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THE CONTAMINATION OF FOOD

United Nations Environment Programme
The Contamination of Food
Nairobi, UNEP, 1992
(UNEP/GEMS Environment Library No 5)

This publication is produced within the framework of the Earthwatch process of the United Nations system.

United Nations Environment Programme
PO Box 30552
Nairobi, Kenya

Editor: Hazel Clarke
Text based on the UNEP/FAO/WHO publication *Assessment of chemical contaminants in food*

Layout and artwork: Words and Publications
Oxford, England

Printed on Savanna Natural Art, a paper that contains at least 60 percent bagasse (sugar cane waste)

THE CONTAMINATION OF FOOD

The UNEP/GEMS Environment Library

Earthwatch was the name given in 1972 by the UN Conference on the Human Environment to the assessment activities included in its action plan. Under the plan, each UN agency monitors and assesses those aspects of the environment that fall within its mandate. The Global Environment Monitoring System (GEMS) was formally created two years later, in 1974, and the system is coordinated by the United Nations Environment Programme (UNEP) and its partner agencies through a Programme Activity Centre at UNEP's Nairobi headquarters.

GEMS now has more than a decade of solid achievement behind it. In that time, it has helped make major environmental assessments of such things as the impact of global warming, the pollution of urban air and freshwater resources, the rate of degradation of tropical forests and the numbers of threatened species—including the African elephant—in the world.

As is proper, the results of these assessments have been regularly published as technical documents. Many are now also published, in a form that can be easily understood by those without technical qualifications, in the UNEP/GEMS Environment Library.

This is the fifth volume in the series, and deals with food contamination—a subject of concern to everyone. Food can easily become contaminated—directly by industrial emissions and indirectly when plants absorb metals, chemicals and pesticides from polluted soil. Improperly stored grains and pulses can become contaminated by fungal growths. As a result, food contamination occurs in both developed and developing countries.

The GEMS/Food programme coordinates the monitoring of a range of foods for specific substances carried out by national centres, and compiles and assesses these food contamination data. The data provide a picture of levels and trends of food contamination over much of the globe. It is hoped that this information will raise awareness of the extent of food contamination and encourage national decision makers to take steps to minimize its occurrence.

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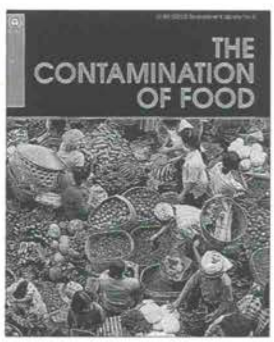

Cover picture shows a market in Bali, Indonesia. Food is susceptible to contamination at any point between the field and the plate.

(Steve Satushek/ The Image Bank)

Foreword

The UNEP/FAO/WHO Food Contamination Monitoring Programme (GEMS/Food) has been collecting data on food contamination through a network of participating institutes since 1976. In 1988, data from the monitoring programme and other sources covering the years 1971–85 were compiled, analysed and published by GEMS as a joint UNEP/FAO/WHO document *Assessment of Chemical Contaminants in Food*. Since then, data for 1986–88 have been compiled and made available. GEMS/Food data therefore provide an overview of the nature and extent of food contamination in participating countries during the period 1971–88.

The data revealed local instances of high levels of chemical contaminants in food in developed countries, generally caused by the contamination of air, water and the soil by industrial emissions of chemicals and metals. Though this is a cause for concern, the data suggested that the problem is more widespread and acute in developing countries, where fewer regulations govern industrial and agricultural practices.

GEMS/Food, as well as highlighting the dangers of food contamination, also shows the way forward. The results indicate that food contamination can be effectively reduced through environmental pollution controls. For example, measures in developed countries to limit industrial and vehicle exhaust emissions have helped reduce lead and mercury levels in food; and regulations restricting the use of pesticides and agricultural chemicals have also reduced food contamination.

The GEMS/Food monitoring programme aims not only to protect public health, but to promote confidence in the purity of foodstuffs through international information exchange on food contamination, and thus encourage international food trade. There is a need for continued vigilance—through national and international monitoring programmes—to ensure that preventative regulations are being effectively implemented and that any safe levels established for contaminants in food are not exceeded.

GEMS/Food will adapt and incorporate additional contaminants into the monitoring programme in the future as the nature and sources of food contamination change. GEMS is also working to establish monitoring programmes in developing countries and in Eastern Europe where data suggest that food contamination is prevalent.

UNEP

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Overview

Countries submit data to GEMS on the concentration of 19 specified contaminants in more than 1200 individual foods.

Widespread contamination of water, air and soil by chemicals and industrial pollutants means that the crops we grow and the animals we use for food are often exposed to toxic substances. Food may be contaminated by environmental pollutants and other substances during the initial stages of production, and during post-harvest processing, handling and preparation. A single source of contamination can affect food consumed by large numbers of people, and contaminated food can have a serious effect on human health.

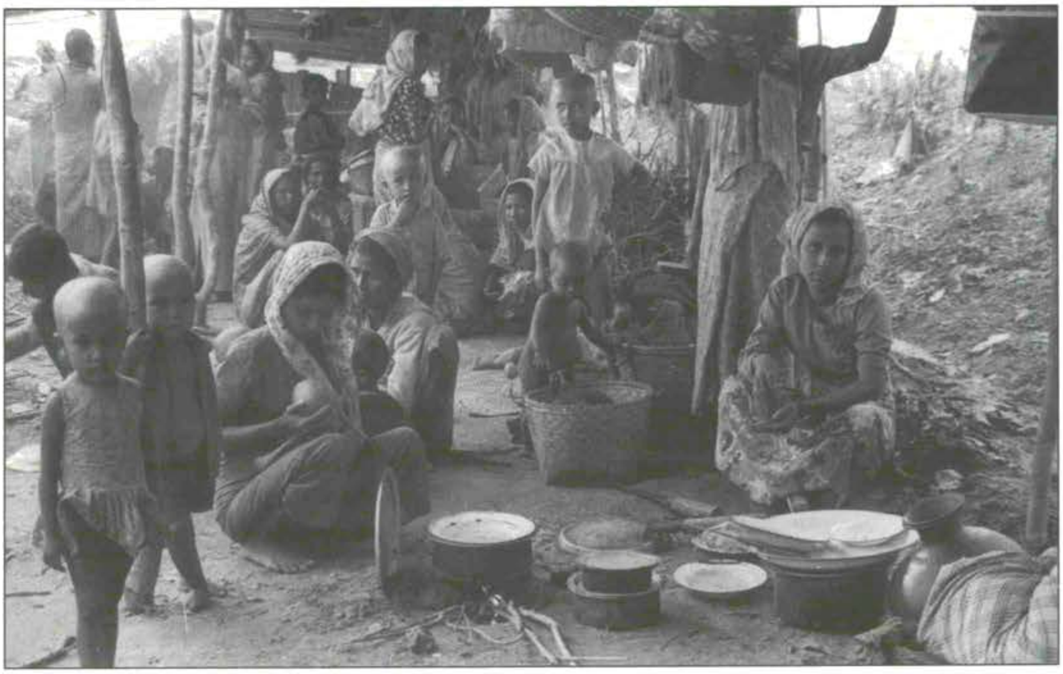
Detailed and accurate information on food contamination is essential if policy makers are to minimize its occurrence. The joint UNEP/FAO/WHO Food Contamination Monitoring Programme (GEMS/Food) was established in 1976 to provide such information. The programme operates through a network of participating institutes. These institutes compile, for submission to the global data centre at WHO, relevant data on chemical contamination in selected food items.

By 1990 the number of countries participating in the GEMS/Food programme had risen from an initial 13 to 39 (since the data were collected, a number of country names have changed; for clarity, the country name pertaining to the period of data collection is retained in this publication). These countries submit data to GEMS on the concentration of a total of 19 specified contaminants in more than 1200 individual foods and in the typical diets of adults and children. The results are then compared with the guidelines for acceptable levels of substances in food established jointly by FAO and WHO.

The results indicate that, particularly in developed countries, the trend in contaminant levels is generally downwards.

For countries involved in GEMS/Food, the data can reveal the occurrence of unacceptable levels of food contamination, indicate the types of food likely to be contaminated, and help identify likely sources of food contamination. When the data from the first 17 years of the programme were compiled and analysed in the late 1980s, the results highlighted levels and trends in food contamination worldwide.

The contaminants chosen for monitoring during 1971–88 were those identified as constituting the major health threats at the time of the study—mainly industrial environmental pollutants and pesticides. The results indicate that, particularly in developed countries, the trend in contaminant levels is generally downwards. This is largely because the use of pesticides that persist in the environment, and other toxic chemicals has been banned or restricted in many developed countries, and measures to reduce lead pollution from motor vehicles and other



FAO

environmental pollutants have been effective.

However, this does not mean that food contamination is no longer a problem. The monitoring programme revealed isolated, though significant, instances of high levels of contaminants in foods from developed countries. High concentrations of metals such as lead and cadmium have been found in staple foods and water from industrialized areas in Europe and North America. Similarly, polychlorinated biphenyls (PCBs) and mercury have been found at extremely high concentrations in some regions, mainly due to local water pollution affecting fish and sea food.

Data are not as comprehensive for developing countries, but the results indicate that there may be widespread and high levels of certain food contaminants in these countries. Many developing countries have not banned the use of persistent pesticides, and high levels of these contaminants have been recorded in many staple foods. In addition, pollution regulations that have contributed to a fall in food contamination elsewhere have not generally been introduced in developing countries, and food is at risk from contamination by industrial toxic metals and chemicals. Poor storage has also led to high levels of biological contaminants in some foods originating in hot or humid regions.

The GEMS/Food programme has made a significant contribution to protecting public health, and to the international food trade by encouraging global information exchange on food contamination. The results have been made available for both governments and the public, and this information has been used in many countries to initiate or improve food monitoring programmes, control the use of pesticides and industrial chemicals, compare national data with those from other areas of the world and introduce new standards to safeguard public health. The data are also used in the assessment of international recommended acceptable levels for contaminants in food.

People in developing countries, such as here in Bangladesh, may be exposed to widespread and high levels of food contamination, though accurate data are frequently unobtainable.

Many developing countries have not banned the use of persistent pesticides, and high levels of these contaminants have been recorded in many staple foods.

The scientific background

How food gets contaminated

Once contaminants enter the food chain they can increase in concentration by up to 100-fold at each stage along it.

The contaminants from a chemical leak, for instance, can contaminate land, air and water, and hence the food supply over a wide area for many years.

As the environment becomes more polluted, so the risk of food contamination increases. Contaminants from human activities pass into the air, into soil and water, and hence into fish, crops, and animals. Once contaminants enter the food chain they can increase in concentration by up to 100-fold at each stage along it. Food can also contain and transmit organisms that cause disease. These organisms in food may multiply from a few to several million in only a few hours. Food is described as 'contaminated' when any chemical or organism in it reaches a level which is potentially harmful to human health.

A major cause of food contamination is the pollution of air, water and soil. Emissions from industry and vehicle exhausts are a common cause of air pollution, and dangerous air-borne elements such as lead can be deposited onto and absorbed into fruit, vegetables and cereal crops.

Industrial and domestic waste is often discharged into water, in which some harmful chemicals and organisms can be broken down by biological or chemical action. However, large amounts of untreated waste and certain chemicals cannot be detoxified, and contaminants therefore remain in the water, from which they are absorbed into the ecosystem and enter our food supply. Water can also become contaminated as rain water passes through contaminated soil and drains into rivers and lakes.

Soil and plant contamination often occur as a result of industrial or mining activities which produce poisonous wastes, particularly if the waste is not stored carefully or is disposed of near agricultural land. Other common sources of agricultural contamination are fertilizers and pesticides which are deposited on crops and may build up in the soil as they are used over a number of years. Substances such as cadmium can be passed into human and animal food in this way.

As air, water, land, plants and animals are linked by a complex web of natural processes, contamination of any one element is likely to affect all the others. The contaminants from a chemical leak, for instance, or—more dramatically—the radioactive substances released from nuclear accidents such as Chernobyl, can contaminate land, air and water and, hence, the food supply over a wide area for many years.

Contaminants are often found in animals, particularly as a result of modern farming methods. Drugs used in animal husbandry, and to prevent disease and to promote growth, for instance, have to be carefully regulated to ensure that levels in meat are safe for human consumption. If animals are not free-ranging, any contamination of feed will affect a large number of animals, and contaminants are likely to build up to dangerous levels in their body tissues. Contamination can also occur during food storage. Coatings containing polychlorinated biphenyls (PCBs) have been used inside silos, for example, and caused high levels of PCBs in milk.

