes where suspect samples would be taken. In addition,

samples may be taken on a national basis or, in the case of a large country, on the basis of an appropriate regional or more local area representative of typical dietary consumption patterns. Samples relating to special problem areas where gross contamination has occurred should, if included, be clearly distinguished.

The meeting reiterated that the monitoring data should be based on random samples drawn so as to represent retail produce. It also noted that the Codex Committee on Methods of Analysis and Sampling was studying sampling plans and establishing general principles, technical methods of sampling and statistical sampling procedures for foods. Sampling plans for determination of the microbiological quality of different kinds of food have been recommended in "Sampling for Microbiological Analysis: Principles and Specific Applications".[a] The meeting recommended that sampling plans from this publication should be used for the monitoring of foods for microbiological contaminants under the Programme. The same principles could also be applied to feeds.

2.2.1 Chemical contaminants

Mercury

The meeting considered the working paper on the "Methodology for Mercury and Methyl Mercury for Food Contaminants Monitoring" prepared by G. Westöö. In the light of its earlier recommendation that total mercury only need be considered in relation to the Programme, the meeting accepted the use of an established method based on wet digestion of the sample under a reflux condenser and flameless atomic absorption spectrophotometry (AAS), e.g., the methods published by Westöö, AOAC, IUPAC and ISO. The meeting also agreed that the use of a dithizone colorimetric method, e.g. AOAC dithizone method, was acceptable as an alternative when atomic absorption spectrophotometric equipment was not available. Neutron activation analysis techniques are also acceptable.

Lead and cadmium

The meeting considered the working paper "Methodology of Lead and Cadmium for Food Contaminants Monitoring" prepared by H. Egan. It recommended that methods based on AAS should be used, e.g. the one described in the working paper. The meeting expressed a preference for digestion by wet oxidation; dry ashing was valid only for lead, for which an ashing aid (magnesium oxide or magnesium nitrate) should be used. The need to use a complexing method, as described in the paper, for the separation of lead from other metals was also stressed. Alternative methods were discussed and the dithizone procedure for cadmium was recognized as being particularly difficult. Some polarographic methods are also available and may be used if their equivalence to the selected AAS methods can be established.

Organochlorine compounds

The meeting considered the working paper "Methodology of Organochlorine Compounds including PCBs for Food Contaminants Monitoring" prepared by E. Somers and recommended the adoption of methods based on the AOAC procedure described in the working paper.

The method will enable the estimation of residues of DDT and its metabolites; endrin, heptachlor and its epoxide; dieldrin and aldrin; methoxychlor; HCB and HCH. It is essential that analytical results are reported together with the recovery factor, and in the case of PCB with information on the analytical standards used, e.g. pp'-DDE, or an individual Arochlor compound. Commercial PCB preparations from different parts of the world are not identical, and only an approximate result can be given, since the preparations may also "age" on exposure in different ways. The meeting recognized that there was need for a collaborative study of a single reference method for estimating organochlorine residue and drew attention to the study currently being organized by the Codex Committee on Pesticide Residues.

---

[a] International Commission on Microbiological Specifications for Foods (ICMSF) of the International Association of Microbiological Societies (IAMS), University of Toronto Press, Toronto, Canada (1974).

Aflatoxins

The meeting considered the working paper "Methodology of Aflatoxins for Food Contaminants Monitoring" prepared by P. Krogh. The method collaboratively studied by IUPAC is published in its Information Bulletin No. 31. It is recommended for the examination of nuts and nut products for aflatoxins $B_1$, $B_2$, $G_1$ and $G_2$ and should also be suitable for the examination of maize. A minicolumn method[a] is available and should be applicable to many foods. The meeting drew attention to the efforts of the International Agency for Research on Cancer to organize an international aflatoxin check sample programme.

2.2.2 Biological contaminants

The widely accepted method of the International Organization for Standardization for the detection of Salmonella in foods was recommended by the meeting. Three methods are available for the detection of Trichinella spiralis: trichinoscopy, a digestion method and a fluorescent antibody method. Work is in progress on a more sensitive serological method. Methods for Trichinella detection are specified in the official meat inspection laws or regulations in several countries. It is recommended that a digestion method[b] be used for the purpose of this Programme.

For detection of Cysticercus bovis and Echinococcus granulosus it is recommended that the macroscopic examination of carcasses be used.

2.3 Comparability and quality control of data

Comparability and quality control of data are critical features for the harmonization of on-going monitoring programmes. The meeting's present proposals are based on methods which have been the subject of collaborative study, preferably internationally, and such characteristics as sensitivity, reproducibility, and recovery for these methods should be available for satisfactory inter-comparison.

The meeting also stressed the need for the establishment of criteria for the acceptability of data from national programmes in the light of the analytical methodology, the sampling programme, the check sample procedure employed, etc.

The meeting recognized that many individual laboratories use their own preferred methods of analysis and sampling and that it would be some time before data produced by one laboratory would be fully comparable on an international basis with similar data produced in other laboratories. Therefore, in the early phases of the Programme before harmonization of methods had been fully achieved, an assessment of data submitted by governments on individual foods or contaminants will be required. Such study might be better undertaken by governments, perhaps on an individual contaminant basis.

3. RECOMMENDATIONS

The meeting recommended that:

1. FAO/WHO develop and implement an effective, well-administered, internationally coordinated food contamination monitoring programme, with a properly constituted central management unit and, as appropriate, regional reference laboratories with defined roles.

---

[a] Romer, J., AOAC 1975, 58, 500-506.

[b] Zimmerman et al., J. Parasit., 1961, 47, 421.

2. FAO/WHO invite governments to:

(a) provide information concerning their on-going food contaminant monitoring activities, and that information relating to these should, in due course, be published by the agencies;

(b) provide selected data from on-going food contaminant monitoring activities to be collected, evaluated and disseminated as part of the International Food Contamination Monitoring Programme.

3. A limited number of contaminants, foods, and selected methods of analysis, together with guidelines for the collection of total-diet samples and other sampling procedures, be included in the initial phase of the International Programme, as indicated in sections 1 and 2 above.

4. FAO/WHO should, in collaboration with individual governments, assess the comparability of data for individual contaminants contributed by governments to the International Programme.

5. FAO/WHO should encourage the use of recommended methods (and alternative methods indicated) and their harmonization by recognized procedures, e.g., by using check samples or standard reference materials.

6. Governments be invited to designate national contact points to which matters concerning the International Programme can be referred.

7. FAO/WHO provide, where necessary, advice and assistance in the training of the required analytical and technical personnel in order to strengthen national food contamination monitoring activities.

8. FAO/WHO provide, where necessary, technical advice and assistance to strengthen or establish effective national systems of food control necessary for the conduct of food contamination monitoring programmes.

9. Governments should initiate or, as appropriate, strengthen dietary intake studies in view of their importance for the proper conduct and evaluation of food contamination monitoring data.

10. FAO/WHO encourage the development of standards for the identification of individual lots or batches of foods which, through damage or otherwise, may constitute a hazard.

11. Close coordination be established between national governments and FAO/WHO for purposes of enhancing the identification and the reporting of food-borne disease outbreaks.

12. FAO/WHO study the existing national monitoring programmes for animal feeds with the view that they might be included in the International Programme in the future.

