Arch. Pharm. Res. 4(1), 63~74(1981)

Recent Problems in Hygienic Chemistry

Food and Environmental Contaminants

Mitsuru Uchiyama

Division of Food, National Institute of Hygienic Sciences, Setagaya, Tokyo, Japan

Hygienic science is the science for the maintenance and the improvement of human health. Every investigation of hygienic science is originated from practical human life and the fruits of every studies should be recovered and utilized finally by social life.

The planning, implementation, evaluation must be carried out by unbiased idea in view of four main aspects in Fig. 1. In the center of that figure you can put any problems that you concern if it is related to health sciences. Today, I want to mention the problems in food and environmental contaminants, referring to some recent status of my country.

TOXIC CONTAMINANTS IN FOOD

An adequate supply of safe and wholesome food, along with water and air, is essential to the maintenance of human health. Food is also playing an important and valuable roles in the recovery of all patients from their diseases.

However, under the present circumstances, various living activities of human produced a wide variety of wastes and hazardous substances, which subsequently contaminated an environment. All foods rely their raw materials upon animals and plants, so the pollution of foods from their growth environment cannot be avoided to some extent.

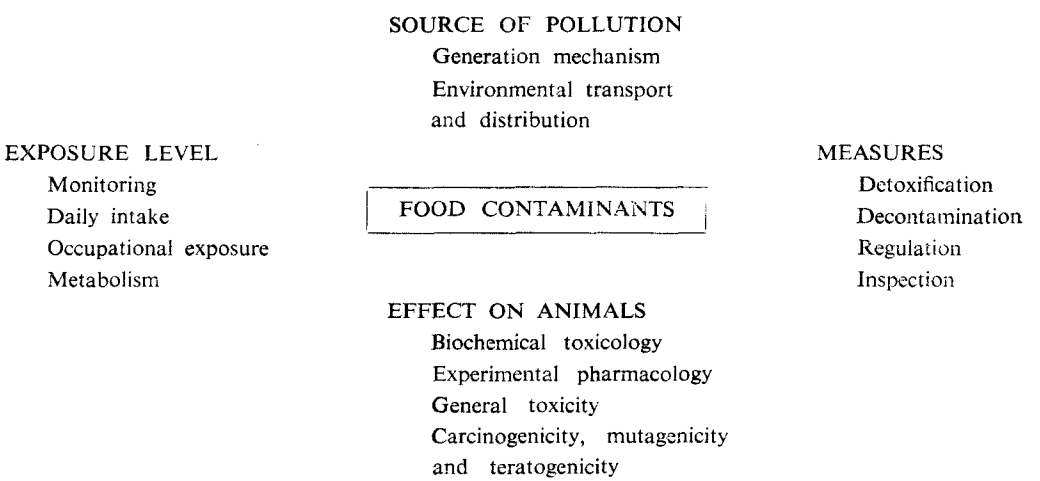

Fig. 1: Attributes for investigating food contaminants.

Table I : Representative food contaminants and their origins.

A. Natural Contaminants ····· Fungal toxins (aflatoxins sterigmatocystin, etc), pathogenic microorganisms
B. Food Processing ····· Nitrosamine, polycyclic aromatic hydrocarbons, protein pyrolysate
C-1. Residues from Agricultural and Livestock Practices ····· Pesticides, fertilizers, drugs used in animal husbandry
C-2. Pollution of Environment ····· Heavy metals, organomercury, PCBs, chlorophenols, aromatic amines, phthalic esters, feul oil components
C-3. Container, Wrapping and Household Materials ····· Plastic monomers, phthalic esters, metals

The potential toxic materials which may injure food safety can be devided into three categories shown as A, B and C in Table I.

A natural poison and fungal toxins might have continuously affected on our health ever since the beginning of human life on the earth for 30–40 million years. Among those, aflatoxin B_1 still has great concern with our health. But today we must focus mainly upon synthesized chemical contaminants, so aflatoxins might become out of the discussion.

