VICISSITUDE OF PESTICIDE USE IN JAPAN

Chojiro TOMIZAWA*

Abstract

Just after the Second World War, Japan suffered from a serious food shortage, and the increase and stabilization of agricultural production were an urgent need in order to secure enough food for the people. For this purpose, pesticides had played a very important role, and their application had spread rapidly to various crops, especially rice. Indiscriminate application of pesticides, however, revealed some adverse effects of pesticides, that is, accidental poisoning of farmers engaged in pesticide application, consumption of pesticide residues in food by the people, environmental pollution, etc. These effects were attributable partly to the application of pesticides which are highly toxic or persistent in the environment. Following the disclosure of adverse effects, various countermeasures were taken by the concerned organizations in every sector with regard to mammalian toxicity, formulation and use of pesticides to prevent human hazards of pesticides, while the development of new pesticides having different chemical structures and modes of action and the improvement of formulations for saving labor for agricultural practices have been promoted actively by the pesticide industry. It is also evident that the changes in the incidence of major pests of economically important crops and the occurrence of pesticide-resistant pests influenced, to some extent, the use pattern of pesticides. On the other hand, registration and inspection systems of pesticides in Japan are at present well organized, and contribute to the proper supply of pesticides needed for agricultural pest control.

Pest control techniques in Japan made great strides with the progress of pesticide chemistry after the Second World War. Control of the rice stem borer which had been one of the most harmful insect pests for rice cultivation in Japan was practically achieved by the introduction of hexachlorocyclohexane (BHC) in 1951 and parathion in 1952. On the other hand, the control of the rice blast fungus which is also a harmful pathogen of rice was achieved by the introduction of organomercury fungicides which replaced Bordeaux mixture and other copper fungicides. Thus, the pattern of pesticide use in Japan had rapidly shifted from the inorganic pesticides to the organic ones in the early stages of the 1950s.

Pesticide production

Pesticide production in Japan reached a value of US$55 million in 1955, which was 6 times more than that in 1950. Thereafter, the production increased steadily. Especially, when the petroleum crisis occurred in 1973, prices of every commodity rose suddenly, and this tendency was also reflected in the prices of pesticides. Pesticide production in 1974 reached a value of US$880 million, and in 1975 the value became 1.65 times higher than that in the previous year. However, this disorganization of the pesticide prices eventually ceased in 1978, and the total production value in 1980 reached US$1,260 million, as shown in Figure 1. Manufacture of technical grade products in Japan started with DDT in 1947 just after the Second World War, followed by BHC in 1948, parathion in 1954 and EPN in 1969. Pesticide industry in Japan can be divided into two sectors – manufacturers and formulators of pesticides. In the early stage of domestic production of technical grade products, the majority of the pesticides had been manufactured under foreign technical assistance, and afterwards, domestic manufacture of several pesticides such as fenitrothion (Sumithion) and CPAS (chlorfenside) took place, and was followed by the manufacture of blasticidin and kasugamycin (antibiotics), EBP (organophosphorus fungicides, later replaced by IBP, diisopropyl S-benzyl phosphorothioate) and carbamates (cartap,

* Senior Researcher, Laboratory for Pesticide Biochemistry, National Institute of Agricultural Sciences, Yatabe-machi, Tsukuba-gun, Ibaraki 305, Japan.

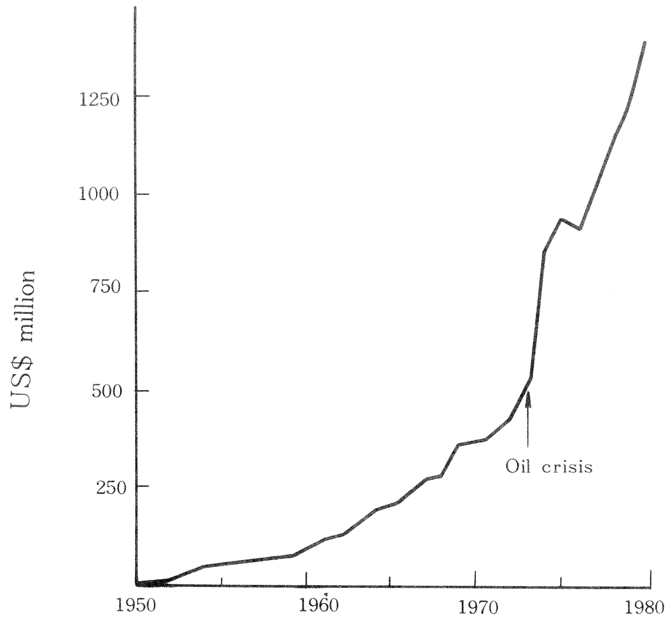

Fig. 1 Annual change of pesticide production in value.