# SUMMARY OF THE CONCLUSIONS AND RECOMMENDATIONS OF THE EXPERT CONSULTATION ON THE DEVELOPMENT OF A SYSTEM FOR THE PROCESSING AND STORAGE OF DATA[a] FOR THE JOINT FAO/WHO FOOD CONTAMINATION MONITORING PROGRAMME HELD IN GENEVA, 17-21 MARCH 1975

In order to arrive at the recommended specifications for system design, the Consultation followed a series of logical steps. First the principal needs for, or application of, conceivable outputs from the system were identified. With these needs identified, system output requirements were developed. This, in turn, led to the development of system input requirements and the processing steps necessary to produce the required outputs. In addition, consideration was given to other steps in the system, such as criteria for the selection of data, quality control, etc.

## 1. USERS OF OUTPUT FROM THE SYSTEM

The Consultation agreed that the system would, inter alia, provide knowledge of representative baseline levels and time trends of contamination in food in individual countries or regions for the purposes of:

(a) estimating the exposure of human populations to a particular contaminant in order to determine health hazards. Estimates of total intake of a toxic substance via food is one method of assessing whether there is a risk to human health. Data from the system, when coupled with information on the amounts of individual foods habitually consumed by the population as a whole and by specific groups within the population will provide a method of estimating the contaminant intake;

(b) establishing maximal or tolerable limits in international food standards. Information on the actual levels of contaminants in different foods would enable the Codex Alimentarius Commission to evaluate the effects of setting such limits, i.e. the rate of rejection which this would involve for the producers of the commodity against the health risk;

(c) promoting better management of food and agriculture resources by appropriate pollution control activities at the national and international level and to better ensure the safety of food supplies;

(d) determining priorities for the allocation of resources for monitoring food contaminants at the national level, and, at the agency level, for the choice of substances to be evaluated, e.g. at meetings of experts and for preparation of criteria documents;

(e) comparing food contamination levels to levels found in other media due to releases of pollutants in the environment - information obtained independently of the system;

(f) the programme would also provide national authorities with a means of exchanging information on the experience and data they acquired and promote comparability of results through the exchanges of analytical samples, evaluation and intercalibration of analytical methods and agreements on common formats of presentation.

---

[a] Copies of the complete report of the Consultation (reference WHO-FAD/FCM/75.1: FAO-ESN:MON 75.1) can be obtained from WHO (Environmental Health Criteria and Standards) or FAO (Food Policy and Nutrition Division).

## 2. SYSTEM OUTPUT REQUIREMENTS

The Consultation decided that the following are essential system requirements for the preparation of outputs to meet the envisaged needs of the users, as stated above:

(a) food
(b) contaminant
(c) origin or source of food
(d) consumer population at risk
(e) level of contaminant
(f) methodology -
    (i) sampling
    (ii) analytical
(g) time.

Each of the above requirements may further define other subitem needs.

### 2.1 Food

The Consultation concluded that a system for the classification of food products at a level of detail appropriate for the intended uses of the data is required. It also stipulated additional subitem requirements which are:

(a) cooked or raw
(b) processing and preservation techniques
(c) physical form (part or portion)
(d) container material (metal, plastic, paper, glass, etc.).

### 2.2 Contaminants

According to the recommendations made by the Rome Consultation (see Appendix 16), the following contaminants have been selected as suitable for inclusion in the system output:

(a) aflatoxins (total, $B_1$, $B_2$, $G_1$, $G_2$, $M_1$, $M_2$)

(b) organochlorine compounds:
    DDT
    DDT + metabolites (specified if possible)
    HCH (BHC)
    HCH (BHC) isomers (total)
    endrin
    heptachlor and its epoxide
    aldrin and dieldrin (expressed as dieldrin)
    methoxychlor
    HCB
    PCBs[a]

(c) heavy metals (Cd, Pb, total Hg).

The system must be capable of indicating when the same group of samples has been analysed for more than one contaminant.

---

[a] Expressed by three eluants (6% ethyl ether or 20% methylene chloride in hexane) and separated from co-eluted organochlorine pesticides by chromatography on silicic gel, as discussed in the working paper of the Rome meeting by Dr E. Somers (WHO-FAD/FCM/74.19: FAO-ESN:MON/84.19).

2.3 Origin or source of food

The Consultation felt it was necessary to distinguish between food of domestic and foreign origin. For staple food, the country (or region) of harvesting was an output requirement. For processed food, information should be supplied, if possible and where available, on the country where the food was processed.

2.4 Consumer population at risk

Unless information is available about a particular group of the population towards which the product is directed for consumption, e.g. children or babies, the output from this section will refer to the whole population of a specified country.

2.5 Levels of contaminants

Concentrations should be expressed as microgram or milligram per kilogram (µg/kg or mg/kg) of wet weight of the food or as percentage of the fat content of the food in the case of pesticides which accumulate in fat.

Levels should be expressed as concentrations present in the food as consumed or as sampled. The recalculation of results expressed in dry weight for application to the original food as eaten, should utilize the average moisture content value for that commodity.

In addition, statistical parameters will need to be applied which may vary somewhat according to the particular contaminant and food product. Which measure of dispersion is appropriate depends on the form of statistical distribution, i.e. the standard deviation, variance and standard error of the mean become less appropriate as the distribution deviated from "normal".

In general, the statistical parameters can be put into two classes: Class A are priority requirements for further evaluation of the data, and Class B requirements are supplementary, but should be supplied if available.

Class A (priority)

(a) Number of samples

(b) Arithmetic mean

(c) Number of samples in each of (up to) 10 defined ranges of contamination

(d) Percentage of samples in each of (up to) 10 defined ranges of contamination

(e) Level of contamination below which 95% of samples fall.

Class B (supplementary)

(a) Standard deviation

(b) Standard error of mean

(c) Geometric mean

(d) Measure of variation of geometric mean

(e) Overall range

2.6 Methodology

2.6.1 Sampling

It will not be possible for the output to give details of how the food sample was taken other than to state at which point in the distribution chain the sample was taken, e.g. production, processing, storage, transport including port of entry, retail centre, etc.

It will be assumed that the sample is representative of the food at that part of the distribution chain. It will probably not be possible to give as an output on what basis this was assessed, since there are quite different approaches to the assessment of randomness. Where samples are non-random and unrepresentative this information must be clearly indicated.

2.6.2 Analytical

The analytical procedures should be harmonized with reference to the recommendations of the Rome Consultation. For this purpose a detailed description of the methodology used is called for as well as the information on the contaminant detection level for the particular commodity.

The actual outputs should be given according to the subitems below:

(a) Standard name(s) for the method
(b) Portion of food sample analysed (standard name(s))
Examples: edible vs nonedible, drained, etc.
(c) Sample preparation (washing, etc.)
(d) Country in which analysis was performed.

2.7 Time

In general, the output should be given annually and in the following form:

(a) Date of harvest or slaughter, year, season (if available)
(b) Data of sampling
(c) Year of analysis
(d) Periodicity of summaries of continuing monitoring
(e) Recover retrospective data since 1970, if possible.

3. SYSTEM INPUT REQUIREMENTS

Since there will be two different levels at which the data handling and collection may occur, i.e.