The next group is also not the artificial compounds, so I want to touch very briefly. Among the toxic components produced by food processing, amino acid pyrolysates are attracting the attention recently. The chemical structure of such pyrolysates, Trp–P–1 or Trp–P–2 from tryptophan, Glu–P–1 or Glu–P–2 from glutamic acid, are shown in Fig. 2. These compounds were isolated from smoke condensate or residual tar of

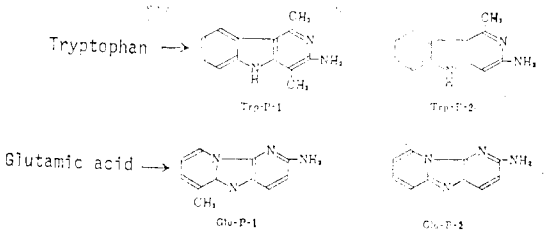

Fig. 2: Chemical structure of amino acid–pyrolysate.

broiled amino acid or protein foods like fish and animal meats. And those all exhibited very strong mutagenicity *in vitro* and, furthermore, some of them showed tumor generating activity by feeding them to mice.

Since the yield of these substances is quite low, and their mutagenicity easily disappear by the addition of several kinds of food components (vegetable juice, chlorophyll or oleic acid) *in vitro,* the significancy of those pyrolysate in food sanitation is not yet evaluated. Anyway, it must have become problem since our ancestor obtained a knowledge of utilizing fire in our lives.

On the other hand, besides those inherently hazardous contaminants, some of the natural components of food are quite susceptible to an oxidative or hydrolytic deterioration and have a tendency to produce several toxic materials. The typical examples of this case are lipohydroperoxide from unsaturated oil and pheophorbide from chlorophyll.

The third group of contaminants listed

under C in Table I are environmental pollutants resulted from various civilized living practices. No matter how severely good manufacturing practice will be carried out for food processing, it is highly probable that there will occur new contamination in the future through unexpected channels which are coupled with the development of agriculure, mining and manufacturing industries,

Since human beings possess themselves a defensive or an adaptation abilities against the exogenous toxic materials, they can generally counteract the toxicity of contaminant by detoxification when the amount of toxic chemical is less than a certain threshold level.

Such threshold is thought as real permissible dose. All of contaminants have their own real permissible doses regardless their chemical nature, except an ionizing radiation, but we cannot know those real permissible doses. Therefore, the estimation of them is usually carried out by an experimental toxicity test under the established guideline to obtain the maximum "non-effect level" which will be employed for the calculation of acceptable daily intake(ADI) and subsequently the permissible concentration in foods as indicated in Fig. 3.

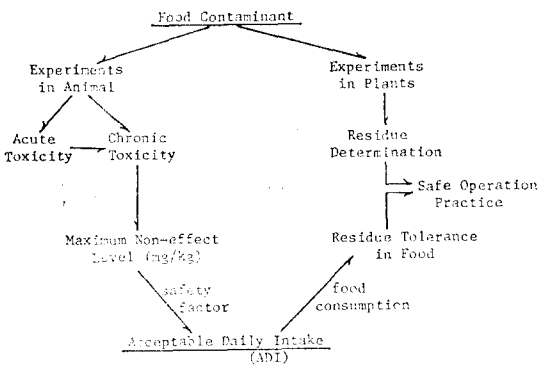

Fig. 3: General route for the establishment of criteria.

This procedure, now in operation in every country, may find out very close values to the real permissible doses in some cases, but incidentally there must be the case that far different value is calculated out.

By the way, most of all, above 90%, of environmental contaminants are introduced into human body along with food intake. Therefore, it can be said that foods act just as carrier between human and polluted environment. Fundamentally speaking, both the preservation of health and the prosperity of human species fully depend upon foods, however, if human being tread the path of downfall by the effect of environmental pollution, most of the responsibility will be attributable to foods, too.

FOOD CONTAMINATION MONITORING

Those facts mentioned above reveal that the fortification of food contamination survey and the safety evaluation are the most important for preventing our health hazard.

Since 1969 Japan has conducted monitoring activities for a variety of chemical contaminants, organic and inorganic, in foods. However, most of them were planned by provincial government and the results has been stored in each laboratories except the data of national monitoring.

Data obtained by those laboratories have recently been collected to my hand using the specified format and are being input to

a computer. By the end of September, 1980, about 560,000 records which are the data covering past 9 years, have been input and their systematization has almost been completed. They are the background data concerning representative food contaminants in my country. The summarized results which indicate time trend and the contribution of a certain food in an intake of a certain contaminants were shown in the following Figures. Surely it might suggest something profitable for the future investigation.