CPMC, MPMC, MTMC, etc.) for rice, and thiophanate and dichlozoline fungicides for horticultural use.

Between 1950 and 1970, the production of inorganic pesticides decreased from 41% to 6% in value, and natural pesticides from 10% to 0.1%. In contrast, the production of organic pesticides increased in value from 42% to 93% for the same period. The ratio of the respective pesticides in 1980 was 3.9% for the inorganic ones, 0.5% for the natural ones and 96.5% for the synthetic organic ones.

Change in the pattern of pesticide use

As shown in Figure 2, insecticides accounted for 72% of the total pesticides in value, fungicides for 20%, and herbicides for 4.4% in 1955. Although insecticides accounted for more than half of the total production of pesticides in 1955, their production declined to 59% in 1960, 49% in 1965 and 38% in 1980. On the other hand, the production of fungicides increased gradually together with the prevalence of organomercury fungicides for the control or rice blast disease from 1952, and reached 32% in 1958. Afterwards, a level of 25 ±3% has been maintained. Herbicide production accounted for about 4% in 1960, and following the development of 2,4-D, extensive application of pentachlorophenol in rice fields started, followed by paraquat, thiobencarb and molinate between 1965 and 1975. Consequently, the ratio of herbicides was 14% in 1961, and reached the 20% level between 1965 and 1975, and finally shifted to 30% level in the past five years.

Another distinctive characteristic was the development of pesticide mixtures, especially binary mixtures of insecticides and fungicides for saving labor of pesticide application in paddy fields, and their ratio to the total pesticide production has been approximately 7% in recent years.

As for the ratio of pesticide production for rice and horticultural crops, only 25% of the total

Fig. 2 Annual change of pesticide production classified by use pattern.

pesticide production had been applied to rice in 1950. The ratio of pesticides for rice started to increase abruptly in 1952 in order to overcome the food shortage at the time, and reached 66% in 1954, while that for horticultural crops declined to 33% in the same year. Afterwards, some fluctuations were observed, in particular with the reduction of land allocated for rice cultivation upon the recommendations of government authorities since 1978. Consequently, the ratio of pesticide production for rice and horticultural crops became 49 and 51% in 1979, respectively. It is noteworthy that the majority of the pesticides used for the control of rice leafhoppers, planthoppers and the rice blast fungus which are extremely important pests for rice cultivation have been developed in Japan.

Change of pesticide formulation

Pesticide formulation after the introduction of synthetic organic pesticides is characterized by the increase of dust formulations as compared with the emulsifiable and wettable formulations which tended to prevail in the past (Fig. 3). The prevalence of dust formulation was promoted by the development of rice paddy pesticides. Production value of dust formulations which was 15% in 1950 increased to 41% in 1953 due to the rapid development of dust formulations of BHC, parathion and organomercury fungicides for rice. Afterwards, its ratio increased steadily and reached 243 thousand tons in 1955 and has fluctuated between 250 and 300 thousand tons since 1970. The prevalence of granules is characteristic in the case of herbicides and insecticides. The application of BHC granules which was carried out in paddy fields throughout the country, was prohibited in 1972 due to its contribution to environmental pollution. The ratio of insecticide granules accounted for 25% of the total insecticide formulations in 1980.

