CHEMICAL ASPECTS OF TRACE CONSTITUENTS OF THE DIET*

I Control and Surveillance of Trace Constituents – Is There a Need?

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1 Introduction

Although the incidence and levels of certain pesticide residues in food in the United Kingdom had been investigated in surveys carried out prior to 1970, it was not until this time that a systematic programme of examining food for residues of potentially toxic substances was developed. The need for a national programme of food surveillance was realized after the discovery that methylmercury compounds were present in a range of species of fish. Because methylmercury had been shown to be the causative agent in the aetiology of Minamata disease, it was necessary to obtain data as quickly as possible to assess the possible health significance to fish consumers. Since this time, support for a nationally co-ordinated programme of food monitoring and surveillance has continued to grow as more and more use has been made of the data that have been generated.

From a comparison of the incidence of chronic disease amongst populations and of the changes observed in the patterns of disease which occur when these populations resettle in other parts of the world, there is good epidemiological evidence that the diet is one of the important factors which predispose individuals to chronic disease, particularly in the incidence of cancer.[1] Whether the factors responsible for these effects are major or minor components of the diet is not known. If scientific progress is to be made to determine what in the diet are the compositional factors which may be the cause of disease, basic information on the chemical composition of food will be necessary to test any hypothesis. One of the most important objectives of a food surveillance programme is to attempt to obtain such data and to observe whether or not there are significant trends in the intakes of individual components of the diet amongst selected populations. These data may be used to undertake risk assessments, which in turn are the basis for deciding whether or not there should be controls on the amounts of the toxin present in food, and to decide on the most appropriate methods of control.

The enormous advances in the analysis of trace substances in food which have

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[1] E. L. Wynder and G. B. Gori, *J. Nat. Cancer Inst.*, 1977, **58**, 825.

occurred within the last decade have been in the application of improved g.c.–m.s., h.p.l.c., and a.a. techniques which have enabled individual compounds to be measured at the parts per 10^6—10^9 level. Much of the impetus for the development of these techniques came from the need to determine the presence – or absence – of chemicals which have been approved for the production or the manufacture of food, such as pesticides or therapeutic substances used in livestock production. The analytical techniques required for regulatory purposes have been developed to the point at which analytical sensitivity is such that very low levels of toxic substances can be detected in food – substances which are an inherent component of that food or which are adventitious contaminants of food and have not been subjected to any form of risk assessment procedure as have the majority of the chemicals which are deliberately added to food.

2 Risk Assessment

We must start on the basis that no chemical is ever completely safe, but there are ways in which many of them may be used safely. This is the fundamental from which risk assessment commences, and in this connection no one has yet defined *risk*. Inevitably risk assessments for humans depend heavily upon interpretations of the results of administration of chemicals to animals, usually by incorporation in their diets, which are themselves inevitably man-made. Immediately, an unknown is introduced into the assessment since direct comparisons between human effects and those observed in laboratory animals are rare.

Nevertheless, for the last 25 years assessments of chemicals *intended* for human consumption as part of the total diet (such as food additives) have been made by utilizing a hypothetical acceptable daily intake (ADI) for the chemical, calculated from the level in the diet of a test animal demonstrated experimentally to induce no observable adverse effect during its life time, by the application of an arbitrary safety factor. It is pertinent to remark here also that no one has yet defined 'observable adverse effect', although experience would lead one to suppose that 'statistically significant pathological variation from a parallel control group of animals not exposed to the chemical' is the intended criterion. The safety factor used to divide into the maximum no-effect level also varies according to circumstances, and in this area there are as many opinions as there are experts! Traditionally the accepted figure has been 100, but this is sometimes increased when the quality of the data is not of the required standard or when the nature of the toxic effects at the higher dose levels gives cause for concern. The safety factor may be less than 100 (sometimes as low as 10) if the substance is a normal constituent of the *human* diet or a normal metabolite of the *human* body or where a substantial proportion of the available data is derived from experiments in man.

Despite all the disadvantages and qualifications which one can apply to the ADI, and recognizing that modern toxicological thinking dictates a move away from 'rigid protocol', the concept may be said to have served us well for those areas of risk assessment related to the deliberate addition of chemicals to food to achieve necessary technological functions. It also enables comparisons, albeit

crude ones, to be made between actual human intake (which can be derived from surveillance programmes) and the socially acceptable yardstick of safety represented by the ADI.