(a) the national level
(b) the international level (FAO/WHO Central Unit) in collaboration with international collaborating centres

the input requirements will have to be specified in accordance with their respective functions. In practice, the input item classes will be the same as the basic output item classes and very minor changes in the subitem requirements, e.g. inputs will be 2.7 (a), (b) and (c) but not subitems (d) and (e). Another important input requirement is the need to check and evaluate reference standards data.

If the data at the national focal points are received in absolute values the transfer to the international level will have to involve processing into defined class ranges which will have to be separately specified for each commodity.

4. PROCESSING AND STORAGE OF DATA

The Consultation concluded that, until enough experience has been accumulated with the operation of the manual system, no useful specification of the features of any eventual computer system can be made. On the other hand, it is possible that microfilming should be considered to improve the efficiency of the manual system, should the volume of data be sufficient to make that worthwhile. However, both the manual system and any eventual computer-based system must permit retrieval by the categories of data specified in the output requirements.

The agencies may receive information from a nation on the understanding that it should not be distributed generally. Should such confidential information be entered into the system, procedures will be required for its protection.

5. SELECTION OF DATA AND QUALITY CONTROL

There are two aspects of quality control of the data - conformity to scientific standards of methodology for chemical and sampling excellence and conformity to statistical standards of both validity and accuracy once the statistical parameters have been identified.

Methods of analysis are frequently superseded by better methods, and a method adequate for certain food control purposes may not provide data of the character required for the JFCMP. Data will also have to be adjusted, e.g. dry weight to wet weight conversions, and specified. Guidelines on scientific and statistical criteria to be used by reviewers for particular foods and contaminants should be drawn up in consultation with national focal points, consultants and through meetings of experts where necessary coordinated by the FAO/WHO Central Unit.

The Consultation concluded that conformity to standards of chemical methodology is likely to be indicated by use of well-known and thoroughly investigated methods (see recommendations of Rome Consultation) and/or by satisfactory participation in national or international collaborative studies on standardization.

The sampling methodology used should be known to the national focal point, which should be satisfied that the samples analysed are representative of the specified population. A summary of the sampling methodology should be submitted to the Central Unit. If the Central Unit is not satisfied that the samples are representative, or that they do not conform to the specifications, or that there is doubt about the analytical results, the data must be excluded from the system, or stored separately, or permanently asterisked.

Statistical standards of validity must be maintained nationally, e.g. by correct calculation of means, and the assignment of samples to classes with defined ranges. Any statistical ambiguity which is foreseen should be resolved between the Central Unit and the national focal point. Nationally available statistical parameters additional to the minimum requested should be welcomed, e.g. where the same samples are analysed for more than one contaminant, scatter diagrams, regression lines or multivariate analysis results would be of interest.

6. MANAGEMENT OF THE PROGRAMME

The Consultation was informed that the system will be managed by an FAO/WHO Central Unit to be located in WHO headquarters, Geneva. The Unit will generally be responsible for the successful day-to-day operations and will coordinate the work being carried out by the participating governments and the proposed international collaborating centres referred to in the Rome report (regional reference centres). The screening and quality control of the data activities of the system will also be the responsibility of the Central Unit which may be undertaken through its own efforts or through the mechanism of the proposed international collaborating centres to be determined between the two agencies and the participating governments. The Unit will also undertake collation and analysis of data which may be necessary in carrying out any joint assessment or evaluation and preparation of reports by the two agencies through consultations of ad hoc groups of experts or other appropriate mechanisms.

It is envisaged that the data handling focal points in the participating governments will be responsible for collection, selection and preprocessing of the data before it is submitted to the FAO/WHO Central Unit at WHO. Preprocessing of data will include quality control and collation. Appropriate data from national and industrial laboratories could be included in the submission of data by the focal points.

Overall policy considerations and the division of responsibility for activities in other areas within the Programme will be determined by both FAO and WHO.

## 7. OTHER CONSIDERATIONS

### 7.1 Mercury in fish

The Rome Consultation recommended the monitoring of fish and other aquatic organisms for total mercury. In this connexion, the attention of this meeting was drawn to the FAO Fishery Data Centre which was currently engaged in collecting, collating and analysing data on levels of a large number of contaminants, including mercury, in fish and marine organisms. It was noted that the objectives and approaches of the Centre are somewhat different from those of the JFCMP. The Consultation felt that with some suitable extension or reorganization of the scope of the Fishery Data Centre it may be possible to obviate the need for setting up a new system. Hence it might be more economical in the long run to utilize the selected pre-processed data on total mercury in fish as marketed for food purposes from the Fishery Data Centre for the Programme.

## 8. OUTLINE OF FEASIBILITY STUDY

### 8.1 Introduction

The meeting suggested guidelines for the submission of data with reference to the development of a feasibility study aware that any proposal must first be acceptable to all governments who agree to participate in such a study. The detailed handling requirements for the study should be determined by discussion between the agencies and the participating countries. The agencies will elaborate a detailed pro forma for the submission of data which would follow the criteria elaborated in the Rome Consultation (October 1974) and the present meeting.

### 8.2 Proposals for the feasibility study

It is proposed that the feasibility study involve all 13 countries whose food contamination monitoring programmes have already been studied by FAO/WHO (see report of Rome Consultation). The acceptance of this plan by collaborating governments will require the nomination of a national focal point which will be responsible for forwarding the data of the Central Unit. It is planned that the study should last for two years.

The following contaminants are proposed for inclusion in the study:

(a) DDT, DDT and metabolites (specified)
(b) Lead.

The choice of these contaminants was based on the recommendations of the Rome Consultation and the ability of participating laboratories to submit data which would satisfy the criteria of the reliability of analytical methodology.

The following commodities are selected for inclusion in the study:

(a) Milk and milk products

(b) Cereals (to include milled products used in the first production steps for the manufacture of cereal products)

(c) Canned foods (for lead only).

The sampling of commodities in groups (a) and (c) is envisaged as occurring at the retail level whereas of commodities in group (b) it would occur at the site of initial processing. In every case only data of samples which are chosen on a random and representative basis will be accepted for inclusion in the study.

9. RECOMMENDATIONS

The Consultation recommended that:

1. As a preprogramming activity, FAO/WHO undertake a feasibility study to be carried out as recommended under 8.2.

2. Before initiating any major study it would be useful for FAO/WHO to draw up a schedule of reports showing how the data from the Programme will be used. This should be done after the preprogramming phase and before the operational phase is undertaken.

3. Because of the importance of collecting data on biological contaminants in food, the Programme in its initial phase should:

(a) collect information on ongoing national monitoring programmes which could be used to assist other countries;

(b) collect, review and disseminate information on biological contaminants obtained in national monitoring programmes and determine trends where possible;

(c) select and recommend internationally acceptable and agreed upon methodologies for sampling and analysis of foods for biological contaminants.

4. FAO/WHO should build up appropriate systematic and detailed classification schemes for food products, contaminants and other descriptive elements as specified under 2.1 as soon as possible. It is one of the purposes of the proposed feasibility study to determine the adequacy of these initial classification schemes.

5. FAO/WHO explore the feasibility of utilizing the facilities of the FAO Fishery Data Centre to meet an input requirement of the Programme.

6. FAO/WHO should collate, compare and evaluate food contamination data obtained from the analysis of mixed total diet samples as part of the Programme, but that such data should not enter into the data handling system of the Programme.