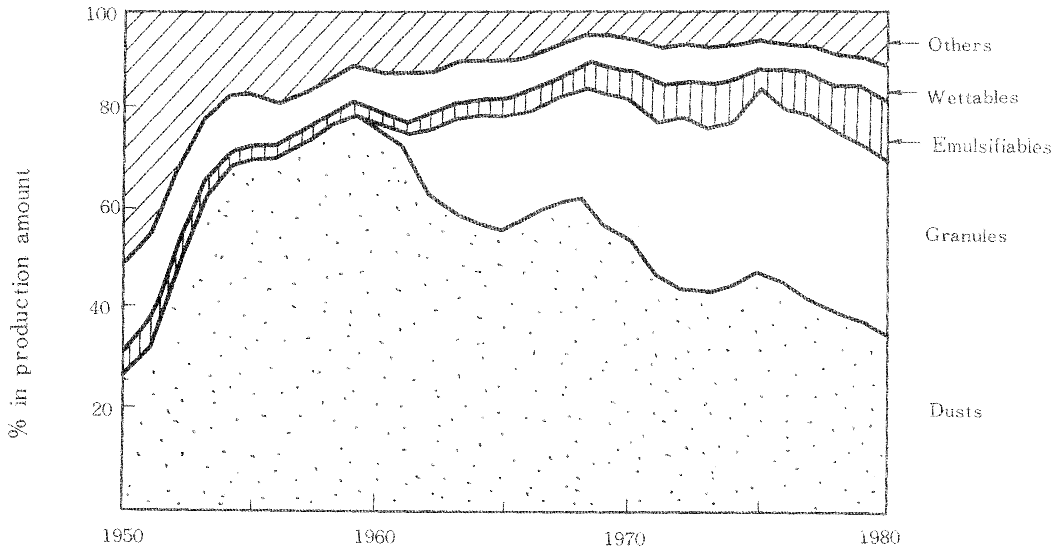

Fig. 3 Annual change of pesticide formulations.

Change of mammalian toxicity of pesticides

As for the development of new pesticides with low mammalian toxicity, Sumithion (fenitrothion) which was discovered in 1961 as a substitute for parathion showed a toxicity of less than 1% to mammals as compared with parathion. In Japan, mammalian toxicity of chemicals including industrial chemicals is regulated by the Poisonous and Deleterious Substances Control Law, and chemicals are divided into the following three classes on the basis of their mammalian toxicity: poisonous, deleterious and ordinary chemicals. Among the poisonous pesticides, those which should be handled with special care due to their fatal effect on mammals, are designated as specified poisonous chemicals. As shown in Figure 4, the ratio of specified poisonous pesticides

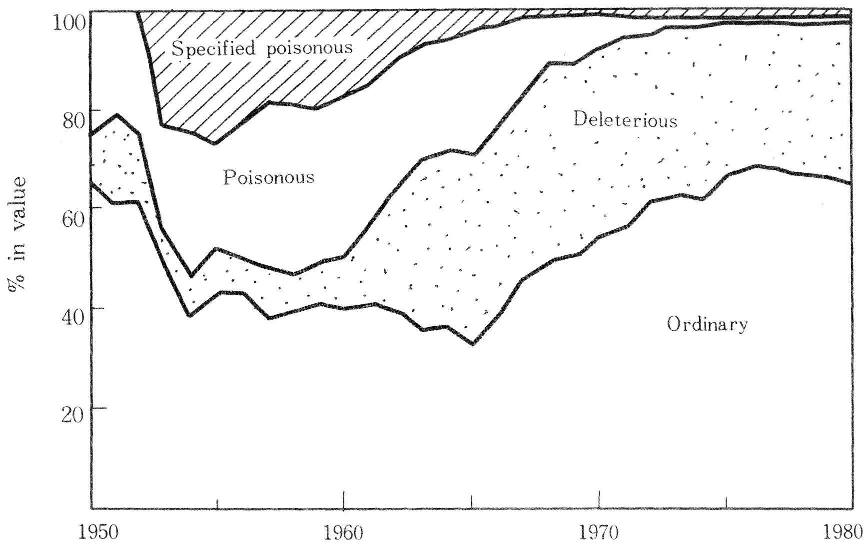

Fig. 4 Annual change of pesticides classified by mammalian toxicity.

increased suddenly from 2.9% in 1952 to 23.4% with the introduction of parathion in 1953 for the control of the rice stem borer, and afterwards, the ratio declined gradually with the development of organophosphorus insecticides with low mammalian toxicity. In 1967, the government authorities decided to discontinue the production of highly toxic organophosphorus insecticides such as parathion and TEPP. Consequently, the ratio of specified poisonous pesticides decreased to 1.4% in 1969, and 0.2% in 1980. The ratio of poisonous pesticides which include the majority of the organomercury and organoarsenic compounds, was 33% in 1958, and later decreased to 9% in 1969 and 1.6% in 1980. On the other hand, the ratio of deleterious and ordinary pesticides ranged around 50% in 1957, and increased to 89.5% in 1969, 98% in 1980 due to the development of new pesticides with low mammalian toxicity. As a result, the pattern of pesticide use changed from the persistent and highly toxic ones to the biodegradable and selective ones between 1965 and 1980.