Chemical substances which *unintentionally* become part of an individual's food intake as 'contaminants' of food are considerably harder to assess in terms of human risk. Their quantities are frequently minute, their distribution in food is invariably random, their nature and chemical identity may well be unknown until the emergence of an unacceptable biological effect, and their origins in the food chain are frequently obscure. If one adds to this plethora of 'unknowns' the fact that many of these xenobiotics may be classified as of 'natural' origin, the presumption must be made that man has been exposed to them over countless generations.

So what effects are we concerned with in any risk assessment of the unintentional food contaminants? In the present state of the toxicological art it is safe to assume that the battery of biological tests to which chemicals deliberately intended to be present in food must be subjected before they are used will eliminate any possibility of the induction of non-reversible effects, such as an increase in tumour incidence or effects resulting from the storage of the compound in body tissues. Contaminants of food either adventitious or naturally present do not have the privileges of precursive biological testing, except in the case of pesticide formulations and certain substances used in animal husbandry and therapeutics. This makes a judgement on the potential hazard difficult to make.

As the amounts of such substances are usually very small, it is unlikely that their presence in food will lead to manifestations of acute toxicity. We are left therefore with the possibility that they might induce non-reversible effects, such as a carcinogenic response or mutagenicity, or that they might, in the long term, accumulate in body tissues. In the case of proximate electrophilic carcinogens which alkylate DNA bases (*e.g.* aflatoxin, vinyl chloride) and which act at the cellular level to produce heritable changes leading to malignant tumour formation, it has not yet proved possible to demonstrate a threshold dose below which no effect occurs. The effect of decreasing the dosage is simply to increase the time to tumour formation.

Attempts have been made to apply mathematical procedures to calculate the risks of exposure to low doses of carcinogens as, for example, the Mantel–Bryan procedure,[2] which calculates a virtually safe dose, the one-hit model (and its modification by Weibull),[3] which assumes that the dose–response curve is linear in the low-dose region, and the Armitage–Doll multi-stage model.[4] However, the choice of mathematical procedures for low-dose extrapolations has no firm biological basis and must, to some extent, be arbitrary. There is also no reason to suppose that, should such mathematical techniques be applied, an 'acceptable' or virtually safe dose for some carcinogens would result that would allow a

[2] N. Mantel and W. R. Bryan, *J. Nat. Cancer Inst.*, 1961, **27**, 455.
[3] D. G. Hoel, D. W. Gaylor, R. L. Kirshstein, V. Sattiotti, and M. A. Schneiderman, *J. Toxicol. Environ. Health*, 1975, **1**, 133.
[4] P. Armitage and R. Doll, Proc. 4th Berkeley Symposium on Mathematical Statistics and Probability, ed. Lecam and Neyman, 1961, Vol. 4(4), p. 19.

maximum level of a carcinogen in food to be above the limit of detection of present-day analytical techniques.

3 Policy for the Control of Adventitious Toxic Substances in Food

Precisely because it is difficult to determine the risk associated with a chronic toxin which is present adventitiously in food, any policy which attempts to regulate the risk should not be so inflexible that no account is taken of this uncertainty or of the fact that the removal of a proportion of food from the market-place may achieve very little in reducing overall exposure in the long term. This is because the substance is rarely present in food with a frequency and at levels that can be represented by a normal distribution. Where the pattern of residues is represented by a highly skewed distribution, as is usual, the removal of a small proportion of the most highly contaminated food, even if this could be achieved by vigorous enforcement, will do little to reduce the long-term exposure. Such a policy might be more effective where there are sections of the community exposed to higher than average levels of the substance in their diets, but rarely do nationally enforced controls need to be considered to deal with such situations.

Should action be considered necessary, or prudent, it is far better to reduce exposure by dealing with the problem at source wherever this is practicable, consistent with available technology and economic cost. Such a policy has more often than not been adopted in the United Kingdom to limit the contamination of food and explains why there are not many regulations made under the Food and Drugs Act which limit the maximum amount of a toxic substance that is permissible in a food. Instead food surveillance can be used to provide data for risk assessment, to identify the source of the residue, and to investigate practical ways of minimizing exposure without the recourse to national legislation.