7. FAO/WHO convene a meeting of experts to review the findings of the feasibility study and to suggest arrangements for further priority activities. A report on the feasibility study should be supplied to all interested governments and UNEP.

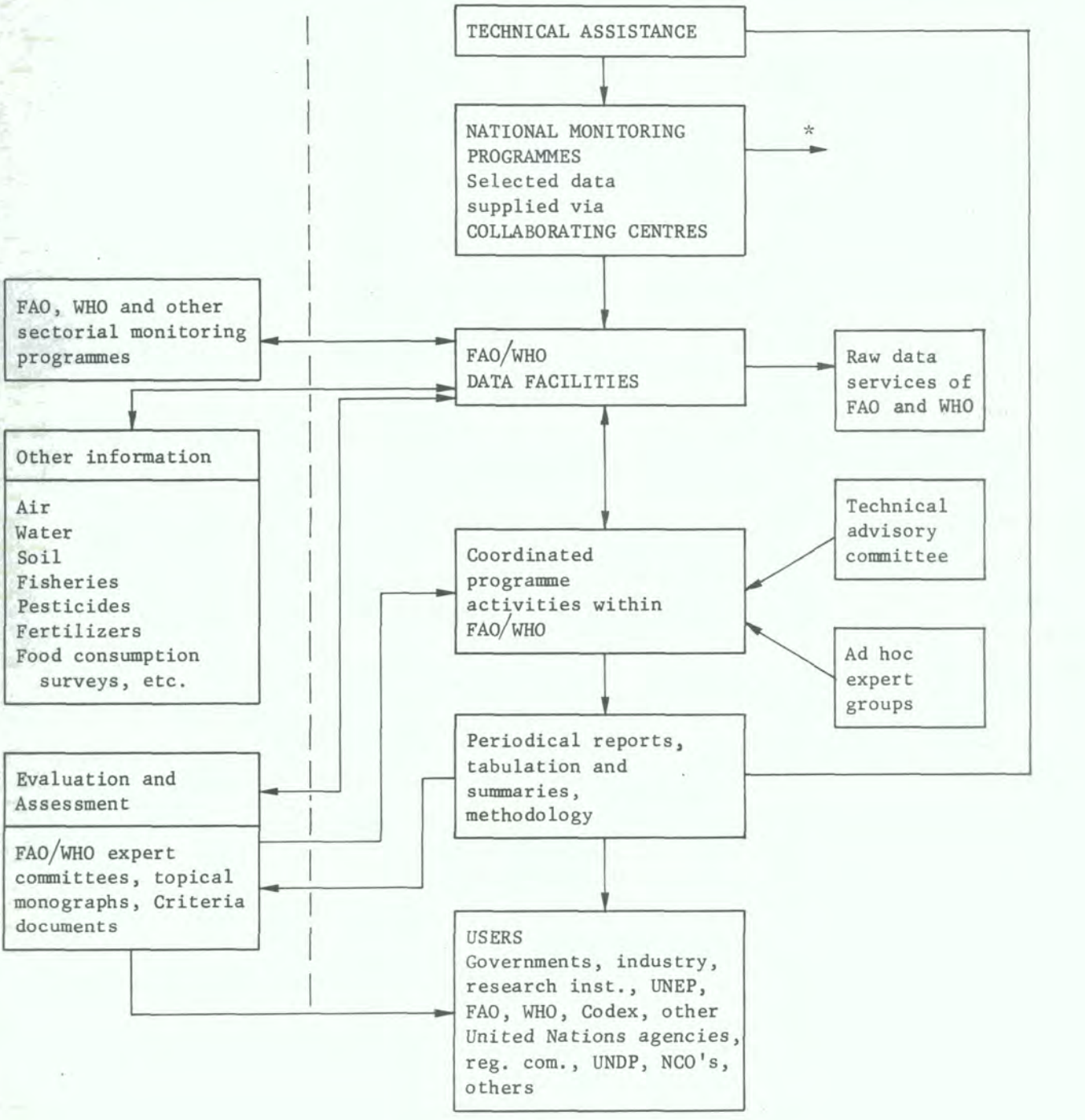
8. FAO/WHO invite participating governments, in line with the technical aspects of the system, to:

(a) nominate the national focal point for the purposes of the Programme;

(b) give a detailed description of pertinent analytical procedures used in national laboratories;

(c) give information on their ongoing national and international collaborative exercises on analytical methodologies.

FLOW DIAGRAM SHOWING THE RELATION OF THE FOOD AND ANIMAL FEED MONITORING PROGRAMME TO OTHER NATIONAL AND INTERNATIONAL ACTIVITIES




* Inputs to national food control services.

## WORLD HEALTH ORGANIZATION ENVIRONMENTAL HEALTH CRITERIA DOCUMENTS

WHO Criteria Documents on the following subjects have been published or are in the process of preparation:

Antimony

Arsenic

Asbestos

Benzo(a)pyrene

Bismuth

Cadmium

Carbon disulfide

Carbon monoxide

DDT

Fluorine and fluorides

Fuels and fuel additives

Germanium

Lead (published 1977)

Manganese (to be published 1978)

Mercury (published 1976)

Microwave radiation

Molybdenum

Mycotoxins

Nickel

Nitrates, nitrites and N-nitroso compounds (published 1978)

Noise

Organic vegetable dusts

Oxides of nitrogen (published 1977)

Platinum and palladium

Photochemical oxidants (to be published 1978)

Polychlorinated Biphenyls and Terphenyls (published 1976)

Selected petroleum products

Sulfur oxides and suspended particulate matter (to be published 1978)

Tellurium

Tin (to be published 1978)

Titanium

UV radiation

Vanadium

APPENDIX 23[a]

# METHODOLOGY IN FOOD MICROBIOLOGY - THE PRESENT POSITION

by

Dr J. H. B. Christian
Associate Chief, CSIRO Division of Food Research
North Ryde, New South Wales, Australia

This review deals only with matters of relevance to microbiological criteria for foods. It contains much unpublished data and is not referenced.

## 1. Sampling and sample preparation

(i) Sampling plans: The choice of sampling plans for the microbiological examination of foods has proved difficult in the past, and few microbiological specifications have given adequate guidance in it. The International Commission on Microbiological Specifications for Foods' (ICMSF) publication "Microorganisms in Foods. II. Sampling for Microbiological Analysis: Principles and Specific Applications" has clarified the situation. It will not be reviewed here, but of particular note are (a) the use of both two and three-class plans, (b) the concept of "case" whereby changes in the level of hazard during subsequent handling or processing of a food are considered, and (c) the clear exposition of the statistics of sampling and sampling plans. In particular, the latter (c) makes the point that for practical levels of sampling, a particular sampling plan, be it harsh or lenient, will give nearly the same level of protection, irrespective of the size of the lot from which the samples are drawn.

(ii) Preparation of samples: The mechanical blender, employing rotating blades, has been joined by the "Stomacher" as an acceptable method of homogenizing food samples. The latter has advantages of more gentle dispersion of the food in the diluent and of avoiding the need to sterilize blender bowls between uses, as it uses disposable plastic bags. Samples of homogeneous liquids do not require such preparation.