DDT is one of the representative organochlorinated pesticides. You can see the general reducing trends of DDT in all foods indicated in Fig. 4. Total DDT means sum of pp'-DDT and its main metabolites, pp'-DDE, pp'-DDD and op'-DDT. They are all persistent in human body and have similar toxicities against animals. The unit of vertical axis is ppb, so 5-10 ppb may be almost not-detectable concentration. The dotted line is officially set limit of quantitation in Japan.

As you see, DDT in beef as well as in fruits and vegetables is already not-detectable level. But pork and fish have still been holding somewhat detectable contamination of DDT.

Human milk is keeping high level of DDT and decreasing trend is very slow. The level in cow's milk is expressed in a fat basis, so it means that the level in cow's milk is about 1/30 of that in human milk.

Fig. 5 shows the trend of HCH(BHC) level in food. Particularly, the level of HCH in beef was extraordinally high in

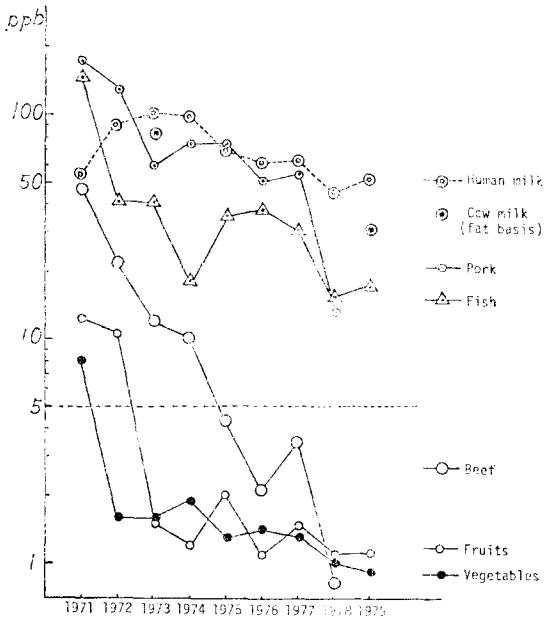

Fig. 4: Alteration of total-DDT level in food (arithmetic mean).

the earlier period, and consequently HCH in cow's milk was also high in 1971-72 period. The reason of this phenomenon is mainly due to a feeding of rice straw to cattles. For the pest control of rice crops, we had used technical HCH, which contained non-effective but most persistent beta-isomer of HCH. Therefore, beef and cow's milk were heavily polluted by beta-HCH. About 3/4 of HCH retained in human milk is beta-isomer.

Alteration of PCB (polychlorinated biphenyls) concentration in food is shown in Fig. 6. You can recognize that the pollution by PCB is likely to be restricted in fish in these years. Therefore, the intake of PCB must be dependent upon the consumption of fish. Again, the decreasing trend of PCB

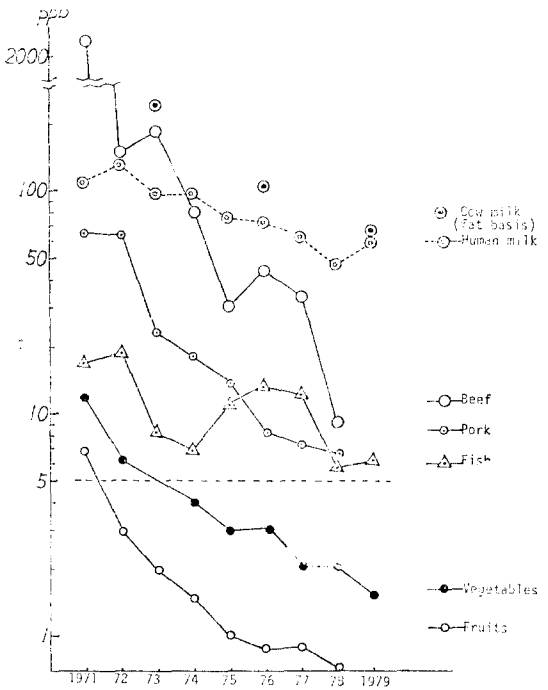

Fig. 5: Alteration of total HCH level in food (arithmetic mean).