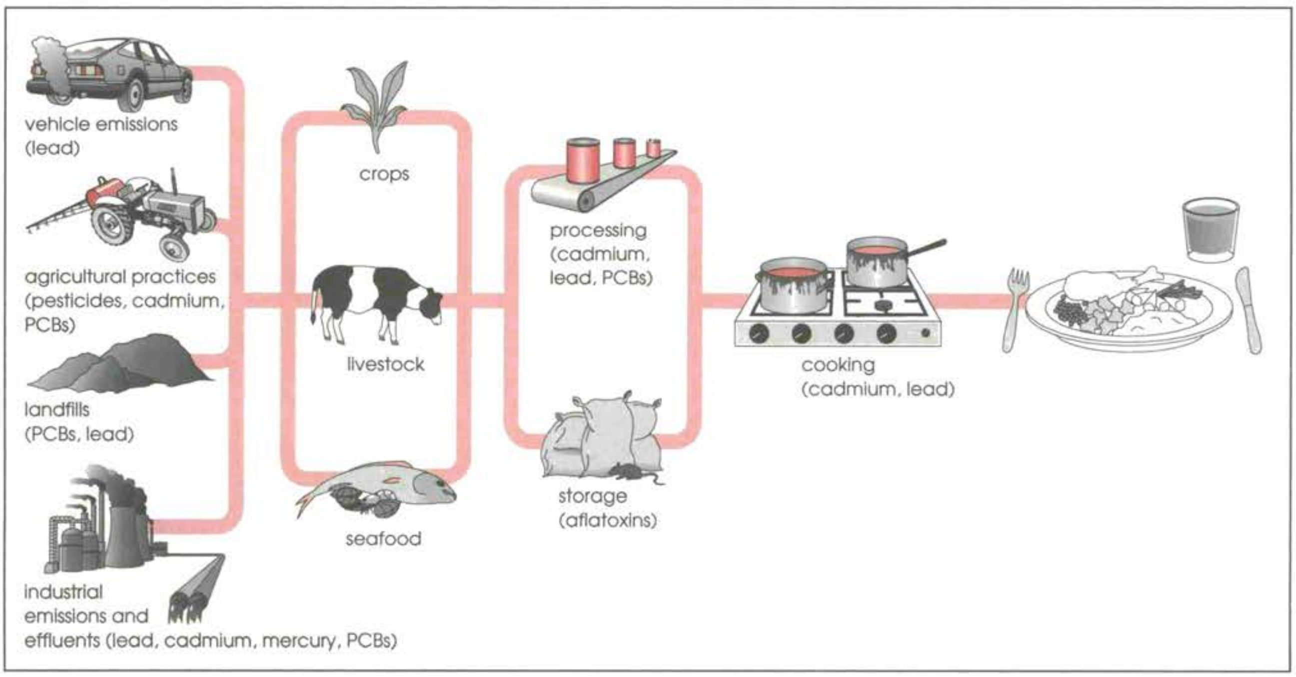
Another potential period of chemical contamination is during food processing. In processing plants there have been instances of heat exchangers, transformers and capacitors containing PCB-based fluids leaking and contaminating food. Commercial and domestic cooking utensils have been identified as a source of lead and cadmium in food; and lead-based solder used in food tins is the major source of lead in canned foods. (Although regulation in some countries has now eliminated this source of contamination, many developing countries have not changed to safer food containers.)

Not all food contaminants are man-made: some occur naturally in the environment. Moulds which produce the biological poisons known as aflatoxins are found on crops which have undergone stress conditions such as insect infestation or drought. They also develop in crops once they are harvested, mainly because of improper drying and inadequate protection against damp during storage.

Storage of fresh or processed food in warm or humid conditions, or in damaged containers can lead to biological contamination. Bacteria are widespread in the environment and if they are allowed to develop in food can lead to diseases such as listeriosis and to salmonella poisoning. Heating of food ensures that some bacteria are killed but, if this is not done at a high enough temperatures for a sufficient period of time, toxic bacteria can remain in the food and cause food poisoning.

Irradiation of food to prevent deterioration has been introduced in a number of countries and is being considered by others. Scientific data have clearly established the benefits of irradiation, but public opinion is at present generally ambivalent towards this process.

Figure 1 Common sources of the main food contaminants are shown below. Animals and crops are exposed to environmental pollution as they grow, and food may also become contaminated during processing and cooking.



Effects on health

Micro-organisms can be present in all types of food, but particularly meat, seafoods, eggs and dairy products.

Food is contaminated either through contact with chemical substances or by the presence of toxic—or toxin-secreting—micro-organisms.

Ingestion of high levels of some chemicals—typically those from industrial or agricultural processes—and certain micro-organisms can be detrimental to human health. Symptoms range from temporary nausea and discomfort to permanent internal damage, or even death. Widespread outbreaks of both types of poisoning have occurred as a result of food contamination.

Some substances have a cumulative effect: for example, metals such as cadmium and lead build up in the body over time before they reach a level which causes poisoning. Contaminants may be present in the body for a long time before symptoms of ill-health appear.

Micro-organisms can be present in all types of food, but particularly meat, seafoods, eggs and dairy products. Bacteria can be taken in by animals through their foodstuff, and infection passed from one animal to another. Such bacteria remain in meat after the animal is killed and can even pass into unprotected food stored near it.

Any raw or cooked food stored in warm conditions can develop bacterial growth. Subsequent treatment of the food such as freezing or cooking might kill the bacteria but does not necessarily make the food safe to eat.

Food therefore has to be monitored for high levels of certain chemicals and even for low levels of contaminants which act as cumulative poisons. Foods also need to be monitored for bacteria which may be present initially, or which may develop in food that is not carefully stored or processed.

Mercury poisoning in Minamata, Japan

Poisoning with organic mercurial compounds results in a wasting brain disease and loss of control of the motor nerves. This form of poisoning became known as Minamata disease because one of the worst outbreaks occurred in Minamata, Japan, in the early 1950s and alerted the world to the dangers of chemical contamination.

People in the small fishing town suffered progressive weakening of the muscles, loss of vision, and eventual paralysis and coma. Minamata sea birds and household cats which, like the fishermen and their families, subsisted on fish also showed signs of the disease. Several hundred people—40 percent of those affected—died, and others suffered permanent damage from the poisoning.

Concentrations of methyl mercury, formed by the action of bacteria on inorganic mercury substances, were discovered in fish and shellfish taken from the local bay, and in 1968 mercury was officially identified as the cause of the poisoning. The source of mercury was traced to the effluent discharged from a local chemical company.

Since 1973, the company concerned has been forced to pay more than £500 million to compensate victims and clean up the bay. Victims claim the government knew as early as 1952 that mercury was poisoning fishing grounds. Because central government has not accepted liability, many victims are still awaiting compensation.

Effects on economies

As well as safeguarding public health, the introduction of regulations on food standards has economic implications for regions or countries which rely on importing and exporting food.

The existence of national food regulations means that, for example, an instance of localized pollution could result in a ban on the sale of fish from the affected region, even though this could seriously undermine the region's economic base.

The situation is similar internationally. Countries are increasingly introducing legal controls on the quality of the food they import. If they do not, countries risk becoming a dumping ground for sub-standard food, to the detriment of both consumers and the national food industry.

Countries that export food must, in turn, ensure that it meets the importing country's standards. If food is not monitored in the country of origin, it is more likely to fail the importer's contamination tests, and be refused entry. This can lead to severe financial losses for farmers, processors and the exporting country, and to the loss of export markets if contamination levels are not reduced.

Farmers who produce food for export, rather than their own consumption, are particularly vulnerable. In South-East Asia, for example, pesticide use was encouraged, but not regulated, by the government, with the result that pesticide levels in food were too high for export and farmers suffered financial hardship (*see box below*).

Cooperation between importing and exporting countries on growing and processing methods reduces contamination in food. Importing countries therefore obtain higher quality food, and exporting countries benefit because their products are more likely to meet both the importing country's, and international, standards.

Countries are increasingly introducing legal controls on the quality of the food they import.

The unregulated use of pesticides

In many developing countries, chemical agricultural inputs are seen as a fail-safe way to raise yields for the home market and for export, and improve farmers' economic security.

Farmers in many areas of South-East Asia, but particularly the Philippines, have been given financial incentives by governments and chemical companies to use laboratory-developed crops, and to buy and use chemical fertilizers and pesticides. In the Philippines this resulted in an increase in national rice production of almost 100 percent over 20 years.

However, this policy has produced mixed results. Often, the pesticides used by farmers, such as DDT and dieldrin, are those banned in Western countries. Farmers are often not instructed on the safe and appropriate use of chemicals and may grossly over-spray the crops. Pesticide levels in food then pose a serious health threat to consumers, who are not informed that food produced by such methods is unfit to eat. Tapioca, beans and fruit have, in fact, been found to be too contaminated to export.

As well as contaminating food crops, dependence on expensive, imported pesticides may impoverish many small farmers. They may use much of their harvest to pay off debts, leaving little food or money for the rest of the year. Altough increased food production has enabled some developing countries export food, many of their people may not be able to afford a nutritionally-adequate diet.

The GEMS assessment

The GEMS Food Contamination Monitoring Programme was established in 1976 in order to:

- monitor and report on levels and trends of food contaminants based on data gathered by participating countries around the world;
- introduce standard methods for collecting and recording data (supported by quality assurance programmes) in order to improve the international comparability and validity of food monitoring data;
- strengthen monitoring programmes in participating countries by providing technical support and training; and
- provide authoritative assessments of data for regulatory and other bodies.

At present, 39 countries submit data from national food monitoring programmes. As shown on the map on page 11, it is mostly developed countries which return information to GEMS. Data from other sources were also used in the GEMS assessment on which this publication is based, particularly in relation to Africa, for which few monitoring data are available in the global GEMS/Food monitoring database, and Eastern Europe and Latin America which are incompletely covered by the monitoring programme.

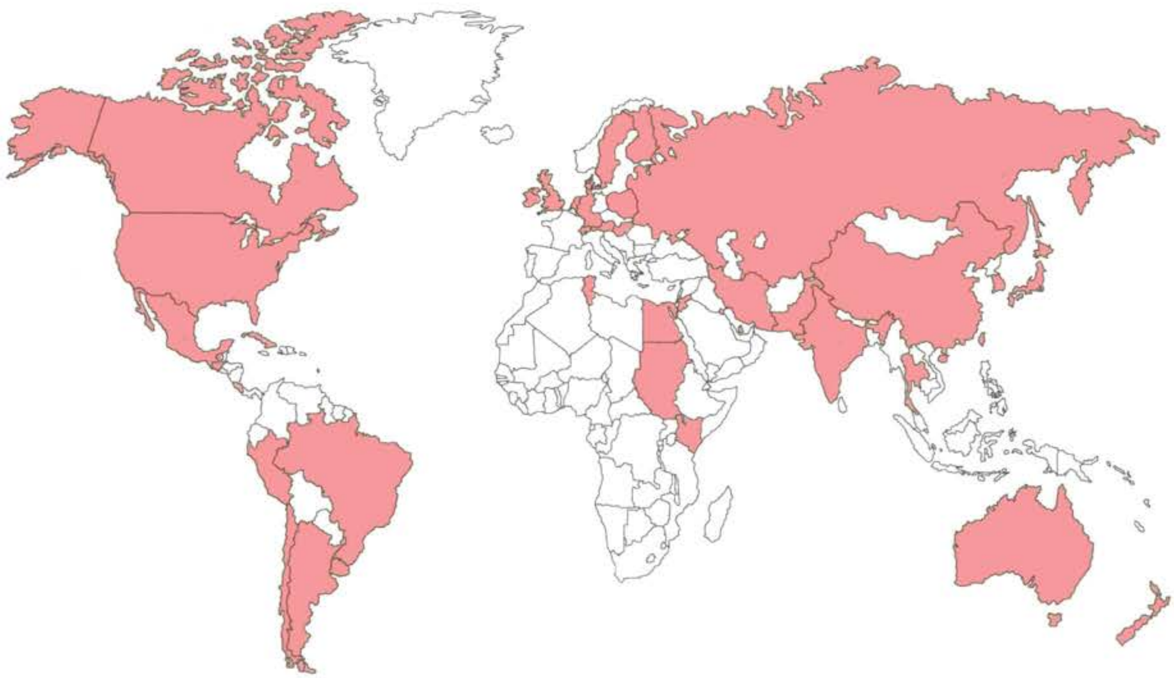
Reporting countries monitor the levels of a number of specified contaminants in a range of individual foods in order to determine in which food contamination is occurring, and to detect rising or falling levels of a specific contaminant in particular foods, regions or countries. The data can be used to check the effectiveness of existing regulations, to establish whether contaminant levels approach or exceed national or international limits and, where necessary, to provide the basis for new regulatory limits.

The choice of foods and contaminants varies from country to country, and even between areas within a single country, particularly if food from one region is known to be exposed to particular sources of contamination—such as emissions from industrial plants. The foods under study may also vary with time as dietary habits change, or as sources of contamination are brought under control and others are identified.

A number of factors are taken into account when selecting which foods and contaminants should be included in the global database:

- the potential health risk posed by a contaminant, in terms of the severity of its potential adverse effects and the number of people exposed to the risk of contamination;
- the dietary importance of a food—staple foods merit special attention;
- the level and frequency with which a contaminant appears in a particular foodstuff—mercury, for instance is known to occur almost exclusively in fish;
- the economic importance of a foodstuff—maize, a major product of the mid-west of the United States, is closely monitored for aflatoxin contamination, for example;
- a contaminant's current level of production or use—those being heavily discharged into the environment, typically by industry or agriculture, are carefully monitored;
- the persistence of a contaminant in the environment—chemicals such as DDT or PCBs are no longer in use in some countries but persist in soil for many years;
- a contaminant's rate of degradation, and the possibility of its conversion to more toxic substances; and
- the likelihood of a contaminant entering and passing along the food chain.

In practice, this resulted in 19 contaminants being monitored during 1971–88. (This publication concentrates on



participating countries (1990)

Argentina	Cuba	India	Netherlands	Switzerland
Australia	Denmark	Iran	New Zealand	Thailand
Austria	Dominica	Ireland	Pakistan	Tunisia
Brazil	Egypt	Japan	Peru	United Kingdom
Canada	Finland	Jordan	Poland	United States
Chile	West Germany	Kenya	Qatar	Uruguay
China	Guatemala	Republic of Korea	Sudan	USSR
Costa Rica	Hungary	Kuwait	Sweden	

Figure 2
Participating countries monitor the level of selected contaminants in a range of foods and in typical national and regional diets.

monitoring data from 1980–88.) The chemical contaminants selected were those causing most concern at the time of the study: chemicals, metals, pesticides, and aflatoxins—the only naturally-occurring toxins covered by the programme.

Microbial contamination of food is not covered but, in 1989, it was decided to consider the possibility of including microbiological contaminants in the monitoring programme.