Food surveillance programmes carried out since 1970 have defined the extent and degree to which a range of toxic substances are present in the United Kingdom food supply. The results of some of this work, together with the approaches which have been adopted to deal with the situation which has been revealed, are well illustrated with reference to some of the work which has been undertaken on the contamination of food by mycotoxins, toxic substances in food present as a result of manufacturing practices, and by certain industrial chemicals.

4 Mycotoxins in Food

Although there have been many reports in past history of the occurrence of acute ill-health, notably ergotism, resulting from the ingestion of mouldy food, it was not until the 1960s that there was an explosive interest in investigating the metabolites of fungi which naturally contaminate food. The impetus for this interest was the discovery that the aflatoxins, metabolites of a strain of the ubiquitous soil-borne fungus *Aspergillus flavus*, were highly carcinogenic. Since that time more than 100 compounds which could be classified as mycotoxins

have been reported in the literature, although to date few of these compounds have been shown to be present in food.

Epidemiological studies indicate an association between the intake of aflatoxins and the incidence of primary liver-cell cancer. This is supported by data for at least eight species of experimental animals.[5] Consequently the levels and incidence of these metabolites in retail food supplies have been investigated in some detail. So far this work has established that the aflatoxins are detected primarily in nuts and nut products and in milk and dairy products.

Table 1 summarizes the data which were obtained for peanuts imported into the United Kingdom between 1977 and 1978. Although these peanuts were intended for human consumption, extensive quality-control procedures and processing in the factories will have reduced consumer exposure considerably.

Table 1 *Aflatoxin levels in imported peanuts* (1977—1978)

Country of origin	*Number of samples*[b] *analysed*	*Number of samples containing average levels of aflatoxin*[a] *in stated range*/μg kg^{-1}				
		0—5	5—30	30—100	100—300	> 300
Brazil	2	0	0	2	0	0
Egypt	2	1	0	1	0	0
Gambia	5	0	3	1	0	1
India	35	18	4	8	4	1
Malawi	53	27	17	7	2	0
S. Africa	6	6	0	0	0	0
U.S.A.	56	43	9	3	1	0

[a] In most cases aflatoxin B_1 was the major component. [b] 20 kg samples taken from each 20 ton batch.

Low levels of aflatoxin M_1, a bovine metabolite of one of the most frequently encountered aflatoxins, which has also been demonstrated to be carcinogenic, were detected in a proportion of the milk and dairy products tested. The results obtained are summarized in Table 2. The likely origin of this contamination is

Table 2 *Range of aflatoxin M_1 levels in milk and dairy products* (1978—1979)

Samples	*Number of samples examined*	*Range of levels found*/ μg kg^{-1}
Producer–retailer milk	278	< 0.03—0.52
Milk powder	203	< 0.10—0.80
U.K. cheese	223	< 0.10—0.40
Imported cheese	143	< 0.10—0.50
Whey powder	88	< 0.10—0.60

[5] Environmental Health Criteria 11: Mycotoxins, World Health Organisation, Geneva, 1979.

through the utilization of groundnut meal as a component of the compound rations fed to dairy cattle. The United Kingdom Feedingstuffs Regulations limit the maximum allowable level of aflatoxin B_1 in 'complementary' feedingstuffs to 20 $\mu g\ kg^{-1}$. In general the levels of aflatoxin M_1 in milk are 300-fold lower than the levels of the feed,[6] which should limit the maximum concentration of aflatoxin in milk to about 0.1 $\mu g\ l^{-1}$. At one time this was the lower limit of detection of the method, but improvements in the analytical methodology presently give a lower limit of detection of 0.03 $\mu g\ l^{-1}$ for liquid milk and 0.1 $\mu g\ l^{-1}$ for milk products.[7]

The surveillance programme has also looked into the contamination of certain commodities by other mycotoxins. Ochratoxin A was detected in maize products in the range < 5—200 $\mu g\ kg^{-1}$, in soya and soya products in the range < 50—500 $\mu g\ kg^{-1}$, and in cocoa beans in the range < 100—500 $\mu g\ kg^{-1}$. Ochratoxin A has been detected in animal products for human consumption in both Denmark[8] and Sweden,[9] and in a limited survey carried out in the United Kingdom ochratoxin A has been detected in pig meat and kidneys. A national survey of the incidence of ochratoxin A in barley and pig meat is under way at the present time.