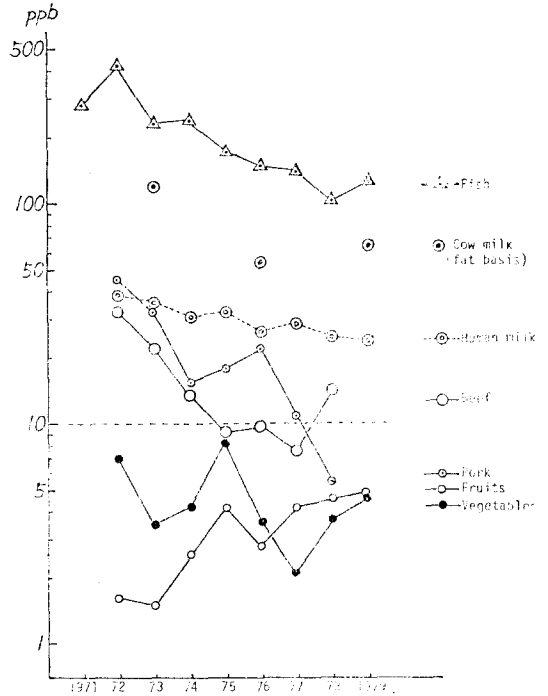

Fig. 6: Alteration of PCB level in food (arithmetic mean).

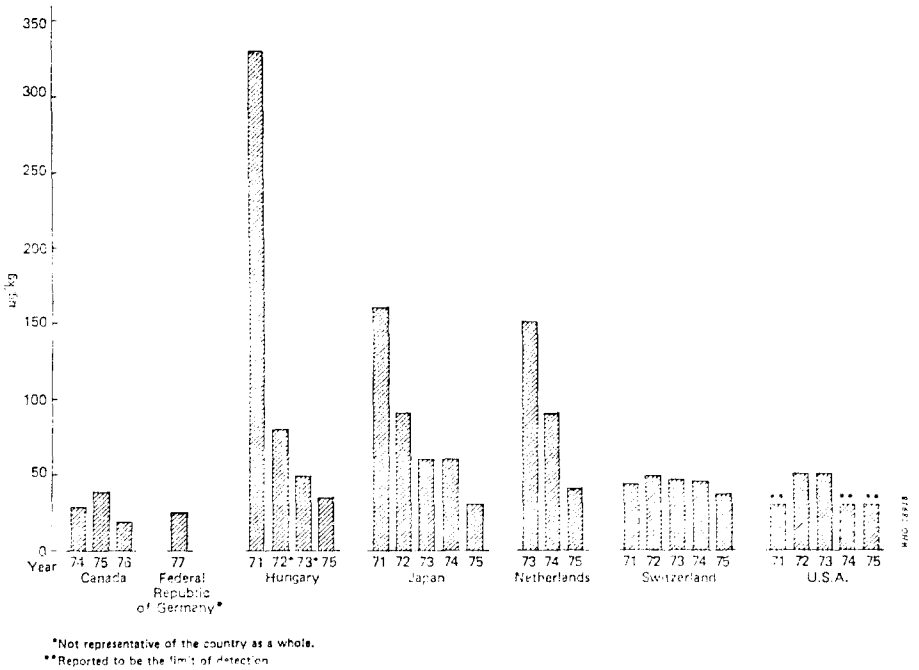

Fig. 7: Median values for the DDT complex in the fat of cow's milk.