In order to assess the threat to health posed by the selected contaminants, staple foods—cereal crops, fruit, vegetables, meat, fish, poultry and dairy produce—are monitored in each country; any foods of local dietary or economic importance are also included. Figure 3 on page 12 shows the foods analysed for each contaminant.

Drinking water is included in some national monitoring programmes, as high levels of contaminants in water can affect

Figure 3 shows the main contaminants covered by GEMS/Food and the foodstuffs that are monitored for each contaminant.

Contaminants and foods monitored by GEMS/Food

contaminants	*foods monitored*
aldrin+dieldrin, DDT endosulfan, endrin gamma-HCH HCB[1], HCH[2] heptachlor, PCBs[3]	fluid milk, dried milk, butter, eggs animal fats and oils, fish cereals vegetable fats and oils human milk total diet
lead	milk canned/fresh meat, kidney fish, molluscs, crustaceans cereals, flour, pulses legumes, canned/fresh vegetables canned/fresh fruit, fruit juice spices infant food total diet
cadmium	kidney, molluscs, crustaceans cereal, grains, flour vegetables total diet
mercury	fish, fish products total diet
tin	canned food canned beverages
aflatoxins	milk, milk products, eggs maize, grains for human and animal consumption pulses legumes groundnuts, other nuts spices, herbs total diet
diazinon fenitrothion malathion parathion methyl parathion	cereals vegetables, fruit cereal grains total diet

1 hexachlorobenzene
2 hexachlorocyclohexane
3 polychlorinated biphenyls

dietary intake levels substantially. Its use in food processing and cooking, and in the washing of food and utensils may also transfer contaminants from water into food.

Some foods are monitored both before and after they are cooked, as contaminant levels can be altered by cooking. Similarly, fresh and canned food are also compared for contamination, as processing is another potential area of contamination.

Monitoring stations return their data to GEMS/Food in a prescribed format. They give the mean (average), median (the point in a set of figures at which there are an equal number of both larger and smaller values) and 90th percentile levels (the range within which 90 percent of a set of values fall) for the contaminants they have monitored. These data form the basis of the assessment, though information from other monitoring programmes, from a number of regional and national studies on food contamination and from scientific literature are also included—particularly where GEMS/Food data are unavailable.

For assessment purposes, data are compared with standards established by the Codex Alimentarius Commission. Levels of pesticide residues in food are compared with the established Maximum Residue Limit (MRL)—the maximum concentration of pesticide residue acceptable in or on a food, agricultural commodity or animal feed. Some countries have set their own standards for acceptable levels of contaminants in a number of foods.

The standard criterion for pesticide consumption is the Acceptable Daily Intake (ADI), which is the daily amount of a chemical which can, over an entire lifetime, be consumed without appreciable risk.

Because certain environmental contaminants, including cadmium, lead and mercury, have a cumulative toxic effect, the tolerable intake for such substances is expressed on a weekly basis—Provisional Tolerable Weekly Intake

FAO

In Europe, there have been an increasing number of cases of poisoning arising from the contamination of food by bacteria such as salmonella, which are often found in eggs and poultry. GEMS/Food is therefore considering the possibility of monitoring microbial contamination in the future.

(PTWI). This figure overlooks daily variations in intake levels, as the real concern is prolonged exposure to the contaminant. Both ADI and PTWI are expressed in terms of microgrammes of the chemical per kilogramme of body weight.

In order to assess daily and weekly contaminant intake, some participating countries have, since 1980, supplied data on total dietary intake of contaminants. These data are compiled by estimating the 'average diet' for a wide range of consumers including babies and children, as well as men and women of different ages and activity rates. Where people eat is also taken into account when estimating average diet, as the preparation and content of public catering and home-prepared foods are likely to differ. After levels of a contaminant are measured in the foods that make up the average diet, the amount of a contaminant which someone is likely to consume in their total diet can then be estimated and compared with the acceptable intake for that contaminant.

Participating institutes are asked to state the reliability of their results. Some institutions have independent studies made on the reliability of their analytical methods and their data, and many institutions check their results through participation in international collaborative studies. Analytical quality assurance studies are also conducted within the GEMS/Food programme in order to ensure the quality and comparability of the data collected.

The results

PCBs

Polychlorinated biphenyls (PCBs) are fluids which were widely used in electrical transformers, heat exchange fluids and hydraulic systems. They have a number of other industrial uses and were, for example, added to paints, copying paper, adhesives and plastics to improve their flexibility. Their commercial production began in the 1930s, but since the early 1970s, when the toxic effects of PCBs were established, their production and use have been drastically restricted in many countries.

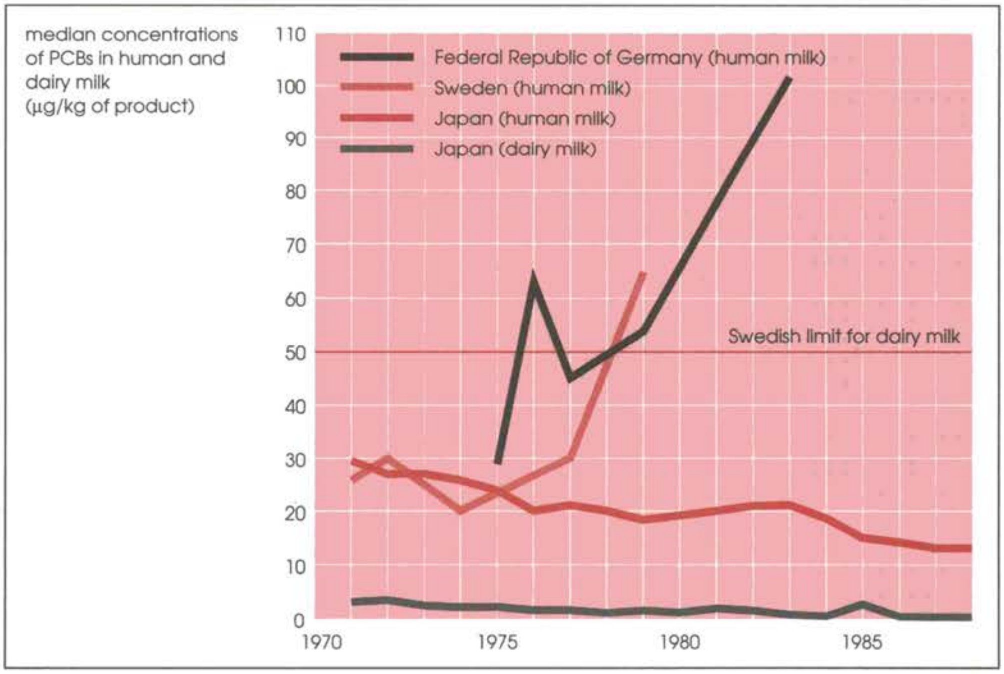
Contamination of edible oil with PCBs led to large-scale poisoning in Japan in 1968 and in Taiwan in 1979. Studies on exposure to PCBs in the working environment suggest that they are a carcinogenic risk to humans.

The GEMS data for PCBs are from 23 countries and cover foods such as milk, cereals, fish, fats, oils and human milk. No tolerable intake levels have been established internationally, though some countries have drawn up national limits for foodstuffs.

The levels of PCBs reported in dairy milk are generally similar to those for Japan shown in the graph below. Levels are below the lowest of the national regulatory limits of 20 µg/kg, and decreasing. Levels reported in human milk are substantially higher, and the general trend is upwards. (Any substitutes for human milk made with contaminated water can also pose a substantial risk to infants' health.)

National limits for meat vary from 200–3000 µg/kg. The data showed that most meat came in the 50–400 µg/kg range during 1970–79, and that after this date the general level fell substantially to just above the limit of detection. There are localized reports from Europe, however, of higher levels of PCBs in meat, which suggests that there are certain regions in Europe where sporadic contamination occurs.

Figure 4 shows that, although levels of PCBs in dairy milk were generally low and falling, levels in human milk were higher; in Sweden and the Federal Republic of Germany they exceeded the limit set for dairy milk.



PCBs are seldom detected in vegetables, vegetable oils, fruits, eggs or cereals. However, high levels have been reported in breakfast cereals in Sweden and Mexico as a result of contamination by packaging material.

GEMS/Food data were collected for a variety of domestic and imported fish—both fresh and canned. Fish generally contain higher levels of PCBs than any other type of food, but the basic trend is downwards. Regulatory limits for fish have been set between 500 and 5000 µg/kg, and the average level is well below this—at about 100 µg/kg—except in Denmark, Japan and the United States, in some instances.

The United States' data showed that domestic fish had been exposed to local sources of contamination, and PCB levels reached 1500 µg/kg in some fish muscle. Other literature indicates that elevated levels of PCBs are also found in fish from locations in Northern and Eastern Europe, the Mediterranean and Canada—these locations are typically inland waters, estuaries and enclosed seas. PCBs, which concentrate in fish liver, have been recorded at very high levels—up to 80 000 µg/kg in some fish liver from Sweden.

As fish are the foodstuff most likely to contain high levels of PCBs, diets that contain a large proportion of fish may result in a high PCB intake. This is illustrated by the data for total diet represented in Figure 6: average fish consumption in Japan is more than four times that in the United States. High intakes of PCBs were also found in some cases in New Zealand, primarily due to a high consumption of dairy products.

The PCB data reviewed in the study indicate that levels are low in most foods and give little cause for concern. Certain areas, however, need to be monitored closely, as they indicate local contamination which is passed on to meat, milk and fish.

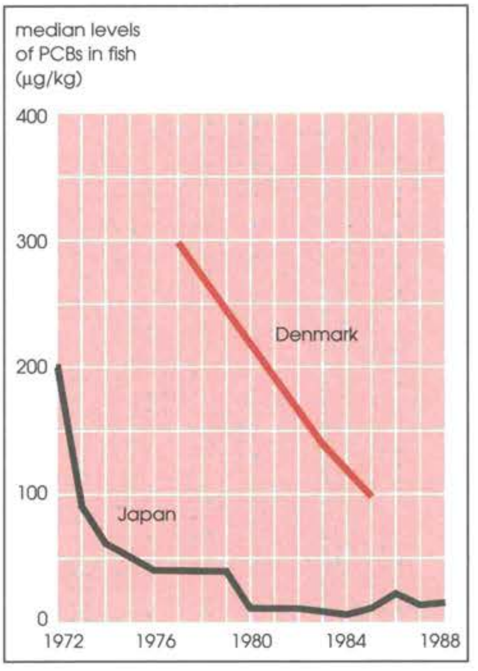


Figure 5 Denmark and Japan reported some of the highest median levels for PCBs in fish. PCB levels are generally low and declining.

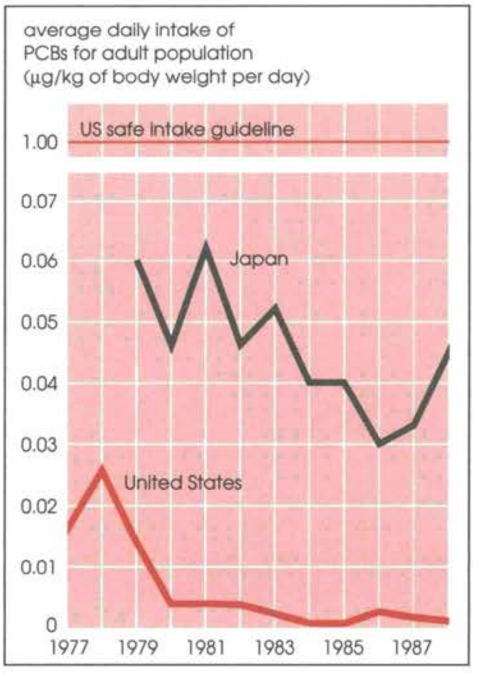


Figure 6 Because of the large amount of fish consumed, average dietary intake of PCBs was significantly higher in Japan than in countries such as the United States.

Lead

Lead is a cumulative poison which produces a series of effects on blood-forming tissues, the digestive and nervous systems, and the kidneys. People affected by lead poisoning become pallid, moody and irritable; their appetite fails and they may become anaemic. In later stages they may suffer dizziness, headaches and visual disturbances, and occasionally paralysis of the hands and wrists. Children are most vulnerable to lead, and adverse effects on intelligence and behaviour have been noted as a result of only very low levels of lead in the blood. In severe cases, poisoning can lead to brain damage or death.

People are exposed to lead every day. It is naturally present in the soil, and is commonly introduced into the environment by industries and through exhaust fumes from leaded petrol used in vehicles. Lead is also found in batteries, solder, dyes and insecticides which can transfer lead into food through direct contact, or indirectly through contamination of the environment. Lead is easily taken into the body by inhaling lead dust, absorbing lead-based chemicals through the skin, or ingesting lead present in food and water.

In the home, lead may be present in drinking water because lead pipes were formerly installed for domestic plumbing, and lead-based solder is used with copper pipes. Lead was also added to paints used on toys and furnishings as well as on walls, and can be present in enamelled kitchenware and pottery glazes, and in the solder in cans containing food and drink.