As will be discussed below, 1:10 or even lower dilutions will often be too dilute for direct plating when the populations of concern are much below 100 viable units per gram of food. A method of concentrating the cells in the homogenate would be useful. Differential centrifugation has not proved very satisfactory.

(iii) Resuscitation: Microbial cells may be damaged but not killed during the processing of a food. The need to permit repair of such sublethally impaired cells, i.e. resuscitation, before subjecting them to selective and hence inhibitory media is now widely recognized. In "Presence or Absence" (P/A) tests, this is conveniently achieved by "pre-enrichment", in which resuscitation precedes growth in the same medium. The same principle can be applied to "Most Probable Number" (MPN) determinations by using a non-selective media for the first set of inoculations. Alternatively, incubation for a short period in a double strength, non-selective medium, followed by addition of an equal volume of double strength solution of the selective agent and further incubation, may be effective. However, where a plate count is to be performed, prior resuscitation in a liquid medium followed by growth is not acceptable. Incubation in broth for a period significantly less than the lag phase of the uninjured culture has been suggested to resuscitate cells prior to plating, but the lag time is rarely known for food homogenates. Plating on recovery medium and replication of resulting colonies on to selective agar has been attempted, but overgrowth by unwanted organisms can make this procedure

---

[a] For the present guidelines Dr Christian has revised (1977) the original paper contained in the Report of a Joint FAO/WHO Expert Consultation on Microbiological Specifications for Foods, Geneva, 7-11 April 1975 (EC/Microbiol/75/Report 1).

difficult. The best hope may lie in (a) the use of membrane filters, which can be inoculated and incubated on recovery medium until resuscitation and several divisions have occurred, and transferred to selective media for subsequent incubation; or (b) plating in nonselective agar, incubating for resuscitation and overlaying with selective medium before the final incubation period.

2. Types of tests

(i) Plate counts: The aerobic plate count remains one of the most useful indicators of the microbiological status of a food. The belief that incubation at 30, 32, 35 or 37°C gives the best estimate of the aerobic bacterial population for all foods persists. There is need for more data on the productivity of various time-temperature incubation conditions for plate counts on refrigerated foods.

Plate counts may be made from pour plates, with or without overlay, or surface plates which may be spread or drop inoculated. The choice of plating technique depends upon the importance attached to surface or submerged colonies. Drop counts are rapid and economical, but might not be commonly used in testing compliance to microbiological standards.

A recent study (Silliker, unpublished) of aerobic mesophilic populations in a range of foods, comparing pour, spread and drop plate techniques, gave overall average 95% confidence limits close to 0.50 log units with the least variation being found in the spread plate counts. The geometric mean counts obtained by spread plating were consistently lower than those recorded with the other two techniques. In earlier ISO studies on meat, however, spread plates gave higher estimates of bacterial populations than did pour plates. These differences may relate to the oxygen requirements of the bacteria predominating in the food. This does not explain the differences observed between drop and spread plates, which probably result from the retention of a significant volume of the suspension on the spreader after use.

A comment is made below on the variability observed in coliform MPN counts. It should be pointed out here that in the study mentioned above, comparisons between MPN and plate counts for coliforms in three foods gave similar, large values for 95% confidence limits.

(ii) Most Probable Number (MPN) and Presence or Absence (P/A) determinations: When the specified limit for a particular microorganism in a food is much below 100 per gram, an alternative enumeration method to the plate count may be required. The present alternatives, if membrane filtration is inappropriate, are MPN and P/A determinations. While both of these methods are quantitative (the sample size in P/A tests being defined), only the former yields a numerical result. Hence MPN determinations are applicable to three-class sampling plans, while P/A tests can be used only with two-class plans, if samples of only one size are tested.

The MPN technique was developed for the enumeration of coliform bacteria in water and has proved most valuable in this context. Its application to foods has been shown in tests sponsored by the ICMSF to be plagued by a number of sources of variability. The most striking of these are between laboratories and between analysts. The subsequent finding of similar levels of variation in plate counts has been referred to above. The alternative would be the P/A test using replicates of, e.g., 0.01 g. There is a growing use of the "three tube test", each tube containing media and 0.01 g of the food. If, after incubation, two or three tubes show growth, the conclusion is that the food contains more than 100 of the relevant organisms per gram. If none or one is positive, the count is less than 100 per gram. Statistically, the MPN for two positive tubes out of three, each containing 0.01 g of sample, is 110 per gram, with 95% confidence limits of 30 and 480. If 10 tubes were used, all at the same dilution, seven positives would give an MPN of 120 per gram, with the 95% confidence limits narrowed to 60 and 270.

(iii) Toxin testing: Microbial toxins have not been included in specifications for foods, but the current interest in staphylococcal enterotoxin and in mycotoxins suggests that they may be in the future.

(a) Staphylococcal enterotoxins are most commonly detected in foods by microslide gel diffusion techniques based on the Casman and Bennett method. This technique is slow and relatively insensitive, requiring an initial toxin concentration step of over 100-fold. It is, however, the current method of choice. A reverse passive haemagglutination procedure of much greater sensitivity has not yet yielded a reliable routine method of adequate specificity. Radioimmunoassay, also of high sensitivity, is being used routinely in Canada on unconcentrated food extracts. The equipment is expensive, radioactive toxin must be prepared in each laboratory using the technique and purified toxin as required. It is possible that this method could be superseded by the enzyme-linked "ELISA" technique, which is similar but relies upon a colorimetric enzyme reaction instead of the measurement of radioactivity.

Unfortunately, all of these methods are toxin specific and all the enterotoxins may not have been identified. Thus any standard would have to specify the toxins to be sought. There are hopes that a common amino acid sequence exists in all enterotoxins, and that a specific reagent can be based upon it.

Work on the assay of the heat-stable nuclease of Staphylococcus aureus suggests that the presence of this enzyme in foods could serve as a useful indicator both of staphylococcal growth and the possible production of enterotoxin.

(b) Mycotoxins are produced by many fungi, some of which produce more than one. It is unlikely that all of the toxic products of moulds have yet been identified, nor is it known whether all of the identified toxins are harmful to human beings or at what level. It follows that any standard must cite particular mycotoxins. At present, the aflatoxins are most frequently sought. The analytical techniques employed for mycotoxins resemble those for pesticide residues, and may well appear in specifications as chemical contaminants rather than in microbiological standards alongside enterotoxins.

(iv) Dye and enzyme tests have been of the greatest importance in the development of microbiological control of several foods, particularly milk and egg products. Dye reduction tests (resazurin, methylene blue) are used routinely as crude measures of "total" bacterial populations in milk and some have been extended to meat. Dye tests are unlikely to be introduced into international standards, but may become more extensively used as routine indicators of bacterial populations in other foods. In the longer term, they may well be replaced by more specific methods, e.g. release of radioactive $CO_2$ from labelled substrates.

Enzyme tests are used as indicators of heat processes. The inactivation of phosphatase indicates a satisfactory time-temperature treatment for the pasteurization of milk. The use of the α-amylase test to indicate an equivalent situation with egg pulp is also quite common and has been recommended as a test in international standards to ensure destruction of salmonellae. However, the inactivation rates of α-amylase and of salmonellae are identical at only one temperature, so that processes exist which will inactivate salmonellae but not the enzyme and vice versa. Microbiological tests must, of course, be used to detect post-pasteurization contamination by salmonellae or other bacteria.