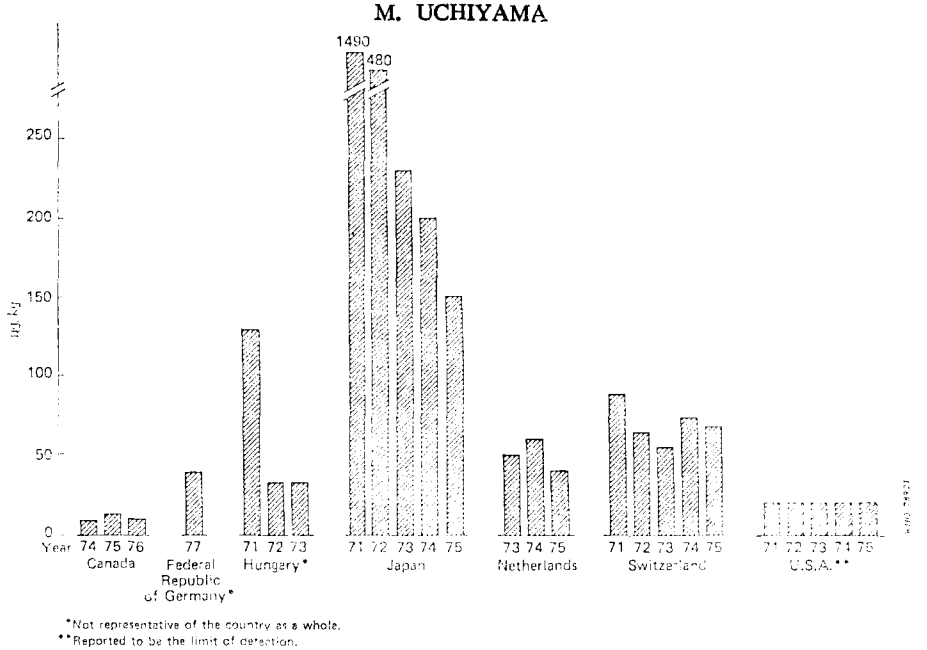

Fig. 8: Median total HCH isomers in whole cow's milk in μg/kg of fat.

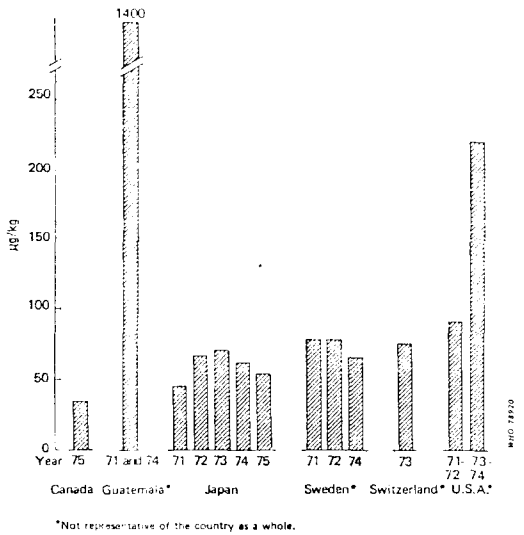

Fig. 9: Median values for the DDT complex in human milk expressed on an "as is" basis.

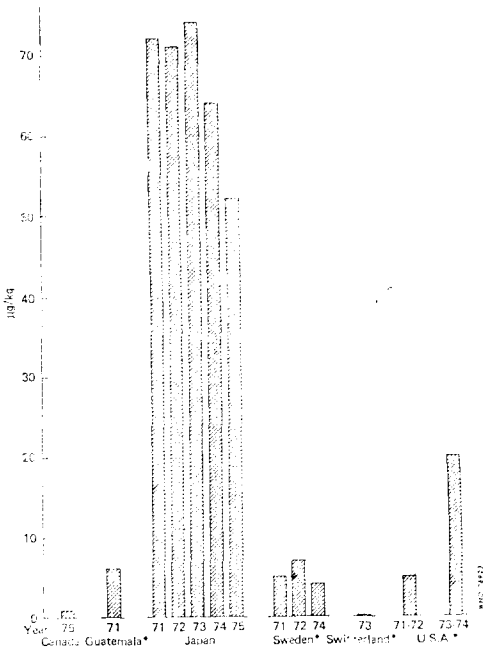

Fig.10: Median total HCH isomers in human milk expressed on an "as is" basis.

in human milk looks quite slow.

Now, I want to compare these results with the conditions of some other countries in Fig. 7–8. The residual levels of DDT in

cow's milk of various countries are almost in the same level.

On the contrary, HCH level in cow's milk of Japan is far higher than that of any other country. It is expected easily from the past mode of usage of HCH in my country as I explained above.

The ultimate objective of food contamination monitoring is to know the degree of human exposure to contaminants. Human milk will be utilized as one of the indices of such assumption. The concentration of DDT in human milk of Japan is rather lower than that of some other countries as shown