The fact that lead is commonly encountered in daily life means that many people, and particularly children, may already have lead present in their body. For this reason there is an increased risk of lead building up to a hazardous level in the

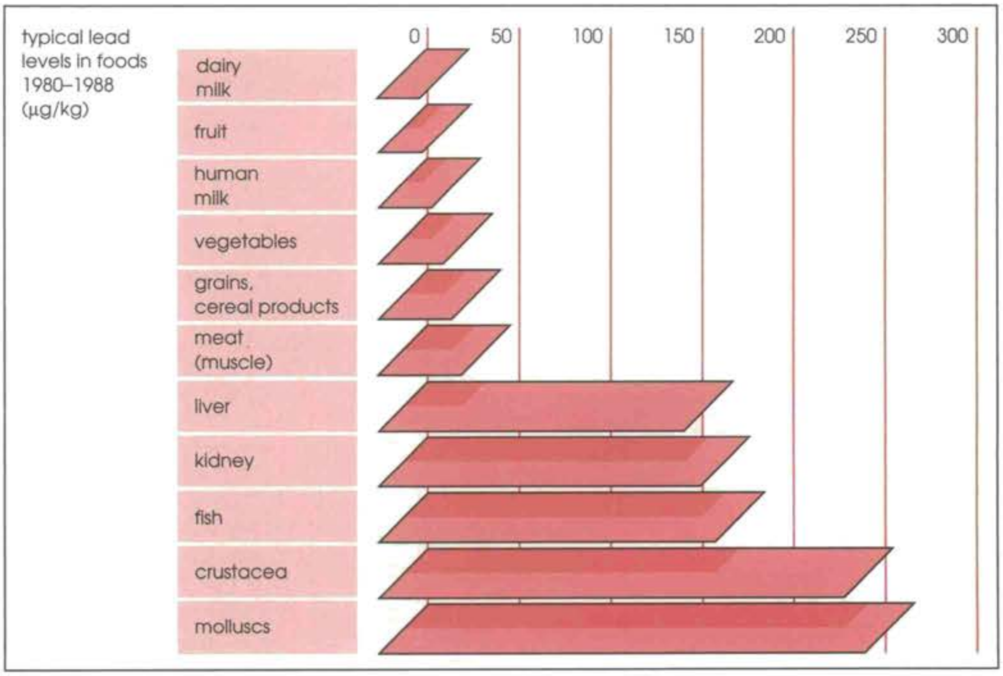
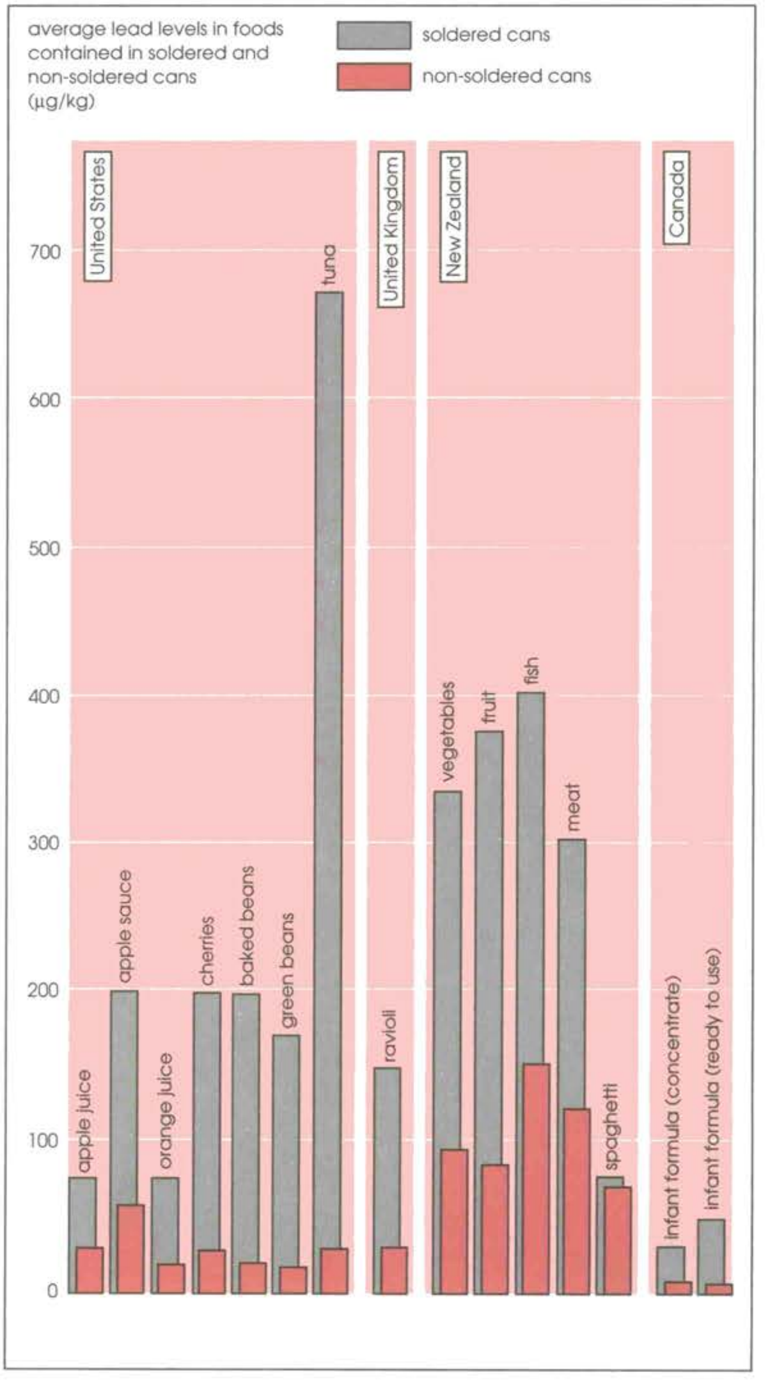


Figure 7 Fish and sea foods typically contained the highest levels of lead. Levels in liver and kidney were higher than those found in meat and other staple foods.

Figure 8 Lead concentrations in canned foods decreased to between one-tenth and one-fifth of their previous levels in GEMS/Food countries that introduced non lead-soldered cans.



body and it is very important to minimize the amount of lead consumed with food.

Because it is so often present, lead is one of the most frequently monitored contaminants in the world, and data were collected by GEMS/Food from 30 countries covering a wide variety of food. The programme concentrated on monitoring lead levels in staple foods such as wheat, rice and potatoes, and on foods that are likely to contain high levels of lead, such as canned food and sea food. The GEMS data (*see Figure 7*) show that fish, shellfish and offal have a higher concentration of lead than meat, cereals, vegetables, fruit and milk. Data from other sources in 21 countries support this conclusion.

As lead is a cumulative poison, tolerable levels of consumption are given as a weekly figure to limit intake on a long-term basis. The PTWI of lead is 50 µg/kg of body weight for adults, and 25 µg/kg for children.

Data from industrial and mining areas show that concentrations of lead are high in vegetables grown there, particularly in the leaves. Vegetables, grains and fruit exposed to heavy vehicle exhaust or industrial emissions also contain higher than normal concentrations of lead.

Lead solder used in cans is the main controllable source of lead in food, and food processors in many countries have started to use non-soldered cans. This is particularly important in the case of baby and infant food. Figure 8 shows the levels of lead in a number of foods before and after the introduction of non-soldered cans which have, on average, cut lead concentrations to between one-fifth and one-tenth of their previous level. Attempts to decrease lead content by improving processing operations for food packed in lead-soldered cans have only achieved a 50 percent reduction.

Information on adult and infant total dietary intake of lead was available from 26 (mostly developed) countries, primarily in the GEMS/Food programme. Some countries reported lead levels over several years, and a downtrend occurred in Finland, the United Kingdom and the United States. This reduction is probably due, in part, to the introduction of unleaded petrol and non-soldered cans.

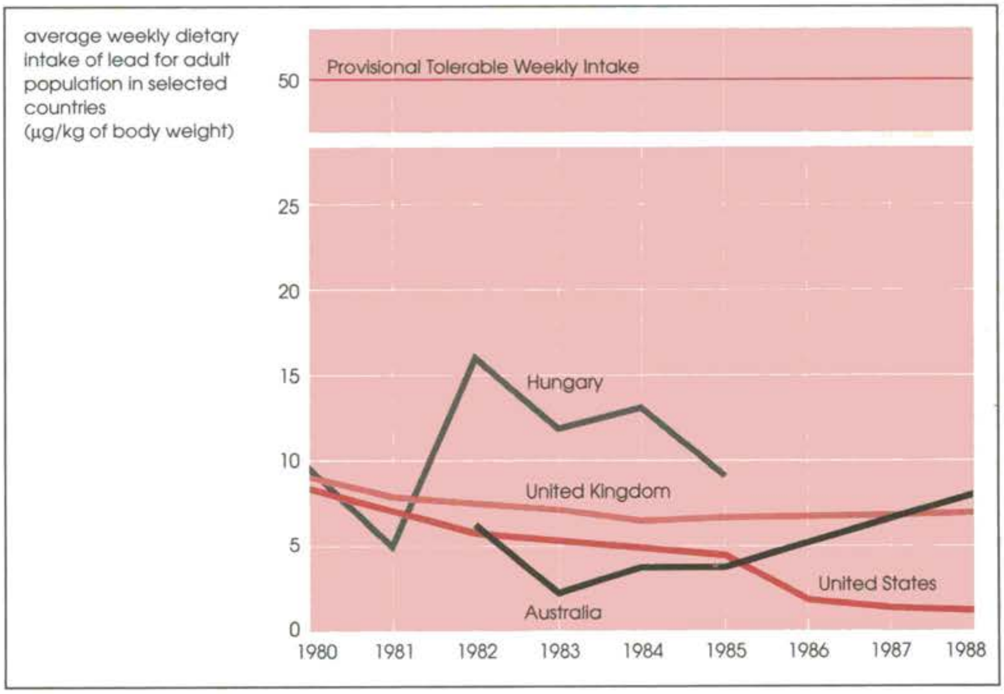
Figure 9 shows the average dietary intake for adults in four countries. The Australian intake was less than 20 percent of the PTWI for lead of 50 µg/kg of body weight. No particular pattern could be traced in the intake variations reported from Hungary, but these are also at an acceptable level. Average intake in the United Kingdom was below 10 µg/kg, but in some areas, where concentrations in tap water were considerably higher than normal, adult intake was approaching the PTWI. Average adult intake in the United States showed a continued decline to a very low 1.1 µg/kg.

Figure 10 shows the average dietary intake of lead for infants and children in seven countries. The PTWI for children is 25 µg/kg, but dietary intake should be well below this level, as children tend to add to the lead they take in with food by swallowing things such as dust, soil and paint.

Data suggested that during certain periods, children's dietary intake was far in excess of the recommended tolerable level in certain regions of some countries, notably Poland, and in areas of Britain with a high lead concentration in drinking water. In such areas, children consume lead not only in drinking water, but in infant food or dehydrated milk prepared with tap water.

In Australia, lead intakes were appreciably higher in the diet of children

Figure 9 The introduction of unleaded petrol has contributed to declining trends in dietary intake of lead in some countries. The average weekly adult intake in many countries was below 50 percent of the Provisional Tolerable Weekly Intake.



aged about nine months than in the diet of those aged about two years. This is attributed to the high proportion of canned baby food in the diet at an early age.

Overall, dietary levels for children are nearer to the PTWI for lead than adult diets. Because children are also more likely to take in lead from non-dietary sources, and can suffer more serious consequences than adults from lead poisoning, every effort should be made to reduce the level in children's diets, and monitoring should continue, particularly in high risk areas.

Data also showed that lead levels in the diet are generally falling in developed countries—from which most of the data were collected. This is mainly a result of the introduction of pollution controls and the conversion to cans that are not lead soldered for food.

There are still, however, vulnerable groups and regions that are a cause for concern. Because lead easily passes the placental barrier every effort should be made to reduce the levels of lead in the diet of pregnant women. In high-risk regions—those with high lead levels in drinking water, areas near industries, and urban centres—dietary intake, particularly of children, should be closely monitored.

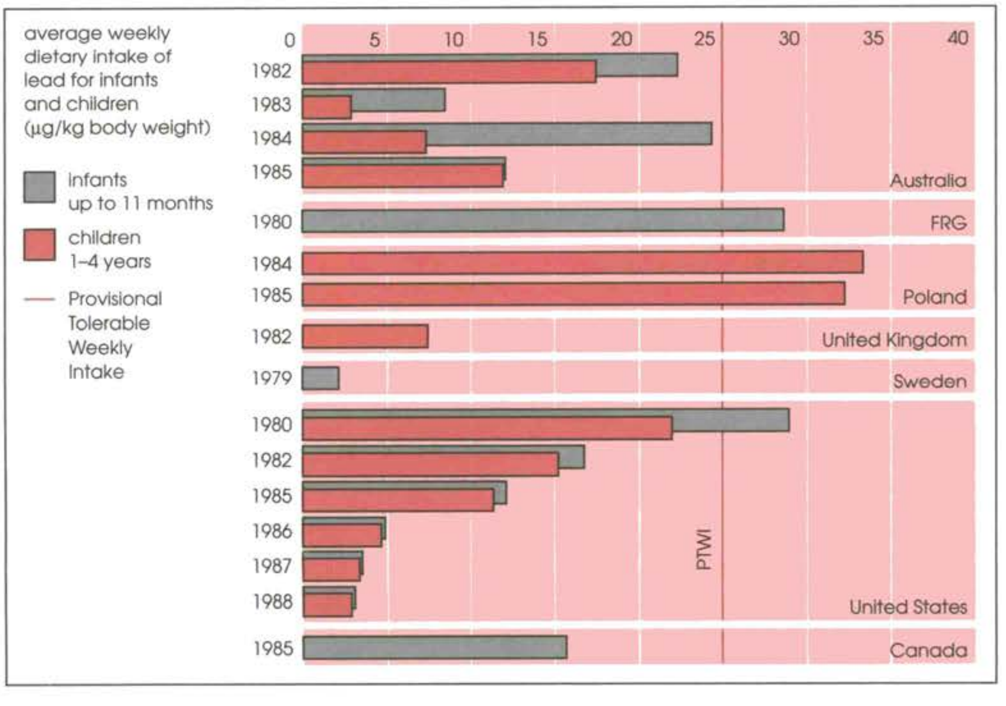


Figure 10 In the Federal Republic of Germany, Poland and the United States children's average dietary intake of lead at times exceeded the PTWI. Since 1980, the United States has taken steps to reduce lead in food, and the level in children's diets has now declined to well below the FAO/WHO guideline.