3. Microorganisms

(i) Clostridium botulinum is not normally enumerated in foods and standards for its presence in foods are unlikely to be set. It is sought, however, when a food is suspected of involvement in botulism. The food is cultured, generally in cooked meat medium, and the culture supernatant tested for toxigenicity by mouse injection, using the appropriate antitoxins for protection tests and to establish the serological type of any toxin present. This is a lengthy procedure, and efforts are being made to shorten it. To identify cells and spores, the use of fluorescent antibody with enrichment cultures is showing promise, while electro-immunodiffusion may prove to be a rapid and specific method for detecting C. botulinum toxins.

(ii) Clostridium perfringens has been shown to produce an enterotoxin during sporulation. It has been purified and shown to be detectable by a range of techniques including fluorescent antibody and haemagglutination. However, the concern in food microbiology is the isolation or enumeration of cells or spores from foods.

The media commonly used for enumeration of C. perfringens contain antibiotics and in many cases sulfite and/or a sulfa drug. They include Neomycin Blood Agar, Sulfite Polymyxin Sulfadiazine (SPS) Agar, modified SPS plus egg yolk (Shahidi-Ferguson) Agar and OPSPA Agar. Some of these media have been compared by ICMSF in tests with naturally contaminated foods. The tests are to be repeated using faecal specimens as source material.

C. perfringens is likely to be acceptable in foods in relatively low numbers (<1 to 100/g), so that enrichment procedures may be important for some products (e.g. foods for special dietary uses). Presently the media most used are basal anaerobic broths such as cooked meat medium and fluid thioglycollate medium. The latter is not to be recommended.

(iii) Staphylococcus aureus, a highly salt-tolerant organism, has traditionally been isolated or enumerated in high-salt media. However, the realization that cells which have been stressed during processing are not recovered quantitatively on salt agars and most other selective media has led to the general acceptance of Baird-Parker agar.

The "coagulase-positive staphylococci" cited in many specifications are, in fact, Staphylococcus aureus. Although by no means all such organisms are enterotoxigenic, relatively few coagulase-negative staphylococci are. Unfortunately, there is some disagreement as to what constitutes a positive coagulase reaction. Attempts have been made to incorporate plasma into the enumeration medium to give a coagulase result on the plate. The technique has been successful in some laboratories but not in others. Efforts are in progress to incorporate a nuclease reaction in such platings.

ICMSF has completed a comparative trial with four staphylococcal media; Baird-Parker, TPEY, Kranep and Milk Salt Agars. Baird-Parker Agar was the most effective, Milk Salt Agar performed relatively well and, as it had advantages of economy and ease of preparation, is being tested further.

As the permissible numbers of staphylococci in foods will generally be low, liquid media for P/A tests are required. Less effort has gone into developing these than into developing agar media. The most widely used are salt broths (e.g. trypticase soy broth with 10% salt) and Giolitti and Cantoni medium. The latter has been recommended by IDF for milk products and by ISO for meat. MPN techniques do not appear to have been used routinely. Extensive studies of resuscitation methods are in progress.

Methods available and being developed for the detection of enterotoxin have been discussed. When a method becomes routine, an enterotoxin standard is most likely to be applied to foods in which toxin production is frequently followed by death of the staphylococci. Cheese and dried milk are possibilities. In most other foods, a check of staphylococcal numbers will probably continue to give adequate security, as at least 500 000 staphylococci per gram of food are believed necessary to induce food poisoning.

(iv) Salmonella spp.: For most microorganisms enumerated or isolated from foods, the main difference between a reference and a routine examination will lie in the extent to which the identity of isolated bacteria is confirmed. With salmonella, however, a routine method may employ one enrichment and one selective medium, while a reference method may demand two different enrichment broths and two or three selective agars. This adds another dimension to the problem of establishing standard procedures. ISO has circulated a draft standard method for isolation of salmonellae from meat and research, particularly in the European Economic Community countries, suggesting that it will be suitable, with minor modifications, for egg products. As it stands, the method will discriminate against detection of S. typhi and of lactose-fermenting salmonellae.

The historical development of salmonella isolation techniques is discussed in Annex III. However, a comment is justified here on which are the main areas of contention in establishing a referee method. These appear to be (a) the nature of the pre-enrichment medium, (b) the incubation temperatures for enrichments, (c) the nature of the second selective agar, and (d) which, if any, biochemical tests should be specified. There is not yet agreement on the most suitable formulations of the tetrathionate and selenite-based media for enrichment.

Some recently recommended sampling plans demand the examination of up to 60 samples of food for salmonella. Many of the problems involved in this level of testing can be solved by combining samples ("dry compositing") or aliquots from pre-enrichments ("wet compositing") without loss of sensitivity, as demonstrated in ICMSF tests. Such modifications can be made only if all samples must be negative for salmonella ($c = 0$). If $c > 0$, samples must be cultured individually.

Developments in salmonella isolation and identification not at present relevant to reference methodology include the following: (a) the general salmonella bacteriophage (Felix O-1) used in Hungary and in Swedish meatworks to test suspect colonies; (b) the "omnivalent" sera developed in Federal Republic of Germany for agglutination tests; (c) the fluorescent antibody (FA) microscopy technique for screening enrichments; and (d) the enrichment serology technique. The FA method is reported to give results very similar to the AOAC salmonella method, and it can be automated by measuring light transmission. Enrichment serology is not appropriate for the detection of non-motile strains. It would also lend itself to automation.

There is a need for comparative evaluation of two media apparently in wide and successful use in Japan, at least in the examination of egg products. These are YCC, a pre-enrichment broth, and DHL, a selective medium. Also used is SS agar plus 1% sucrose.

(v) Faecal indicator organisms continue to be widely used, but with more discrimination than when the techniques found so useful in water testing were transferred directly to food testing. While both coliforms and *E. coli* are valuable indicators of bacterial pollution of waters, they are used in different situations in the testing of foods. Originally chosen as indicating faecal pollution, the use of coliforms has been extended to cover in addition inadequate sanitation and processing.

The five groups used are *E. coli*, faecal coliforms (presumptive *E. coli*), coliforms, Enterobacteriaceae and faecal streptococci (Lancefield's group D). Except for the introduction of the Enterobacteriaceae test, there have been few recent changes in media and techniques used in enumerating these groups. There has been, however, more concern about what the various tests mean, which is most appropriate for a particular food, and how much reliance can be placed on results obtained.

A development in *E. coli* enumeration technique is a direct count on membrane filters. Suspensions are spread on to the filter and may be resuscitated before transfer to a selective medium, which does not include lactose, for incubation at 43°C. Finally, an indole test is carried out on colonies on the filter.

Tests for *E. coli* and faecal coliforms are particularly useful in monitoring the faecal contamination of many foods not processed to destroy Enterobacteriaceae. Shellfish are the classical example. Faecal coliform tests have often been preferred to *E. coli* tests, being quicker to perform. However, the appreciation that enteropathogenic *E. coli* (EEC) may be a significant cause of food-borne disease has increased the popularity of *E. coli* enumeration in many foods, processed as well as raw. It must be remembered that "faecal coliforms" are defined by administrative decision, not on taxonomic grounds. Thus they need not be *E. coli* and *E. coli* need not be "faecal coliforms" by the standard tests.