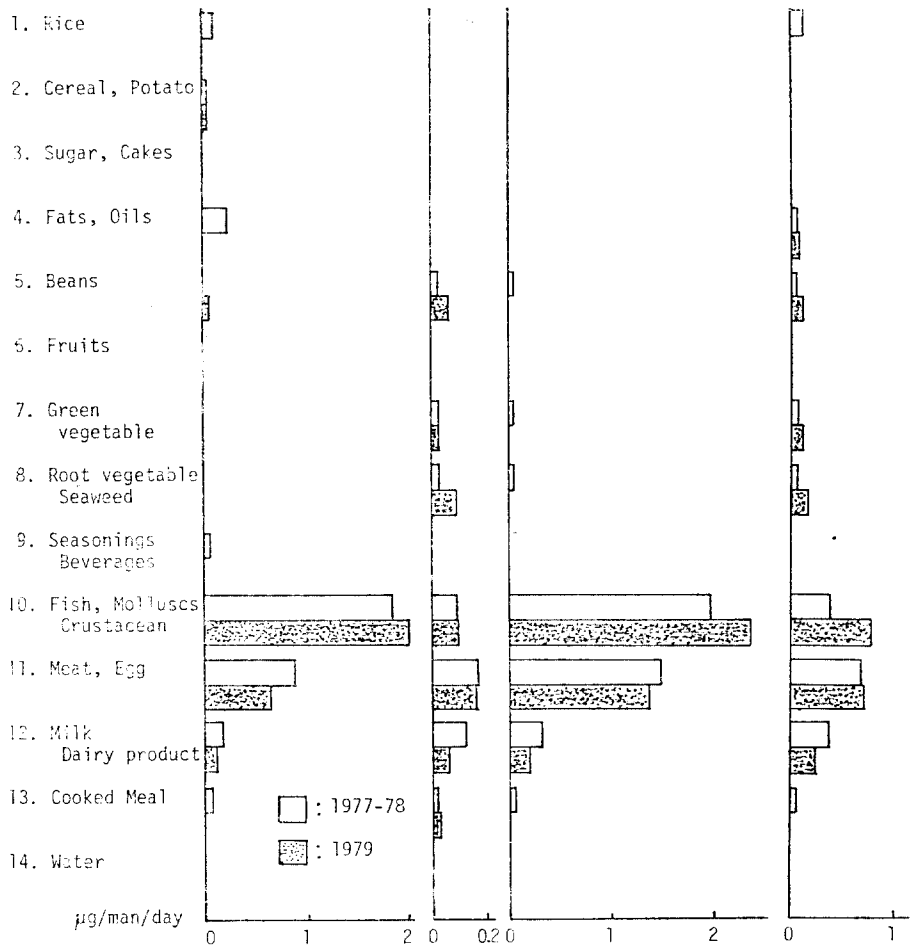

Fig.11: Total dietary intake of organochlorinated compounds from each food composite.

in Fig. 9.

However, as expected, the level of HCH is clearly higher than that of any other country (Fig. 10). The residual HCH of other countries is all gamma isomer.

TOTAL DIET STUDY

Such a monitoring of human specimens can provide us with the past states of daily intake of contaminants. But if we want to know the present status of daily intake of contaminants through all the cooked food the total diet study is extremely important