Cadmium

In Belgium, eating mussels or kidney only once a week would result in a cadmium intake equal to the Provisional Tolerable Weekly Intake.

The main way cadmium, a cumulative poison that affects the kidneys even at relatively low levels of exposure, enters the body is through contaminated food.

The main sources of cadmium in food are industrial emissions and fertilizers which can contaminate soil and crops. Cadmium is present in phosphate rocks, which form the basis of commercial fertilizers, and in municipal sludge and compost used as fertilizers on agricultural land. Other potential sources of cadmium in food are cadmium-lined metal equipment used in commercial food processing, and kitchenware enamel, pottery glazes and plastics containing cadmium.

National regulatory limits for cadmium vary from 10 µg/kg in milk or eggs to 2000 µg/kg in fish and shellfish, and the established PTWI is 7 µg/kg body weight. Data were obtained from 31 countries and a set of typical results is shown in the table above right. The data showed that average levels were lowest in dairy products, vegetables, fruit, cereals, meat and fish. There was a sharp increase in cadmium concentration in molluscs and crustacea, and in kidney—the organ most affected by cadmium—in which contamination was found to increase with the age of the

Typical reported cadmium levels

	typical level (µg/kg)
milk, eggs	5
fruit	10
meat muscle	15
vegetables	25
cereals/cereal products	30
fish	35
molluscs and crustacea	350
kidney	500

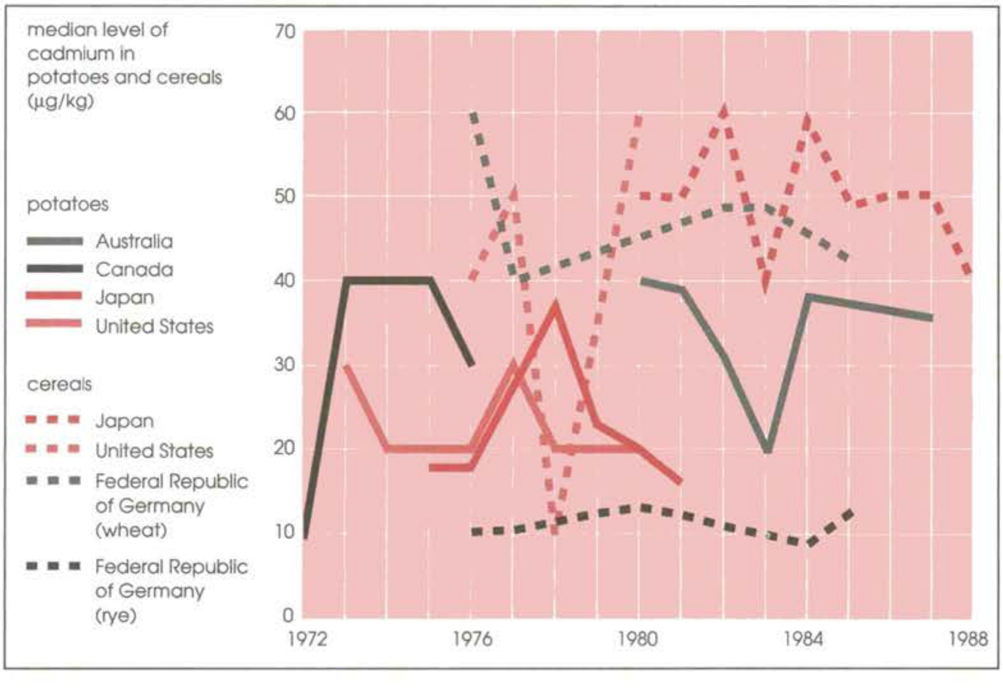


Figure 11 The median level of cadmium in potatoes—a staple food in many countries—was between 15 and 40 µg/kg. Concentrations of cadmium in cereals varied with the cereal; air-dried grains grown in industrial areas showed high levels of contamination.

animal. In Belgium, eating mussels or kidney only once a week would result in a cadmium intake equal to the PTWI. Similarly, in Denmark, above average consumption of beef kidney, mussels from contaminated water, or wild mushrooms would mean cadmium intake exceeded the PTWI.

Figure 12 shows the average cadmium intake of adults in 15 of the reporting countries. In some cases levels are approaching the PTWI of 7 µg/kg. This is because cadmium, even though usually found only at low levels, is present in staple foods which are eaten regularly. A few countries reported dietary intake over a number of years, and the trend was downwards in Japan, the United Kingdom and the United States.

Certain areas within the reporting countries had levels of cadmium higher than the national average. In Denmark the average intake is about 35 percent of the PTWI, but in an area near a lead smelter consumption of home-grown vegetables and fruit took the level to about 70 percent of the PTWI. The same level of increase was noted in other industrial areas in comparison to the national average.

Figure 13 shows average cadmium intake associated with different levels of cadmium in drinking water for children in the Federal Republic of Germany. The higher level in water increases weekly cadmium intake significantly. Intake levels in Figures 12 and 13 illustrate the general tendency for children's intake, in relation to body weight, to be above that of adults. Dietary cadmium intake above the PTWI may be a health risk only if it is sustained for long periods of time, as PTWI is based on exposure for 50 years.

It will be necessary to continue monitoring for cadmium in staple foods—particularly animal organs, shellfish, vegetables and grains—and in foods from areas of known cadmium contamination.

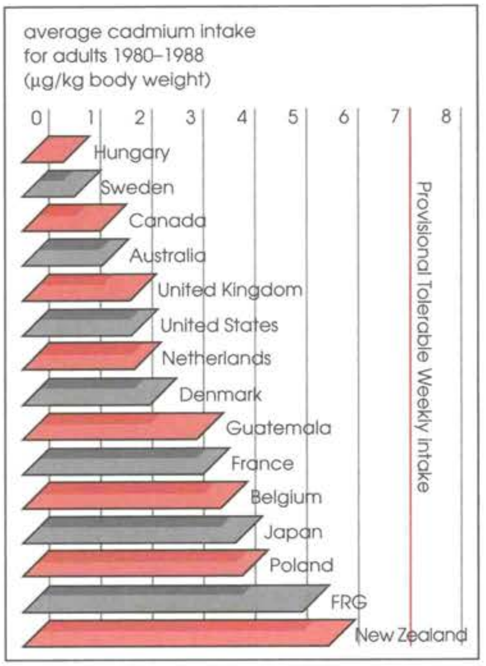


Figure 12 None of the reporting countries had intakes of cadmium in the average diet above the Provisional Tolerable Weekly Intake. Certain foods did show very high concentrations of cadmium, however, and eating these could take individuals over the recommended limit.

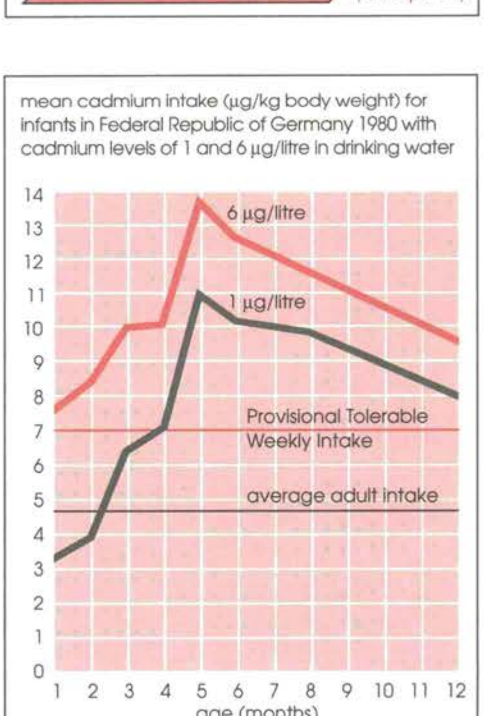


Figure 13 A study in the Federal Republic of Germany shows that children's mean dietary cadmium intake is significantly increased by high concentrations of cadmium in drinking water.

Mercury

Mercury has been used by man for many centuries—it was known to the ancient Chinese and has been found in Egyptian tombs more than 3500 years old. Today it is still commonly used—in thermometers, batteries, fluorescent lights and in many industrial processes including the production of fungicides and paints.

Mercury has toxic effects on animals and people—pregnant women, nursing mothers and children are particularly sensitive to mercury poisoning. The most toxic form is methylmercury which causes damage to the central nervous system.

A PTWI of 300 µg per person (equivalent to 5 µg/kg of body weight) has been established, of which no more than 200 µg (3.3 µg/kg) should be methylmercury.

Methylmercury is often found in fish because industrial effluents containing mercury are discharged into rivers or seas where they are converted by bacteria into methylmercury which concentrates in the bodies of fish. Many countries have therefore set limits specifically for mercury in fish, mostly at about 500 µg/kg.

Extensive data on mercury in food compiled by other bodies were incorporated into the GEMS/Food assessment. Data from the 1960s and 1970s showed mercury levels in grains, cereal products, vegetables, fruit and meat to be generally below 30 µg/kg. Levels in fish from unpolluted waters were found to vary, but not exceed about 200 µg/kg, and levels in molluscs and crustacea were rarely above 100 µg/kg. In contaminated freshwater areas mercury levels of 500 to 700 µg/kg were often found in fish, and large carnivorous saltwater species such as shark and tuna normally fell in the range 200–1500 µg/kg.

The Mediterranean area accounts for 50 percent of the world's production of mercury and extensive data have been collected by the UNEP Coordinated Mediterranean Pollution Monitoring Programme on mercury in fish from the area. The data showed that levels of

Marine fish* in which high mercury levels have been recorded

species	*mean value (µg/kg)*	*maximum value (µg/kg)*
dogfish	450	1170
garfish	550	1250
mackerel	1200	
meka	1600	3000
milkfish	640	
perch	500	1700
purbeagle	1800	4200
shark	1000	8350
snapper	380	990
swordfish	1000	3000
tuna	300	2000

* species in which high mercury levels have been found on certain occasions and in specific places

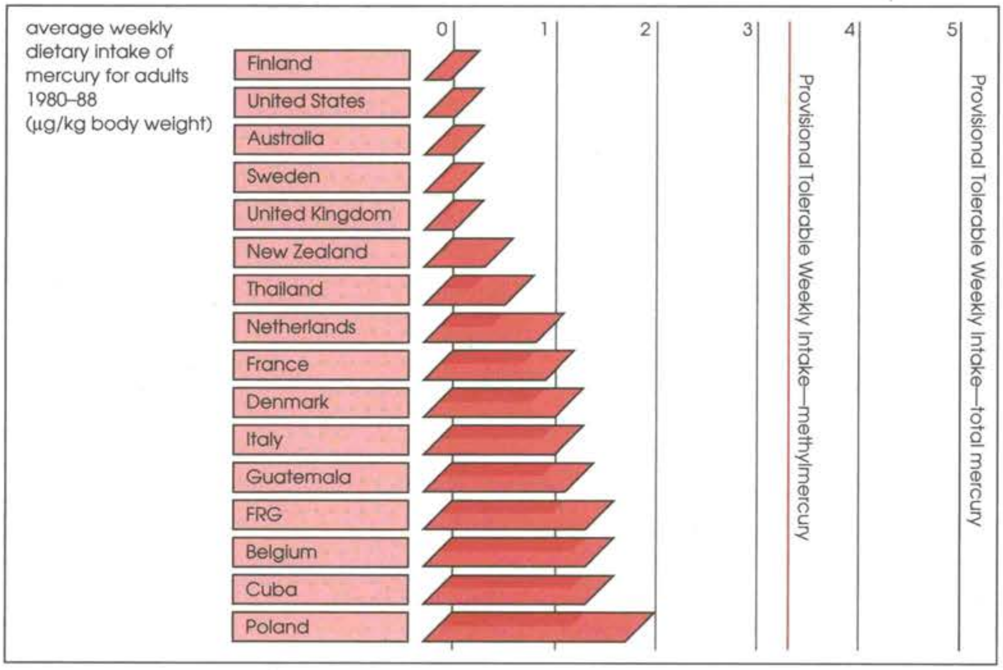


Figure 14 Mercury is not present at high levels in the average diet, but regional variations in fish consumption can take individuals over the Provisional Tolerable Weekly Intake.

mercury were very high—up to 7900 µg/kg—in fish from Mediterranean waters near mercury mining areas.

GEMS/Food collected data on mercury concentrations in fish from 31 countries. On average, mercury levels for marine and freshwater fish were in the 10–300 µg/kg range, but much higher levels were also reported. Marine species containing higher than average mercury levels are shown in the table on page 22. Some freshwater fish also had high levels of mercury.

Total weekly mercury intakes for 1980–88 in an average adult diet are shown in Figure 14. Countries that reported children's dietary intakes found them to be equal or higher in relation to body weight than those of adults. In all countries average adult consumption is below the PTWI, but these figures obscure regional variations that occur in diet, and hence in mercury intake.

In the United Kingdom, for instance, the average amount of fish eaten per day is about 20 g, but in fishing communities it is about 50 g per day. Studies in two UK fishing communities revealed that the average dietary intake of mercury was about 1.7 µg/kg per week in a fishing area affected by industrial pollution, and about 1.3 µg/kg in a non-industrial fishing community. These levels are significantly higher than the average UK intake level of 0.3 µg/kg of mercury per week. Because of the large amount of fish consumed in coastal regions, 12 percent of the people surveyed were over the PTWI for methylmercury.

These results highlight the need to control the sources of pollution that lead to methylmercury forming in water. Health risks could also be reduced by banning or limiting fishing in polluted areas; setting standards to limit the mercury level in all fish and seafood; and advising the public to limit the amount of fish eaten or to restrict a fish-based diet to those species which commonly contain low mercury levels.