Because of the carcinogenic potency of the aflatoxins it is prudent to keep exposure to a minimum. The practical ways in which this can be achieved are being actively investigated. As far as nuts for human consumption are concerned, developments in quality control have been adopted by the industry, including the careful choice of raw materials through improved sampling and analytical techniques. More fundamental work, such as the development of aflatoxin-resistant strains of nuts, improved harvesting, and chemical preservation techniques, is being investigated on a world-wide basis. At the present time, however, it is impossible to ensure that all edible nuts are free of aflatoxin. The policy of attempting to minimize the problem requires a close working relationship between Industry and Government which we are fortunate in having.

In investigating ways of keeping the contamination of milk to a minimum, options for control include the possibility of decontaminating oil-seed meal by a process such as ammoniation, avoidance of the use of oil-seed meal as a straight feed or in dairy rations, and the development of methods of sampling to detect contaminated batches. The feasibility of these and other options must be evaluated with regard to cost and practicability.

As far as the contamination of food by ochratoxin A is concerned, there are still insufficient data on the incidence and levels of residues in the diet and of factors which contribute to the contamination, as well as insufficient toxicological data, to consider options for control. Nonetheless, because of the potential risks

[6] J. V. Rodricks and L. Stoloff in 'Mycotoxins in Human and Animal Health', ed. J. V. Rodricks, C. W. Hesseltine, and M. A. Mehlman, Pathotox Publishers Inc., Illinois, 1977, p. 67.
[7] D. S. P. Patterson, E. M. Glancy, and B. A. Roberts, *Food Cosmet. Toxicol.*, 1978, **16**, 49.
[8] P. Krogh, *Nord. Veterinaermed.*, 1977, **29**, 402.
[9] L. Rutqvist, N. E. Bjorklund, K. Hult, and S. Gatenbeck, *Zentralbl. Veterinaermed., Reihe A*, 1977, **24**, 402.

associated with the presence of mycotoxins in food it is possible to investigate methods which could reduce, or eliminate, this potential, *e.g.* through the use of non-toxigenic strains of fungi in the manufacture of those foods, such as cheeses and fermented sausage, where mould ripening is a fundamental part of the production process.

5 Contamination of Food by Manufacturing Processes

A particularly striking example of the use of surveillance to identify and resolve avoidable exposure to toxic substances has been the recent detection of nitrosodimethylamine (NDMA) in beer as a result of the direct-fired kilning of malt. In 1978 it was reported that traces of NDMA were being found in beers produced in Germany, the Netherlands, and the U.S.A., and this contaminant was subsequently detected in beer in the United Kingdom. Levels were low, typically around 2 $\mu g\ kg^{-1}$. In view of the potent carcinogenicity of NDMA and the amount of beer consumed in the United Kingdom (240 pints per head of population in 1979) the matter was viewed with some concern.

During malt production the germinated barley is dried and heated to a moderately high temperature. In the United Kingdom the drying process is based on blowing hot air through the germinated barley over a period of 24—48 hours; in the majority of United Kingdom kilns the hot air is obtained by taking a suitable fuel, burning it, and diluting the combustion gases with an appropriate amount of air. In the early 1970s commercial supplies of natural gas became available and this was seen as offering significant advantages to the malting industries as a fuel. The cost was very attractive and as a low sulphur fuel it was environmentally 'clean' and offered the prospect of introducing energy recovery systems in the form of copper heat-exchangers in the exhaust air; with more conventional fuels these were not economically feasible because of corrosion problems arising from the sulphur oxides in the exhaust gases. With these advantages in mind, gas-fired kilns were introduced widely in the United Kingdom during the middle and late 1970s.

The mechanism of NDMA production appears to involve a reaction sequence in which nitrogen oxides (NOx) in the combustion gases react with an amine in the 'green' malt and NDMA is released later in the 'kilning' cycle. The reaction is inhibited by sulphur dioxide, and it seems that quite fortuitously anthracite and 'heavy' oil contained sufficient sulphur to prevent NDMA formation when they were used as fuels in the past. But the change-over to natural gas also removed the SO_2; NDMA formation was no longer inhibited and in the worst cases levels of some hundreds of p.p.b. of NDMA were formed in malt.