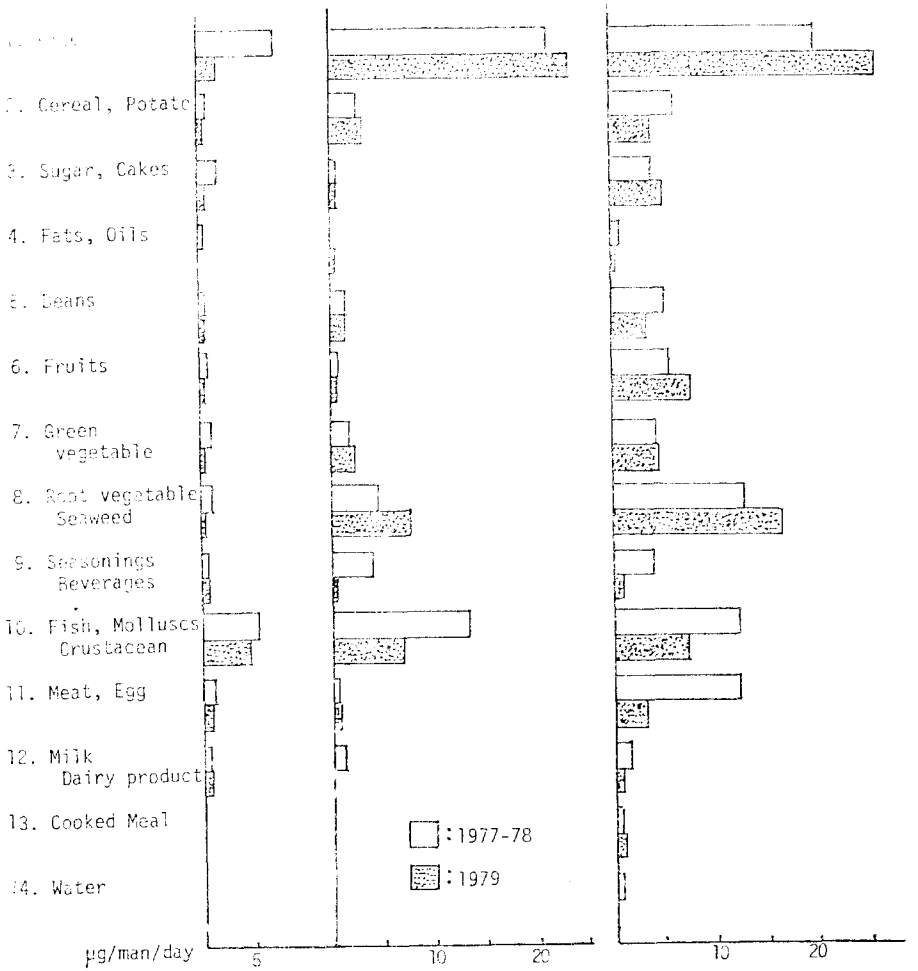

Fig.12: Total dietary intake of heavy metals from each food composite.

and effective.

One of the representative methods of total diet study is market basket method. The method is based on the authorized statistics on food consumption data in a certain area. Various kinds of food are purchased from the market so as to give menu similar to those of diets, and after cooking as necessary, contaminants in question in those foods are determined directly and thereby average daily intake of these contaminants are calculated. In my country, in compliance with the "National Nutritional Survey" of the Ministry of Health and Welfare, it is obligatory that 89 kinds of food are purchased and they are analyzed divided into 13 groups.

As techniques of micro-analysis have been developed, with respect to contaminants which can be analyzed in sufficiently high sensitivities, the total diet study can be said to be the most appropriate method to know the degree of human exposure.

Fig. 11 and 12 are graphical showings of a part of our results which were obtained in these three years by each 10 different total diet studies. The length of the bar shows the absolute amount of contaminant intaken per day per person.

As clearly understandable, organochlorinated materials are mainly intaken through fish and meat. On the contrary, more than 50% of cadmium is originated from rice.

In the bottom of Fig. 11 you can see the ADIs of these chemicals, which is recommended by FAO/WHO expert committee. The actual total daily intake of them in my country is around 1/100, but the intake of dieldrin is almost 1/10 of ADI value. So the tracing of the tendency of dieldrin intake must be emphasized hereafter.

Such a total diet study has various advantages, for instance, we can know what proportions multiple contaminants are taken in and through what food a particular contaminant is mainly taken up as well as overall picture of contamination regardless of import or local supply.

The data of total diet study obtained in some other countries are listed in Table II. Naturally, the daily intake is highly influenced

Table Ⅱ : Comparison of average daily intake of some contaminants from total diet (μg/day/man).

		T-BHC	T-DDT	Dield.	PCB	Hg	Pb	Cd
Japan	1978	1.89	4.05	0.54	3.28	14.5	102.6	46.0
	1979	2.32	3.94	0.66	3.09	8.6	82.1	46.2
USA	1975	0.68	5.0	2.32	0.34	3.7	67.2	34.0
	1978	0.72	4.2	1.02	—	—	—	—
UK*	75-77	3.9	5.0	2.3	0.06	22.0	170	21
Australia**	1978	0.65	11.4	1.4	—	7.2	—	—
Netherland*	1978	5.0	8.0	2.0	—	—	—	—

*Non detectable data were substituted with 'limit of quantitation.

**Above ND were substituted with 1/2 of limit of quantitation.

Table Ⅲ: Consumption of foods mainly responsible for the intake of contaminants.

Food item	Japan	USA(adult)		Canada		Australia
		Southeast	West	Summer	Winter	
	1977	1975		1978		1978
Rice	229	17	27	5.2*		4
Potatoes	62	179	179	191*		128
Fish	85	30	18	6	6	32
Shell-fish	4	—	—	0.5	0.4	—
Meat	68	242	253	146	153	216
Milk, dairy	107	756	756	328	336	369

*data for 1969 g/day/man

by the mode of food consumption. The relatively high intake of PCB in my country will be derived from higher consumption of fish than in western countries. The intake of DDT is rather lower in Japan than mother countries, which will be attributable to less consumption of animal protein in our country. Such assumption was proved by the comparison of food consumption summarized in Table III.