Aflatoxins

Aflatoxins are toxic substances produced by certain moulds, such as *Aspergillus flavus*, which grow on plants and seeds. The amount of aflatoxin produced depends on the growing conditions—under stress conditions such as drought, insect infestation or cyclone it is likely to be high. Storage conditions can also lead to aflatoxin contamination after crops have been harvested—hot, humid conditions lead to moulds forming on the food and to high levels of aflatoxins.

The incidence of liver cancer shows a distinctive geographical distribution similar to that of aflatoxin contamination of food and from this and other data it has been concluded that aflatoxins are potentially carcinogenic to humans.

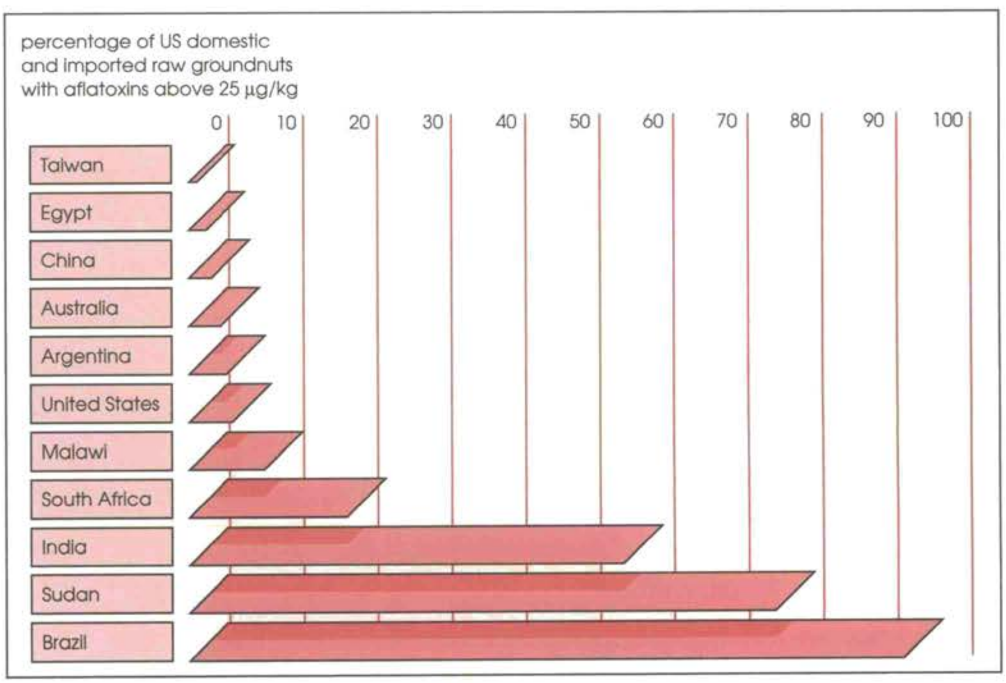
More than 50 countries have introduced recommended limits for aflatoxins in food which range between 5 and 20 µg/kg, and the Codex Committee has proposed a level of 10 µg/kg.

Data on a variety of foodstuffs were reported by 34 countries in 1980–88. Some of the highest aflatoxin levels in grains were found in maize, particularly from the Soviet Union, India and the United States.

However, data can only give an accurate picture of the particular area the food was grown in, for one specific time of year, as surveys carried out in other areas of the country, and at different times of the year, give different results. For instance, the United States had low aflatoxin levels in the Midwestern states until 1983, when drought and other stress conditions caused high contamination levels in the area.

Other grains such as barley, oats, rye and rice were low in aflatoxin contamination in most of the reporting countries. However, foods from Nigeria were more contaminated during the rainy season, and the highest levels of contamination in rice

Figure 15
The percentage of contaminated samples of groundnuts (the highest recommended level is 20 µg/kg) detected in US monitoring for 1981 indicates that existing regulations are not effectively controlling aflatoxin contamination in all countries.



from India were found in parboiled (partly-cooked) rice and rice from cyclone-affected areas.

Aflatoxins are most commonly associated with nuts. Because of this, the United States has introduced mandatory testing of domestic and imported groundnuts (peanuts). A shortfall in the 1980 US crop resulted in an unprecedented volume of groundnuts being imported. Tests on these nuts showed that contamination can occur in all parts of the world (*see Figure 15*). Fifteen other countries reported significantly high aflatoxin levels in about 0.5 percent of groundnut samples, which included imported US groundnuts.

To reduce levels of aflatoxins in their imported nuts the United States has introduced a number of programmes in cooperation with producer countries and these have been largely successful.

Oilseeds and the oils produced from them were generally low in aflatoxins. High levels tended to correlate with unrefined oils which make up the majority of oils used in developing countries.

Pulses, milk, dairy products, meat and eggs contained only low levels of aflatoxins apart from instances of contamination of pulses in Nigeria, Thailand and India, and in a small number of imported cheeses reported by Japan and the United States.

Some of the foods which were found to contain aflatoxins are also used in animal feeds—particularly grains, maize and oilseeds.

Australia, Guatemala, Japan and Kenya submitted data on intake of aflatoxins in the typical diet. Japan did not detect any aflatoxins. The highest mean intake (0.26 µg/kg body weight/day) was reported by Guatemala.

The data show that developed countries are taking effective steps to reduce aflatoxin levels in foods, though certain commodities still need to be closely monitored, particularly those from tropical regions.

Aflatoxin levels in maize, rice and groundnuts

maize

country	*year*	*no of samples*	*median range (µg/kg)*	*90th percentile range (µg/kg)*
Brazil	1981–86	556	n/d*	n/d–5
Canada	1986–87	35	n/d	n/d–1
China	1988	29	4	21
Guatemala	1984	63	3–5	22–82
Ireland	1986–88	11	n/d	n/d
India	1987–89	100	3–7	85–91
Mexico	1980	31	n/d	n/d
United States	1980–88	4053	n/d–80	n/d–239
Soviet Union	1981–82	219	n/d	n/d–662

* not detected

rice from India (1977)

type of rice	*no of samples*	*determinable toxins: % of samples*	*determinable toxins: range (µg/kg)*
raw	35	0	not detected
parboiled	43	32	30–130
paddy	272	0	not detected
cyclone-affected	161	17	trace–1130

ground nuts

country[1]	*year*	*no of samples*	*median range (µg/kg)*	*90th percentile range (µg/kg)*
Brazil (D)	1980–88	1566	n/d–1009	30–6864
Guatemala (D)	1988	35	9	198
India (D)	1988–89	169	9–19	264–275
Ireland (I)	1980-88	72	20-2000	120–400
Mexico (D)	1980	29	43	700
UK (I)	1984	26	n/d	2990
USSR (D, I)	1982	21	n/d	329

[1] countries with significantly elevated levels
D=domestic, I=imported

Organochlorine pesticides

In the early 1970s organochlorine pesticides were identified as one of the major classes of environmental pollutants. Developed countries have, since then, reduced or banned their use, though they are still used in developing countries. These pesticides persist in the environment after they are used and are absorbed by animals and fish. They accumulate in fatty tissues and increase in concentration as they pass up the food chain. Organochlorine compounds therefore occur primarily in milk and dairy products, animal fats, fish and eggs.

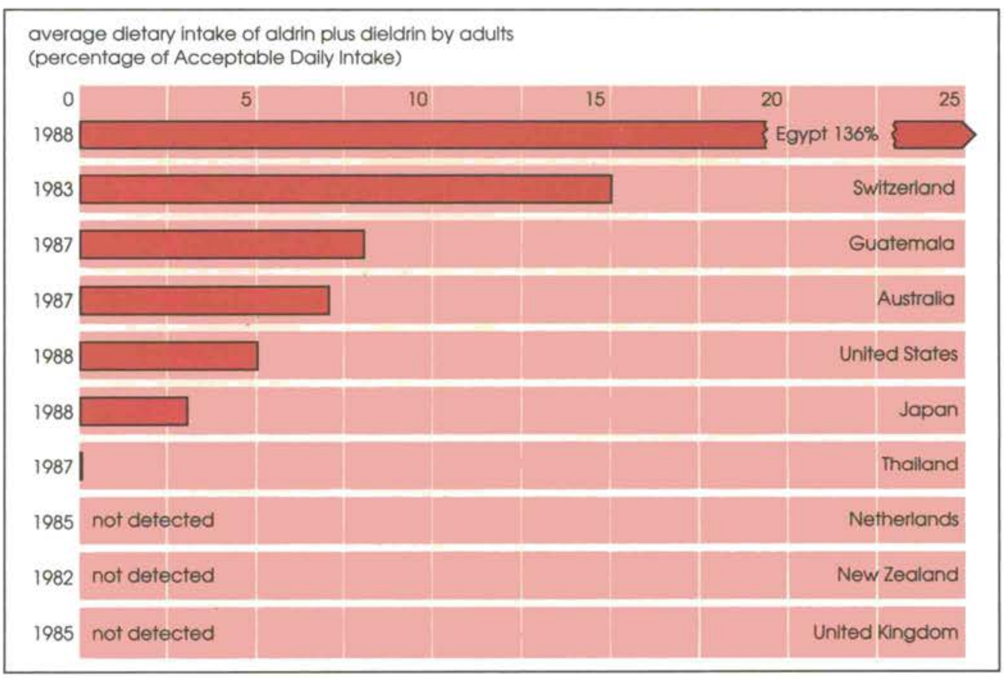
Pesticides work by breaking down the nervous system of insects but, at high concentrations, human nerve cells are not immune to their effects. Ingestion of small amounts of pesticides can cause shaking and fatigue comparable with flu. Ingestion of high pesticide concentrations can cause a breakdown of the central nervous system.

Aldrin, an organochlorine compound first used as an insecticide in the 1940s, is toxic to warm-blooded animals and can be absorbed into the body by ingestion, inhalation or through the skin. Aldrin is readily converted by plants and animals to dieldrin, and it is mostly dieldrin which is found in food.

GEMS/Food data show a decline in aldrin and dieldrin residues over the past 15 years in dairy and human milk—which have in some countries exceeded acceptable levels. Levels in butter, cereals, fruit, vegetables, eggs meat and fish have remained very low.

The FAO/WHO Acceptable Daily Intake (ADI) level is 0.1 µg/kg for aldrin plus dieldrin. Figure 16 shows recent data from 10 countries on average dietary intake, shown as a percentage of the ADI. In most of these countries, intakes have declined and are well below recommended dietary intake levels. This general downward trend is largely due to the restrictions or bans imposed on the use of aldrin and dieldrin.

Figure 16 In most reporting countries, average daily intake of aldrin plus dieldrin has declined to less than 0.01 µg/kg of body weight or 10 percent of the Acceptable Daily Intake.



DDT, an organochlorine pesticide, was used widely from the 1940s to the 1960s. DDT persists in plants and soil, passes along the food chain, and can thus be present in food for human consumption. These dangers were recognized in the 1970s and the use of DDT was restricted in many countries. It is still, however, one of the major pesticides in India; and is widely used in developing countries to destroy mosquitoes and thereby combat malaria.

DDT is most often found in food with a high fat content, particularly milk and dairy products. Data from the returning countries showed that levels of DDT in milk were generally declining. Comparatively high fluctuations did occur, though they were usually well below the recommended residue limit of 1250 µg/kg. Reports from Egypt and India, however, indicate a high level of DDT contamination, with median levels in milk fat of 3400 and 4000 µg/kg respectively. Data from tropical countries (which reported the highest levels to GEMS) and from Eastern Europe are very limited. Average DDT levels in human milk are shown in Figure 17.

Most countries reported low levels—less than 100 µg/kg—in cereals, pulses, fruit, vegetables, eggs, fish and meat. Literature from India, however, again showed much higher levels in cereals (more than 400 µg/kg), eggs (more than 900 µg/kg) and meat (more than 600 µg/kg for pork).

The ADI for DDT is 20 µg/kg body weight. Most data from countries reporting to GEMS, and from published literature, have shown that average DDT intake levels are declining, and have been less than one percent of the ADI since 1980. In Egypt and India, however, average intakes were about 70 and 20 percent of the ADI respectively. Most countries which are major users of DDT have not submitted data, and literature suggests that there is highly contaminated produce in some regions.