Happily, as a result of intensive collaboration between Government, maltsters, the Gas Board, and the burner manufacturers the problem has rapidly been brought under control. Within two years of the first recognition that a problem might possibly exist, the nature of the problem has been identified and measures have been devised which have dramatically reduced NDMA levels. New gas burners have been designed; these have lower flame temperatures and give low NOx concentrations in the combustion gases. These burners either alone or in

combination with burning sulphur (or injecting SO_2) have brought NDMA levels down well below 10 μg kg^{-1} in most cases; in kilns which previously produced malts with very high NDMA content it is common to find that the levels of NDMA have been reduced by factors of 30—100.

There is also a real prospect that the identification of the role of NOx in combustion gases in determining NDMA levels in malt and beer will lead to the development of a novel catalytic burner with intrinsically low NOx characteristics which will find applications in processes extending far beyond the malt-kilning application which prompted its development.

6 Environmental Contaminants in Food

With the exception of the gaseous pollutants, the exposure of the general population to industrial chemicals is primarily through food consumption. There are many well documented accounts of where food has been so heavily contaminated by the industrial discharge of chemicals, or through careless controls over the use of certain chemicals, that food consumption has led to chronic disease. The Minimata tragedy in Japan was first recognized in the 1950s and traced to the contamination of fish by methylmercury.[10] Contamination of rice oil by polychlorinated biphenyls (PCBs) and polychlorinated dibenzofurans led to the outbreak of Yusho disease in Japan in 1968,[11] and Itai–Itai disease has also been attributed in part to the contamination of rice through cadmium pollution.[12]

Less severe effects were observed in Turkey in 1955 when hundreds of people consumed grain treated with hexachlorobenzene and developed porphyria.[13] More recently residents of Michigan were found to have been exposed to polybrominated biphenyls (PBBs) as a result of the accidental use of this fire-retardant agent in animal feed. Although effects were observed on lymphocyte production and function,[14] the short- and long-term implications of these differences are not known.

7 Methylmercury Levels in Fish

Extensive monitoring of fish caught from United Kingdom coastal waters has been undertaken as part of the food surveillance programme since 1970. These data have demonstrated that average methylmercury levels in fish caught in the north-east Irish Sea were raised to about 0.3 mg kg^{-1} compared with levels of about 0.15 mg kg^{-1} in other areas. Before any assessment of the risks associated with the ingestion of this chronic toxin could be made, it was necessary to obtain information about the likely exposure of consumers to these raised levels since it is only this information which can be compared with the extensive toxicological data existing in both experimental animals and humans on the toxic effects of

[10] 'Minamata Disease', ed. M. Katsuna, Kumamoto University, Japan, 1968.
[11] S. Katsuki, *Fukuoka Acta Med.*, 1969, **60**, 403.
[12] 'Cadmium in the Environment', ed. L. Friberg, M. Piscator, and G. Nordberg, CRC Press, Cleveland, Ohio, U.S.A., 1971, p. 111.
[13] C. Cam and G. Nigogosyan, *J. Am. Med. Assoc.*, 1963, **183**, 88.
[14] J. G. Bekesi, J. F. Holland, H. A. Anderson, A. S. Fishbein, W. Rom, M. S. Wolff, and I. J. Selikoff, *Science*, 1978, **199**, 1207.

methylmercury compounds. This in turn requires detailed information about the food consumption habits of the exposed population, and these data are as important a part of the food surveillance programme as is information about the actual levels of a toxic substance present in the diet.

Dietary intake studies have been organized in which consumers of fish taken from the north-east Irish Sea were compared with a control population. The study group was chosen from amongst the highest consumers of fish in each population, and the corresponding levels of mercury in whole blood and hair were measured. Consumers were found in both communities whose intake exceeded the W.H.O.-recommended tolerable weekly intake of methylmercury of 200 μg.