Import and export of pesticides

Immediately after the Second World War, the pesticide industry in Japan lagged behind that in the USA and European countries, and many pesticides developed in foreign countries were imported year by year. Imports of pesticides started with DDT and BHC, followed by 2,4-D, parathion, EPN, etc., and those of endrin, carbaryl, trichlorphon in 1960 and fenthion and nitrofen in 1964 caused a rapid increase of their import value. The import value was US$700,000 in 1952 and increased rapidly to US$2.5 million in 1957. Afterwards, carbaryl, diazinon, simazin and paraquat were imported successively between 1966 and 1969, and methomyl, simetryn, benomyl and molinate until 1971. The import value reached US$140 million in 1975 and US$220 million in 1980.

Before the Second World War, chrysanthemum and inorganic compounds had been exported, and the ratio of exports to the total pesticide production was about 17%. After the war, Japan became a country importing pesticides in order to increase the yield of rice, the staple food crop. Therefore, the export value fluctuated around US$100,000 in 1955, and afterwards, with the increase of the production scale and the development of new pesticides, Japan became an exporting country. The export value was in the range of US$2.5 to 5.6 million between 1956 and 1963 and at this stage the major countries were the Republic of China and the Soviet Union. Then the exports increased rapidly with an increase in the ratio ranging from 30 to 70% per year for various countries in the world. The export value reached US$40 million in 1970, US$125 million in 1975 and US$240 million in 1980. On the other hand, the export of formulated products decreased gradually and the ratio to the total export value was only 28% in 1980. Kinds of exported pesticides were mainly BHC and DDT at the early stage until 1963, and the export of domestically developed pesticides increased steadily. Major pesticides exported are fenitrothion, diazinon, isoprocarb, MIPC, thiophanate-methyl, cartap and thiobencarb as technical grade products and IBP, thiophanate-methyl and thiobencarb as formulated products.

Registration of pesticides in Japan

Although the rapid progress in the manufacture of synthetic organic pesticides in Japan has contributed to the stabilization of agricultural production and the increase in the production of agricultural commodities, some undesirable problems arose as a result of large-scale application of pesticides, namely, accidents sustained by farmers in relation to pesticide application, pesticide residues in agricultural commodities, environmental pollution and disturbance of the natural ecosystems by pesticides and degradation products.

In the past decade, the law concerning pesticide regulation was amended and the safety of pesticides has been re-evaluated for preventing accidents due to pesticides and protecting the health of the people. Safe handling of pesticides could be secured on the basis of the abundant data on the toxicity of pesticides. Since 1973, data on all pesticides applied hitherto have been assessed again at the time of re-registration. When the safety of pesticides submitted for re-registration is considered to be questionable on the basis of the data submitted or when the submitted data are insufficient with respect to safety, re-registration is not authorized and the registration is discontinued. The application fields of invalidated pesticides may be offset by the expansion of those of pesticides which passed the registration procedures or by newly developed and registered pesticides. On the other hand, new formulations of pesticides have been registered in order to prevent various accidents after pesticide application and to save labor in pesticide application. As shown in Figure 5, the number of pesticide registrations totalled 14,273