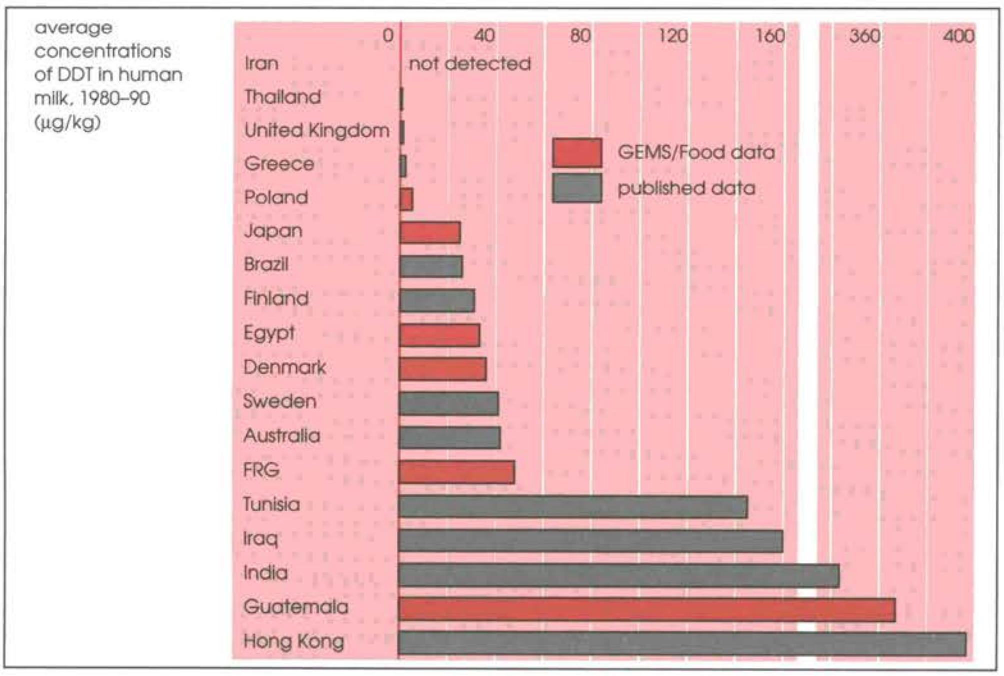
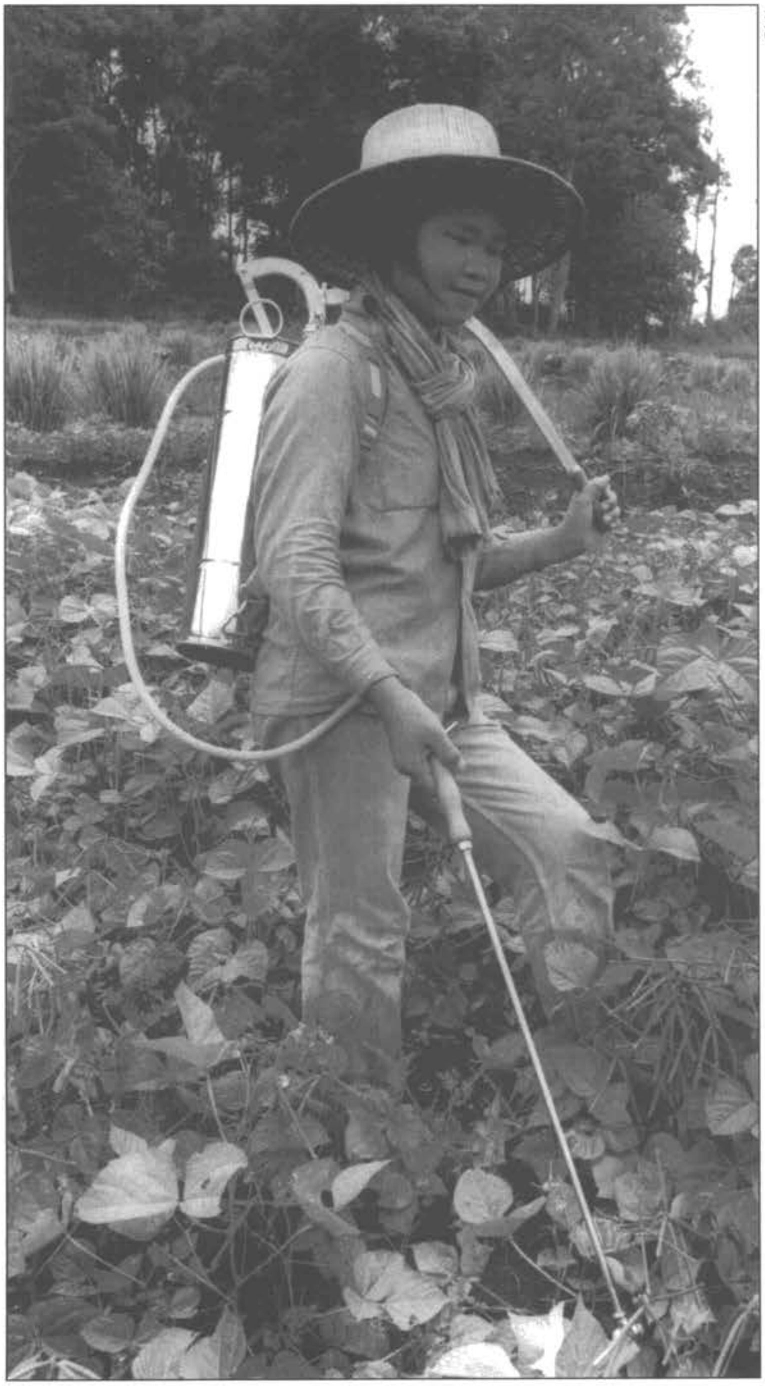


Figure 17 DDT is commonly found in high-fat foods such as milk, and levels are higher in human milk than in cow's milk. The highest DDT levels were reported by developing countries.

Spraying crops in Thailand. The use of organochlorine pesticides in developing countries has led to high levels of pesticide residues in some foods.



FAO

Hexachlorobenzene (HCB) was widely used on cereal grains as a fungicide until the 1970s. HCB emissions from chemical industries and waste disposal operations can also contaminate food. Levels reported to GEMS were generally low, except those for dairy and human milk which, in some countries, were either increasing or fluctuated widely. The highest median level in dairy milk from Japan was about 70 μg/kg, while more representative average levels from The Netherlands, Brazil, Canada and the United States were less than 10 μg/kg. Average levels for human milk reached 30 μg/kg (*see Figure 18*).

No ADI has been established for HCB since the conditional level of 0.6 μg/kg was withdrawn in 1978. Many countries reported dietary intakes of less than 0.02 μg/kg body weight.

Hexachlorocyclohexane (HCH) is an organochlorine pesticide which has been banned or restricted in most developed countries, though it is still used in India and some other developing countries.

Most food contained low levels of HCH. Dairy milk fat usually contains 20–30 μg/kg, but elevated levels were occasionally reported, particularly in developing countries. Levels of HCH in human milk were generally much higher than in cow's milk: Hong Kong and India reported levels around 500 and 200 μg/kg respectively.

Levels of HCH in meat, vegetables, cereals and eggs were generally low (below 30 μg/kg). Studies in India, however, reported very high levels of HCH—9860 μg/kg in wheat from Punjab, for instance.

Figure 19 shows average dietary intakes for adults reported to GEMS or found in open literature. No ADI has been established, but average intake levels were less than 0.03 μg/kg body weight in all countries except India, where 20.1 μg/kg was reported. Data from all countries reporting intakes over several years revealed a down trend in HCH levels.

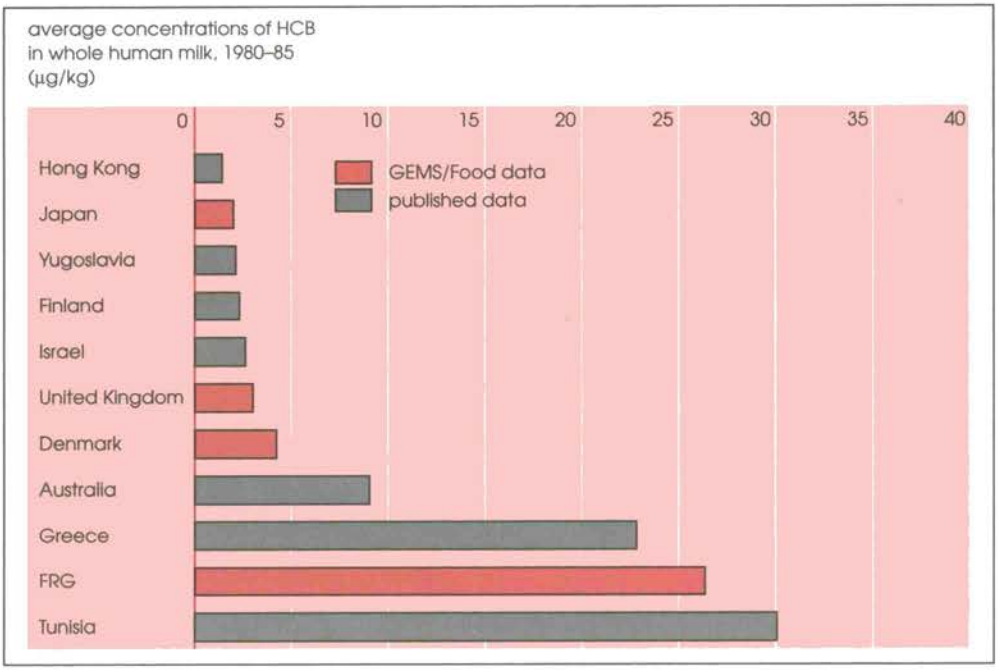


Figure 18 Human milk was the food in which the most HCB was found. The increasing level of contamination in the Federal Republic of Germany is mainly a result of the continued use of HCB in industry and waste disposal operations.

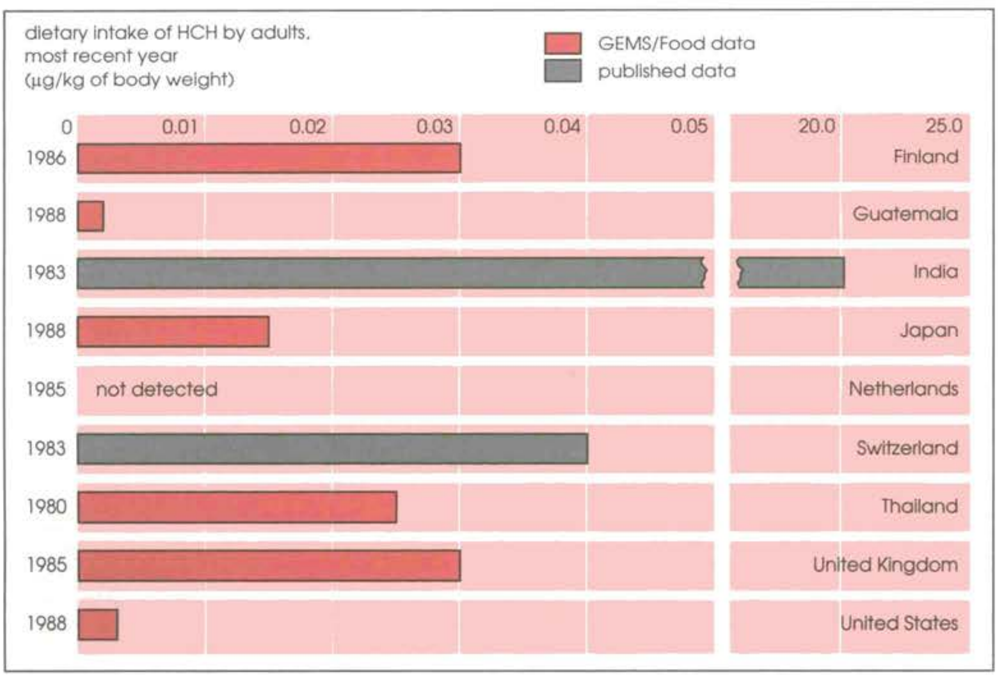


Figure 19 Average dietary intake of HCH is low—less than 0.03 µg/kg in all reporting countries. Literature from India suggested elevated HCH levels.

Organophosphorus pesticides

In contrast to organochlorine compounds, organophosphorus pesticides cannot remain in the environment for prolonged periods, and do not remain in the tissues of animals that ingest the pesticides. Because of this they have increasingly replaced organochlorine pesticides, and this led to their inclusion in the GEMS monitoring programme in 1980. Organophosphorus pesticides pose a serious risk to health when ingested at high concentrations.

Because organophosphorus pesticides are not present in animal tissues, GEMS requested data on these pesticides in cereal grains, vegetables and fruit of dietary importance. The results of monitoring five of the major pesticides—diazinon, fenitrothion, malathion, parathion and parathion methyl—are dealt with here. There are no internationally established limits on organophosphorus pesticide levels in food, except for the Maximum Residue Limit (MRL).

Diazinon was first produced in the 1950s and was used in public health programmes and on fruit and vegetable crops. For diazinon the MRL is set for certain cereals at 100 μg/kg and for vegetables at 500–700 μg/kg. In most of the fruit and vegetables in the study, organophosphorus pesticide levels were hardly detectable, and those in cereals were below 5 μg/kg.

A few exceptions did occur—some fruit and vegetables monitored in Ireland, the Republic of Korea, The Netherlands, Sweden and Thailand contained 90th percentile levels in the 100–400 μg/kg range. These occasional high concentrations suggest that there are isolated occurrences of contamination with diazinon.

Data on dietary intake indicated the same pattern of contamination. Intake was generally less than 0.01 μg/kg in Australia, Japan, New Zealand, Switzerland and the United States—well below the ADI of 2 μg/kg.

FAO

Pesticide spraying in Saudi Arabia. Organophosphorus pesticides are now widely used in countries with high-technology agriculture.

Fenitrothion is another insecticide that has been widely used on fruit, vegetables, cotton and in public health programmes. Temporary MRLs for fenitrothion in certain foods are the only limits which have been established to date. These include bread, 200 µg/kg, and cereal grains, 10 000 µg/kg, but no limit has been set on citrus fruit.

In general, levels in cereals were far below the MRLs, but Australia did report extremely high 90th percentile levels in 1984 and 1987 in bread and wheat bran—which exceeded the MRL. Levels in fruit were also generally very low, except for citrus fruits—oranges imported into Ireland had median levels of 710 µg/kg in comparison to an average of less than 10 µg/kg in other fruits.

These exceptional levels represented only a very small proportion of the total food tested; and the US and Japanese data showed mean dietary intake of less than 1 percent of the temporary ADI of 5 µg/kg body weight. In Australia, however, mean dietary intake for 1986–87 was about 44 percent of ADI.

Malathion is a general pesticide, but is used mainly on cereal crops. Nearly all the data returned showed that levels in food were barely detectable. Again, certain exceptions came to light—notably US grain in 1984–88, which on average was low, but did include samples which exceed the MRL of 8000 µg/kg. Fruit and vegetables were the same, in that the average levels were very low, but isolated samples from the United Stated and Sweden did exceed the MRL. In general, levels were no cause for concern—the average dietary intakes reported by Australia, Guatemala, Japan, New Zealand, Switzerland and the United States were less than one percent of the recommended level.

Parathion, an insecticide with a wide range of uses, has now only a restricted use in agriculture and has largely been replaced by parathion-methyl.