Table 3 compares the data which were obtained. In comparison with the mercury levels in blood and hair assessed by a W.H.O. Task Force[15] as likely to result in a slight increase in the earliest signs of methylmercury poisoning, namely parasthesia, the consumer with the highest intake of mercury was shown to be protected by at least an 8-fold factor of safety from the levels in blood and at least a 4-fold factor of safety from the levels in hair.[16]

Table 3 *Intake of mercury and corresponding levels in whole blood and hair amongst U.K. fishing communities*

		North-east Irish Sea	*Control area*
Intake of mercury/μg week^{-1} (70 kg)$^{-1}$	range	5—443	4—560
	mean	130[a]	94
Mercury in whole blood/μg (100 ml)$^{-1}$	range	0.04—2.58	0.04—1.21
	mean	0.50[a]	0.35
Mercury levels in hair/μg g^{-1}	range	0.1—11.03	0.27—5.8
	mean	2.03[a]	1.28

[a] Significant at 95% level.

Although it was judged that this increased exposure to methylmercury amongst north-east Irish Sea communities was not a health risk, these findings have resulted in a review of the level of discharges into the north-east Irish Sea with the ultimate aim of ensuring that fish caught in the north-east Irish Sea do not have significantly raised methylmercury levels in comparison with other areas of the United Kingdom.

8 Polychlorinated Biphenyls in Food

These compounds are some of the most persistent contaminants that are known. The fact that they are stable to acidic and basic hydrolysis and to heat and that they have a high dielectric constant led to their use in such applications as dielec-

[15] Environmental Health Criteria 1: Mercury, World Health Organisation, Geneva, 1976.
[16] J. Haxton, D. G. Lindsay, J. S. Hislop, L. Salmon, E. J. Dixon, W. H. Evans, J. Reid, C. J. Hewitt, and D. S. Jeffries, *Environ. Res.*, 1979, **18**, 351.

trics and heat-exchange fluids. Although they have been used since the 1930s they were only detected in the environment in 1966 when developments in the analysis of the organochlorine pesticides revealed unexplained peaks. Their persistence has resulted in the contamination of food principally by three routes: (*a*) the direct contamination of food or animal feedstuffs by an industrial accident, (*b*) migration of PCBs from packaging into food, and (*c*) absorption from the environment by fish.

Studies on the incidence and levels of contamination in fish by PCBs have shown detectable levels of PCBs in a large proportion of the fish landed.[17]

Toxicological evaluation of the PCBs have shown that there is a direct relationship between PCB exposure in laboratory animals and an increasing incidence of various sub-chronic and chronic toxic effects including adverse reproductive effects, tumour production, and possible carcinogenicity.[18] The U.S. Food and Drug Administration have concluded that there are insufficient toxicological data with which to make an assessment of risk. Since it is not possible to derive a 'no-effect' level of intake it is impossible to set an acceptable level of intake.

Because of the generally low levels of PCBs that are found in food and because there is no identifiable point source of discharge of PCBs in the United Kingdom, it is not practicable to consider imposing controls over the levels of PCBs in food other than by controls over the manufacture, use, and disposal of the PCBs. As a consequence of the health and environmental effects of the PCBs their manufacture has ceased altogether in the U.S. and the United Kingdom, and their use is restricted solely to closed systems such as transformers and capacitors. However, it is expected that the levels of PCBs in food will not decline appreciably for many years owing to their continued release from old equipment in land-fills or because they are currently in use in equipment which was manufactured some years ago.

9 Miscellaneous Industrial Chemical Residues in Food

Table 4 summarizes some of the classes of chemical compounds that have been detected in freshwater fish in U.S. monitoring programmes.[19] These classes cover a

Table 4 *Classes of chemical compounds detected in freshwater fish in U.S.A.*[19]

Aromatic amines
Brominated aromatics
Chlorinated aliphatics
Chlorinated benzenes
Chlorinated benzotrifluorides
Chlorinated non-aromatic cyclics
Chlorinated toluenes
Triaryl phosphates

[17] Ministry of Agriculture, Fisheries and Food, unpublished data.
[18] 'Polychlorinated Biphenyls (PCBs): Reduction of Tolerances', US Food and Drug Administration, Fed. Register, Washington DC, 1979, Vol. 44, p. 38 330.
[19] P. Lombardo, *Ann. N. Y. Acad. Sci.*, 1979, **320**, 673.

very wide range of individual compounds, some of which may fall into the category of 'recognized contaminants'. However, there are likely to be industrial compounds not yet recognized which are contaminants of food or potential contaminants of food.