The coliform test is now usually applied to processed (e.g. pasteurized) foods, where it indicates either inadequacy of the process or inadequacy of sanitation, and hence recontamination, post-processing. In dairy technology, the incubation temperature may be reduced to 30°C to include more non-faecal species. The faecal connotation may be slight - the coliform test may be meant as an indicator of the prevalence of gram-negative organisms. In fact, of course, lactose-negative, gram-negative bacteria are excluded. A logical step was the introduction of the Enterobacteriaceae test, which aims at excluding few gram-negative, but all of the gram-positive rods and cocci which are in general much more resistant to processing (especially by heat).

From this aspect, the two tests may be interchangeable, although numerical standards might be somewhat different. However, the Enterobacteriaceae test has another property which should be considered. As the medium employs glucose, not lactose, as carbon source, the test enumerates such non- or slow lactose fermentors as Salmonella, Shigella and some strains of EEC not picked up by coliform tests. Conversely, it may detect the presence of lactose-positive Salmonella strains which would be missed in most salmonella detection programmes. Thus its two salient properties lie at the extremes of the indicator spectrum.

There have been few recent developments in the use of faecal streptococci as indicators in foods.

To check compliance with standards, indicator tests are usually of the MPN type. However, with E. coli and coliforms there is a growing use of the three-tube P/A test. Concern about the reproducibility of the coliform MPN led to a series of tests organized by Silliker for the ICMSF. The differences found in results between laboratories and even between analysts must cast some doubts on, or at least demand great care in, the setting of standards for MPN counts on foods.

When such standards are set, the problem of standardizing media arises. Three sets of media are commonly used for coliform, faecal coliform and E. coli tests: lauryl sulfate tryptose, MacConkey, and brilliant green bile lactose broths. In the comparative tests referred to above, significant differences between media were found in several foods examined. Overall, however, the coliform media appeared comparable. Unfortunately, the types of organisms enumerated as "coliforms" are defined by the method and by the medium - there is no basic yardstick. However, for two of the foods tested, very low values for faecal coliforms (in EC broth at 45.5°C) and confirmed E. coli were obtained using inocula from lauryl sulfate tryptose cultures. Lactose glutamic acid medium has recently been claimed superior to the conventional coliform broths.

The main difficulty in standardizing an MPN method may therefore be in deciding whether any of the media is significantly preferable to the others. This problem does not arise with the Enterobacteriaceae test, with only one set of media.

In ICMSF (1974) recommendations, m values for coliforms in foods range from $< 3$ to $10^3$. It is unlikely, therefore, that this group will be enumerated commonly on solid media.

Optimal methods of plating for enumeration of Enterobacteriaceae on VRBGA medium have been widely studied recently. Pour plates with overlay are favoured.

(vi) Enteropathogenic Escherichia coli are of growing concern as food-borne pathogens. As they are physiologically identical with non-pathogenic strains, they can be identified only by serology or pathogenicity testing. Currently, serotyping is carried out on cultures obtained during orthodox E. coli enumeration. A method has been evolved by which enteropathogenic serotypes can be concentrated by agglutination with antisera before culturing, thus increasing the yield relative to other serotypes. Those strains which synthesize enterotoxin owe this capacity to a plasmid which can be transmitted to other strains of E. coli and to other Enterobacteriaceae, so that no serological approach can give complete certainty that enterotoxigenic strains are absent. Meanwhile the E. coli standards likely to be applied to

appropriate foods in international trade would be low enough to ensure the presence of only small numbers of any serotype.

(vii) Bacillus cereus has become of worldwide rather than of regional interest as a food-borne pathogen over recent years. This has led to several reassessments of methodology for its enumeration. Commonly polymyxin is the selective agent and lecithicinase activity (towards egg yolk) and lack of mannitol fermentation (alkaline to phenol red) are the indications observed on the plate. A number of confirmatory tests in various combinations have been suggested, but the selective media outlined above are fairly specific. The only additional testing that is warranted may be a VP test and microscopic examination for (a) spore formation and (b) unstained globules in the protoplasm of lightly stained cells grown on glucose nutrient agar.

(viii) Vibrio parahaemolyticus: In the short period after this halophilic bacterium was identified as pathogenic, the media and techniques for its isolation and enumeration became fairly standard. Enumeration was achieved by surface inoculation of plates of thiosulfate citrate bile salt sucrose (TCBS) agar, with identification by three biochemical tests and three tests related to the salt requirements for growth. For enrichment, either salt colistin broth (SCB) or glucose salt teepol broth (GSTB) was used, with subsequent streaking on to TCBS plates. Confirmation of colonies identified as V. parahaemolyticus involved further biochemical testing.

Reassessments have since produced a large number of other enrichment and plating media, and several comparisons have been made. However, it is clear that more comparative tests will be needed to show whether any of these later suggestions give consistently superior results to the media summarized above.

The Kanagawa reaction, a $\beta$-haemolysis on a modified Wagatsuma agar plate, is used to categorize isolates into Kanagawa positive or negative. The addition of calcium chloride to Wagatsuma agar greatly enhances the Kanagawa reaction. There is a high level of correlation between pathogenicity and a positive Kanagawa reaction. However, there are reports of great variation in results both within and between laboratories. Isolates from patients are mostly, but not always, Kanagawa positive, while those from foods and marine sources are rarely positive.

(ix) Yeasts and moulds have been isolated and enumerated mainly on acidified media, e.g. potato dextrose agar, malt extract agar. The reduced pH does not inhibit all bacteria and has been shown to suppress some fungi. Improved media containing antibiotics and other anti-bacterial agents include oxytetracycline glucose yeast extract agar (OGY) and rose bengal chlortetracycline agar (RBC). RBC appears the preferred medium under the conditions that have been tested, although it does support the growth of certain gram-negative bacteria.

While the interpretation of yeast counts in foods is relatively straightforward, the significance of mould counts is greatly influenced by homogenizing treatments and whether the mould is present chiefly as mycelial growth or is sporulating vigorously. Standards for mould counts on some foods require very careful consideration for these reasons.

(x) Mesophilic and psychotrophic bacteria are conventionally enumerated by agar plating and there is general agreement on a draft ISO standard for a medium and procedure for the Aerobic Plate Count for mesophiles. Whether the same medium is also most appropriate for psychrotrophic counts, after incubation at 20°C or lower, has not yet been discussed. Standardization of a temperature or temperatures for psychrophilic incubation is necessary.