MRLs for parathion have been established in citrus fruit at 1000 µg/kg and for most other fruits at 500 µg/kg. A small number of samples from Canada, Ireland, Thailand and the United States showed 90th percentile levels of 100–200 µg/kg. A few vegetable samples from Canada, Thailand and The Netherlands had 90th percentile levels up to 400 µg/kg.

Dietary intakes were reported by Australia, Guatemala, New Zealand, Switzerland, Thailand and the United States. Average daily intake was generally less than 0.4 percent of the ADI of 5 µg/kg.

Parathion-methyl is used on a large number of agricultural crops, particularly cotton, and was found in food only at low levels. Denmark, The Netherlands and Thailand reported a few instances of 90th percentile levels of 200–500 µg/kg in fruit and vegetables. Average dietary intake was generally less than one percent of the ADI of 20 µg/kg. Such low levels may be due to the fact that this pesticide is used mainly on non-food crops in the reporting countries.

The data show that organophosphorus pesticides are seldom present in foods. However, the isolated instances of high levels show that contamination of cereals, fruit and vegetables can still occur.

Prevention and control

The results from GEMS/Food highlight the effectiveness of government regulation in relation to food contamination. However, the results also show that even in countries with such regulations, accidental contamination is still a danger, and continual vigilance is necessary. In developing countries, the apparent occurrence of serious and widespread food contamination threatening the health of millions of people can be prevented only by government action.

Contaminated food can be prevented from reaching consumers by eliminating contamination during growth, processing, transportation and storage of food; and, if contamination should occur, by controlling the source of contamination, and preventing the sale of contaminated food. In practice, these methods are most effective when used in conjunction with one another.

Controlling food contamination once it has occurred does not provide as effective protection for consumers as preventative methods. Producers, for instance, may not be aware that contamination has occurred, and if the contaminated food is not otherwise detected, it will be passed on for sale. Even if monitoring reveals that the level of contaminant in a foodstuff exceeds the official limit, all the affected food cannot be easily traced and withdrawn from sale.

As well as being more effective, preventative measures require fewer resources in the long run, and it is the responsibility of governments to introduce and enforce such measures. Regulations must apply to industrial operations in order to reduce levels of toxic effluents and emissions released into the environment; to agricultural practices in order to control the chemicals applied to crops and reduce the spread of disease amongst animals; and to food processors to ensure that otherwise wholesome food is not contaminated by bacteria or toxic substances during processing or packaging.

Accurate data on current national levels and trends in food contamination are essential to governments when implementing regulations to prevent food contamination. A national monitoring programme can provide this information, monitor the effectiveness of regulations, and supply governments with information on any contamination detected.

Effective measures to both prevent and control food contamination are discussed below. The over-use of pesticides is an area of particular concern. To prevent this, governments and agencies should inform farmers of Good Agricultural Practice (GAP) in the use of pesticides as set up by the FAO International Code of Conduct on the distribution and use of pesticides, and encourage farmers to adopt these agricultural methods. The aim of these GAP recommendations is to protect the food supply, agricultural workers and the environment from contamination by pesticides.

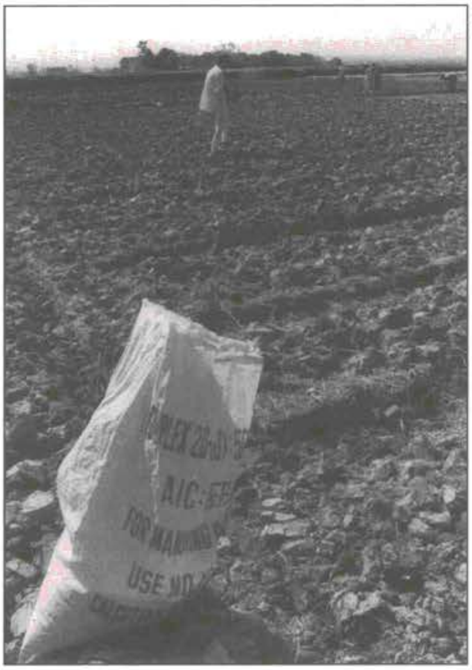
GAP involves following the officially recommended use of pesticides at every stage of production, storage, transport, distribution and processing of food, agricultural commodities and animal feed. GAP also entails the use of only the minimum quantity of pesticide necessary to achieve adequate results, and makes recommendations about the choice of pesticides, their application and post-treatment practices.

Another area of concern is the effect of fertilizers on food plants. Most fertilizers contain phosphate rock, and one of the naturally-occurring impurities in this is cadmium, which can be transferred into crops. It has been estimated that half of the cadmium in food in The Netherlands comes from fertilizers. Municipal sewage sludge used as fertilizer is a source of both cadmium and lead in food crops.

The contamination of food by fertilizers can be controlled through regulations that establish a maximum level of cadmium in the raw material used in the production of fertilizers, and a maximum level of pathogens and contaminants in sewage sludge used on crops.

The discharge of toxic metals and organic chemicals into the air, water and soil is a major source of food contamination. Levels of some contaminants can be effectively controlled at source through technology and government regulation.

Lead emissions from vehicle exhausts can be reduced through the use of unleaded petrol. Lead levels in rivers and lakes can often be reduced by regulating emissions from battery plants, lead alkyl and pigment plants; and atmospheric lead, which contaminates crops, can be reduced through the regulation of emissions from vehicles, and mining, smelting and refining operations. Contamination of



FAO

In some countries, half the cadmium present in food comes from fertilizers.

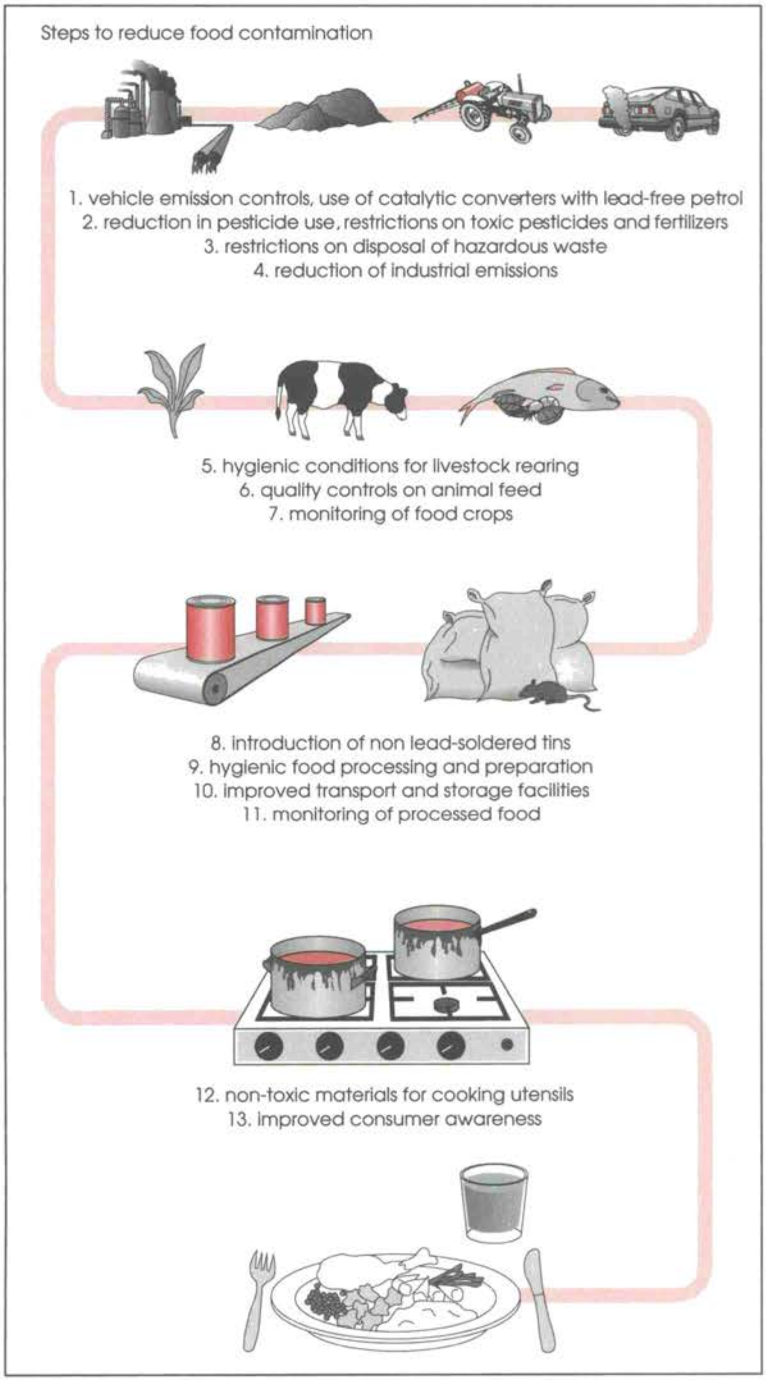
The role of national food monitoring programmes

A national monitoring programme provides accurate data on levels and trends in food contamination which can be used as the basis for preventative regulations. Should contamination occur, monitoring can detect unsafe food and prevent it from being sold. As well as protecting domestic consumers, regulations and monitoring strengthen a country's position in international markets by ensuring the quality of exported food.

National monitoring programmes can:

- determine the extent of national food contamination levels and the risk they pose to public health;
- identify foods which are likely to become contaminated, and determine the source of, or reason for, their contamination;
- point out the need for control to producers and governments, and provide guidance for regulations, if necessary;
- provide the impetus for cooperative action between government agencies responsible for health, agriculture and environmental protection, and the food and chemical manufacturing and processing industries;
- furnish monitoring data to ensure the effectiveness of existing government regulations;
- provide access to international markets by ensuring the quality of exported food ;
- prevent countries from becoming a dumping ground for sub-standard food from abroad; and
- advise other bodies carrying out food and environmental monitoring.

Figure 20 Government regulations, food monitoring programmes, and technological improvements in agriculture, industry and commercial food processing can significantly reduce food contamination.



drinking water by lead pipes can be remedied by replacing the pipes with non-lead plumbing.

Atmospheric cadmium from mining and smelting affects crops in the vicinity of the plants; and other industrial processes such as electroplating are a major source of cadmium contamination of water. Effluents and emissions from these industries need to be regulated to reduce cadmium levels in the environment.

The effectiveness of such regulations is illustrated by the case of the discharge into water of mercury-bearing industrial waste—the major source of mercury in fish. Strict guidelines introduced in the early 1970s in the United States led to a reduction in the amount of mercury released into water from 540 000 kg to less than 9000 kg per year within a few years. Effluent controls have significantly reduced the amount of mercury found in fish from inland and coastal waters.

Reductions in HCB levels can be reduced through careful disposal or incineration of hot tar, a waste product of the chlorine chemical industry. If it is disposed of indiscriminately it can affect nearby crops, meat and dairy animals.

If the effects of food contamination by a commonly used substance are extremely serious and potentially widespread, its use should be restricted or prohibited. Such was the case with DDT and aldrin in most developed countries; and PCBs have also been banned or restricted and their disposal regulated. However, a ban on the manufacture and use of chemicals which persist in the environment will not prevent their contamination of the food supply for many years to come. The presence of these chemicals in food therefore still needs to be carefully monitored.

If regulation of common toxic substances at source is not effective in reducing their levels in food, then governments need to introduce regulations which set safe levels of these substances in food. Such regulations are a strong incentive for industry and agriculture to clean up their operations themselves.

The formation of aflatoxins in food can be largely prevented through care of the crops during growth, storage and transportation. Crops should be protected from damage during growth—by using disease-resistant varieties of seed, appropriate pesticides and proper irrigation; and crops should be dried as quickly as possible after harvesting, and kept dry during storage and transport to reduce mould growth. Governments and producers need to devise prevention strategies to combat aflatoxin formation.

The processing of food has now become a largely industrial process, and one in which contaminants can easily be introduced into otherwise wholesome food. Certain technological improvements have enabled contamination at this stage to be minimized—the development of acid-resistant ceramic ware has cut down the chances of lead and cadmium entering food through contact with cooking utensils; and the use of non lead-soldered tins has drastically reduced lead levels in food. Regulatory bodies should ensure that these and other 'good manufacturing practices' are followed during food processing, particularly canning.

A number of steps can be taken to reduce bacterial contamination of food which should be implemented through government regulations. Premises that process, prepare or sell food should be regularly inspected for standards of hygiene and the use of appropriate technology in processing food. Clear details on labels regarding storage and cooking of food can help prevent microbiological contamination.

Consumers need to have clear and accurate information about the food they buy. Governments are responsible for issuing information about the dangers of food contamination, such as outbreaks of disease or infection that are liable to affect meat, and instances of localized marine pollution which may affect fish and shellfish.

To date, the results of the GEMS/Food programme have highlighted both the effectiveness of government regulation in controlling food contamination, and the need for continued vigilance—through national monitoring programmes—to ensure that preventative measures are effective and to detect any new sources of contamination.

In the future, GEMS hopes to involve in the monitoring programme more countries from Eastern Europe and the developing world, areas which are presently incompletely covered. National monitoring is likely to bring significant improvements in food standards in these countries. Under the GEMS/Food programme, technical expertise and quality control assistance are available to all countries wanting to establish national food monitoring.

In time, the contaminants monitored under the GEMS/Food programme will change as some sources of pollution are brought under control and others emerge. The microbial contamination of food, for instance, is currently being considered for inclusion in the programme.

Another area in which GEMS/Food is becoming increasingly involved relates to the reduction of non-tariff barriers in regional and international food trade by promoting international cooperation and information exchange on food contamination. The aim of this work is to prevent the dumping of sub-standard food on markets in developing countries and, by promoting international confidence in the purity of food supplies, to bring greater economic security to food-exporting and importing countries alike.

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