10 Future Developments in Surveillance

In part the problems of food contamination that have occurred have arisen as the result of the lack of any system of control over the manufacture, use, and disposal of industrial chemicals, and they have been the impetus for the introduction of registration schemes for the production of new and existing chemicals in a number of countries. The application of such schemes will no doubt be highly effective in minimizing food contamination problems, but they in turn will require the development of appropriate monitoring programmes, particularly as no registration scheme can avoid the occurrence of accidents.

All the monitoring work which has been carried out so far for environmental contaminants has concentrated on establishing the extent to which chemicals known to be stable in the environment are present in food. In order to avoid having to take arbitrary judgements on what is an acceptable level of intake of a chronic toxin, it would be better to consider the development of a system of monitoring which was able to detect at the very earliest stage changes in the pattern of residue distribution in samples of food which are sentinels of environmental contamination, *e.g.* fresh fish, milk, or meat or other foods which are not normally highly processed

The analysis of suitable extracts of such foods by high-resolution capillary g.c. coupled to m.s. and computer storage facility would enable a 'fingerprint' of the output of the chromatographic system to be stored in terms of both retention time and peak intensity. The stored data could be compared with the output of the analysis of a number of similar samples taken from the same or different locations and any changes in the fingerprint observed. Significant alterations could be identified and the source controlled before the problem developed into a major issue.

Although such an approach could detect compounds which are detectable by g.c. methods, this may well overlook classes of compounds which are not amenable to g.c. analysis. Those techniques which will have a great impact on surveillance programmes include developments in m.s. instrumentation such as pulsed positive- and negative-ion detection techniques, developments in selective detectors for g.c. and particularly l.c. systems, and developments in computer system software capable of handling massive volumes of data of the type obtained from monitoring programmes.

There is no doubt that had such a surveillance system been in operation widespread pollutants such as PCBs could have been detected long before they became ubiquitous. So far this approach has mainly been limited to the detection of unknown contaminants in water,[20] but a number of laboratories in the U.S. are

[20] J. A. McFall, W. Y. Huang, and J. L. Laseter, *Bull. Environ. Contam. Toxicol.*, 1979, **22**, 80.

evaluating the possibility of applying this approach to food monitoring. The application of such techniques should enable us to develop from a situation where we are wise after an event into one where we become wise before an event, thereby minimizing the economic costs of environmental and industrial constraints.

11 Food Surveillance – Is There a Need?

The results of some of the recent work of the food surveillance programme, which have been reviewed in this paper, serve to illustrate the wide range of different topics that have been covered so far and have come to light through improvement in analytical methodology.

This systematic collection of data on the levels of toxic substances in food has:

(*a*) enabled assessment to be made of the health significance associated with the consumption of a particular chemical residue in the diet,

(*b*) highlighted localized problems of food contamination,

(*c*) shown the effects of changes in the composition of food through changes in technology both in agriculture and food manufacture,

(*d*) provided information on whether or not the restrictions placed on the use of toxic substances in food production are being met in practice,

(*e*) allowed assessment to be made of the need to introduce new legislation or to revise existing legislation,

(*f*) indicated whether non-tariff barriers to international trade have been set up unreasonably, and

(*g*) provided information about the incidence of *potentially* toxic substances in the diet, which in turn has been the stimulus for further R and D work.

Little of this activity has resulted in legislative control over toxic substances in food since, where appropriate, modifications in manufacturing practice have been adopted. This has been a direct consequence of the response of United Kingdom industry.

Because of the enormous complexity of people's diets, of knowing what individuals eat over a period of time, of finding suitable control populations, and of bringing about a change in exposure through the diet, epidemiological methods attempting to study the possible factors in the diet that are responsible for disease will be fraught with limitations. It is clear that developments in the analytical chemistry of food will outpace our knowledge of the potential health significance of low levels of trace non-nutritive constituents of food. Nonetheless, a continued search for such constituents is justified in order that the highest standards of food quality are maintained and, when appropriate, that further studies may be made of the relationship of diet to health.