SUMMARY OF DATA TO BE COLLECTED IN PHASE II OF THE JOINT FAO/WHO FOOD AND ANIMAL FEED CONTAMINATION MONITORING PROGRAMME

| Stage | Contaminant | Food or diet | Time period[b] |
|---|---|---|---|
| Stage I - 1977 | (a) Organochlorine pesticides[a] and polychlorinated biphenyls | (a) Whole fluid milk, whole dried milk, butter and human milk | (a) 1971-1975 |
| | (b) Lead | (b) Canned fruit, canned fruit juice including concentrates, canned vegetables and canned milk (all in cans with lead-soldered seams) | (b) 1971-1975 |
| Stage II - 1978 | (a) Organochlorine pesticides[a] and polychlorinated biphenyls | (a) (i) Whole fluid milk, whole dried milk, butter, human milk | (a)(i) 1976-1977 |
| | | (ii) Edible fats and oils and fin-fish | (a)(ii) 1971-1977 |
| | (b) Lead | (b) (i) Canned fruit, canned fruit juice including concentrates and mixed juices for infants, canned vegetables and canned milk (all in cans with lead-soldered seams) | (b)(i) 1976-1977 |
| | | (ii) Cereal flours, potatoes and other vegetables of major dietary importance, molluscs, crustaceans and kidney | (b)(ii) 1971-1977 |
| | (c) Cadmium | (c) Molluscs, crustaceans, grains, cereal flours, potatoes and kidney | (c) 1971-1977 |
| Stage III - 1979 | (a) Organochlorine pesticides[a] and polychlorinated biphenyls | (a) (i) Whole fluid milk, whole dried milk, butter, human milk, edible fats and oils, and fin-fish | (a)(i) 1978 |
| | | (ii) Cereals, eggs, fruits and vegetables | (a)(ii) 1971-1978 |
| | | (iii) Total dietary intake | (a)(iii) 1971-1978 |
| | (b) Lead | (b) Total dietary intake | (b) 1971-1978 |
| | (c) Cadmium | (c) Total dietary intake | (c) 1971-1978 |
| | (d) Aflatoxin | (d) Peanuts, tree nuts, maize, milk. Special intake studies | (d) 1971-1978 |
| | (e) Arsenic | (e) Specified foods and total dietary intake | (e) 1971-1978 |

[a] DDT-complex, total HCH isomers, heptachlor and beta-heptachlor epoxide, aldin and dieldrin, HCB and PCBs.

[b] Refers to time of sample collection.

REFERENCES

1. World Health Organization, Expert Committee on Microbiological Aspects of Food Hygiene (1976) Wld Hlth Org. techn. Rep. Ser., No. 598

2. United Nations Environment Programme (1974) Report of the Intergovernmental Meeting on Monitoring, UNEP/IG.1/4

3. United Nations General Assembly (1972) Report of the United Nations Conference on the Human Environment held at Stockholm, 5-16 June 1972, A/CONF.48/14

4. World Health Organization (1973) Handbook of Resolutions and Decisions of the World Health Assembly and the Executive Board, 1948-1972, Vol. I, resolution WHA25.59, p. 155

5. World Health Organization (1975) Handbook of Resolutions and Decisions of the World Health Assembly and the Executive Board, 1973-1974, Vol. II, 1st ed., resolution WHA26.58, p. 18

6. FAO (1973) Report of the Conference of FAO, Seventeenth Session, Rome, C73/REP.

7. United Nations (1975) Report of the World Food Conference, Rome, 5-16 November 1974, resolution V, United Nations, New York

8. Federal Register, United States of America, 19 November 1975 (document 75-30331)

9. Committee on Food Protection, Food and Nutrition Board (1969) An evaluation of the Salmonella problem, NAS-NRC Publication No. 1683, National Academy of Sciences, Washington, D.C., United States of America

10. Working Party on the Monitoring of Foodstuffs for Heavy Metals. Fifth Report (1975) Survey of Lead in Food: First Supplementary Report, Her Majesty's Stationery Office, London

11. Federal Register, 1974, 39, 42748

12. Food Additives and Contaminants Committee (1975) Review of the Lead in Food Regulations, 1961, FAC/REP/21, Her Majesty's Stationery Office, London

13. Buss, D. H. & Lørstad, M. H. (1975) Food consumption surveys: a data source for contamination monitoring programmes, Food and Nutrition, 1(2), 26-28

14. Duggan, R. E. & Corneliussen, P. E. (1972) Dietary intake of pesticide chemicals in the United States (III), June 1968 - April 1970, Pesticides Monitoring Journal, 5, 331-341

15. Harries, J. M., Jones, C. M. & Tatton, J. O. (1969) Pesticide residues in the total diet in England and Wales, 1966-1967. 1. Organisation of a total diet study, J. Sci. Food Agric., 20, 242-245

16. FAO/WHO Codex Alimentarius Commission (1977) Report of the Ninth Session of the Codex Committee on Pesticide Residues, The Hague, 14-21 February 1977 (document ALINORM 78/24)

17. FAO/WHO Codex Alimentarius Commission (1975) Report of the Ninth Session of the Codex Committee on Methods of Analysis and Sampling, Budapest, 27-31 October 1975 (document ALINORM 76/23)

18. FAO/WHO Food Contamination Monitoring Programme (1974) Report of Meeting of an Expert Consultation on the Identification of Contaminants to be Monitored and Recommendations on Sampling Plans and Methodology, Rome, 7-11 October 1974, FAO-ESN: MON/74.21 Report, WHO-FAD/FCM/74.21

19. FAO/WHO Expert Consultation (1976) Report of Meeting on Methods of Sampling and Analysis of Contaminants in Food, Rome, 12-16 January 1976, FAO Food Control Series No. 3

20. Schuller, Pieter L. & Egan, Harold (1976) Cadmium, lead, mercury and methylmercury compounds, a review of methods of trace analysis and sampling with special reference to food, Food and Agriculture Organization of the United Nations, Rome

21. Schuller, Pieter L. (1975) Working paper on methods of analysis and sampling for aflatoxins, FAO/WHO EC/MAS/FC/75/2

22. FAO/WHO Expert Consultation (1975) Report on Microbiological Specifications for Foods, Geneva, 7-11 April 1975, EC/Microbiol/75/Report 1

23. FAO/WHO Expert Consultation (1977) Report of Second Meeting on Microbiological Specifications for Foods, Geneva, 21 February - 2 March 1977, EC/Microbiol/77/ Report 2

24. World Health Organization (1974) Food-borne disease: methods of sampling and examination in surveillance programmes, Wld Hlth Org. techn. Rep. Ser., No. 543

25. FAO (1975) Interlinked computer storage and processing system of food and agricultural data, FAO-ESN-1, M.D. 75/9

26. FAO/WHO (1972) Evaluation of certain food additives and the contaminants mercury, lead and cadmium. Sixteenth Report of the Joint FAO/WHO Expert Committee on Food Additives, FAO Nutrition Meetings Report Series No. 51; Wld Hlth Org. techn. Rep. Ser., No. 505

27. FAO/WHO (1977) Pesticide residues in food. Report of the 1976 Joint Meeting of the FAO Panel of Experts on Pesticide Residues and the Environment and the WHO Expert Group on Pesticide Residues, FAO Food and Nutrition Series No. 9; FAO Plant Production and Protection Series No. 8; Wld Hlth Org. techn. Rep. Ser., No. 612

28. FAO (1974) Fisheries Circular No. 325 Rev. 1, Food and Agriculture Organization of the United Nations, Rome

29. FAO/UNEP Expert Consultation (1975) Impact monitoring of residues from the use of agricultural pesticides in developing countries, Rome, 29 September - 3 October 1975, AGPP:MISC/22

30. WHO/UNEP (1977) Report of the Meeting of a Government Expert Group on Health-Related Monitoring, Geneva, 28 March - 1 April 1977, CEP/77.6

== == ==