Thus the total dietary survey and the check of the trends of contaminants in foods are the most effective measure to prevent serious problems caused by food contaminants.

FUTURE ASPECTS ON CHEMICALS IN FOOD

1) Simultaneous analysis and their chemical forms

As I mentioned so far the contamination monitoring and the total diet study are two main measures for the inspection and preservation of food safety for us, but there are some additional problems to be investigated.

In future contaminants analysis, it is desireable that multiple contaminants in a given food be analyzed to the possible extent. The reason is that hereafter the effects of all the contaminants in the condition of co-existence should be considered as the basis of safety evaluation rather than the effect of each individual contaminant.

With respect to heavy metals, their contents are naturally determined as whole amount, but the analysis should be made with their chemical forms in food being kept in mind.

2) Specimen banking

Recently, the necessity of storing each component present in environments (air, water, soil, food, bio-organisms and human specimens) for many years to come is being proposed internationally. Unfortunately, no large scale and complete system is formed yet. In the case of food contaminant which is once newly detected and needs retroactive investigation, the storage of past samples provides extreme usefulness. Only thing we can do now regarding contaminants which would be detected in the future, is to store samples.

3) Assurance of comparability of analytical results

In Japan we much owes to Provincial Rese-

arch Laboratories with regard to investigation or monitoring of food contamination. Under such situation, it is a basic requirement that analytical results be comparable with one another. Presently, there is no practice of quality assurance on the contamination monitoring in Japan rather than conducting trainings based on the official analytical methods.

4) Technical development

Incidentally, variations in accuracy of analysis in many cases are arisen at stages of extraction of clean-up rather than at a terminal detection stage, viewed from the standpoint of whole analytical procedure. Therefore, in order to improve the efficiency and reliability of future contaminant monitoring, particularly the automation in extraction and clean-up stages should be expedited.

At the same time, when various chromatograms are obtained in terminal quantitative procedures, it is desirable that not only signals of intended substances but also all other signals appearing simultaneously be recorded and be stored after digitization. This method will play an extremely important role in detection of unknown contaminants which follows next.

5) Establishment of detection system of unknown contaminants

Food contaminations in past years in our country due to PCB and methylmercury were not found out by any detection system but brought to light by livestock accidents, labor incidents, or human poisoning. These contaminations were so intense (close to subacute toxicity) that they led to accidents. However, even now there is a possibility of the appearance of new contaminants which will chronically affect health.

Unless what is called "good disposal practice" permeates widely among all the people, contamination of chemical substances into food from environments will not cease. Hence, an effective detection system against unknown contaminants is desired.

In 1969 Jensen found out PCB in food. And the finding was made through investigation of an unknown peak detected on a gas chromatogram. The detection of unknown contaminants will also be made in the future by the method which is similar to the Jensen's in principle. But, improvements are possible in analytical specimens or analytical indices.

As analytical specimens, the ones representing contamination of environments most sensitively are preferred. Considering the characteristics of our eating habit, namely, the fact that marine products and rice are taken in more quantities, marine shell-fish will be the best specimen.

Analytical indices are obtained as patterns appearing when samples are analyzed under given conditions. Patterns had better be complicated as much as possible and be of high reproducibility. Since detection relies upon change of mutual ratio of various signals observed in the pattern, appearance or disappearance of particular signals, etc., variation ranges of each standard pattern must be investigated elaborately beforehand.

CONCLUSION

In order to supply food in safer conditions, many things have to be done hereafter besides fortified contamination monitoring and completeness of total diet study. Those will be specimen banking, establishment of the detection system of unknown contaminants and application of analytical methods to multiple components and their automation.

However, monitoring should not be regarded as an end in itself. Although it may facilitate the removal of contaminated food from distribution channels, it does little or nothing to reduce contamination. To do this, the source of contamination must be identified and eliminated or controlled.

For the expansion and the implementation of sanitation which is said to indicate the cultural level of human, not only to keep the technical level of analysis in high quality or to clarify the toxicity mechanism, but to evaluate sufficiently preventive investigation or research is essential. I hope such works will make remarkable progress in the every field of pharmaceutical sciences in this country.