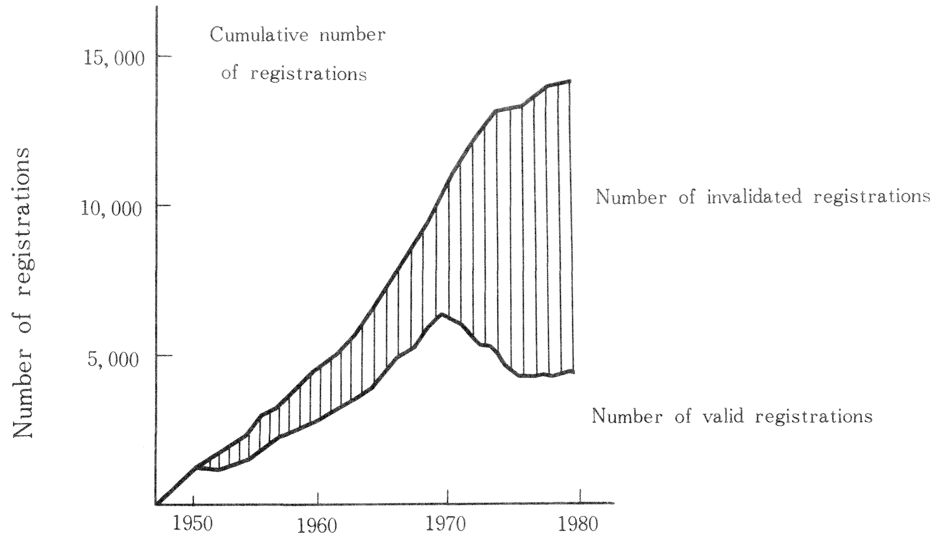

Fig. 5 Annual change in the number of pesticide registrations.

up to March 31, 1980. The Agricultural Chemicals Regulation Law was first enacted in 1948, and the number of pesticide registrations increased linearly. By the amendment of the Law in 1971, some changes in the registration number occurred, and the number of valid registrations was 6,200 in 1970 and 4,329 in 1980. In 1969 and 1970, registration of BHC, DDT and organomercury compounds became invalid, and as mentioned previously, re-evaluation of pesticide safety in 1973 caused the decrease in the number of registrations. However, recent trends in the status of registration suggest that the procedures for the assessment of pesticides submitted for registration have been completed and the number of registrations appears to increase again since 1979.

In the past thirty years, the total number of active ingredients registered reached 580, but some of them were withdrawn in view of their high mammalian toxicity, adverse effects on the environment and inferior efficacy for agricultural pests. About 330 active ingredients have been registered in March, 1980. The reason why some pesticides have become invalid since 1974, is not necessarily ascribed to their mammalian toxicity, but to the high costs required for the preparation of the data on the evaluation of safety. Enterprises have felt that such pesticides do not make a good return economically even though excellent pesticides may be developed. On the other hand, the decrease in the number of pesticides due to the invalidation of registration affects greatly practical aspects of pest control, and the limitation of application due to mammalian toxicity and residues in crops has posed other difficult problems. Some examples include insect and disease pests which are difficult to control due to the unavailability of registered pesticides for target crops and the difficulty of pesticide rotation due to the unavailability of alternate pesticides when insect and disease pests become resistant to pesticides.

The requirements for the data on pesticide safety at the time of registration have become more strict, and the volume of the work for the evaluation of toxicity for registration has increased in the government offices. This is one of the reasons why the registration of new pesticides was discontinued between 1977 and 1979.

In conclusion, the main events which have taken place in the pesticide field in Japan in the past thirty years may be summarized as follows:

1. DDT and BHC: Due to environmental pollution, the production of these insecticides was discontinued in 1969, and their application to rice was prohibited in 1970. At the same time, the registration became invalid and sales were also prohibited in 1971.
2. Lead arsenate and endrin: These pesticides were designated as crop-persistent pesticides by the Environment Agency, and their use was strictly curbed in 1971.
3. Dieldrin and aldrin: These pesticides were designated as soil-persistent pesticides in 1971 by the Environment Agency.
4. Endrin, isobenzan (Telodrin), endosulfan, rotenon and PCP: These pesticides were designated as water polluting pesticides.
5. Parathion, methyl-parathion and TEPP: Manufacture of these insecticides was discontinued in 1969 and their use was prohibited in 1971 in order to prevent the accidents caused by their handling.
6. Organomercury compounds: These pesticides were switched to other non metallic fungicides for the control of rice blast between 1966 and 1968, and their registration was repealed in 1970. Moreover, their use for seed disinfection became invalid in 1973.
7. New fungicides such as PCBA (pentachlorobenzyl alcohol) and its derivatives for the control of rice blast disease: These fungicides were developed as substitutes for organomercury compounds and exhibited very good control effect on rice blast disease. However, when rice straw and leaves to which these fungicides were applied, were used as compost manure for nursery beds of vegetable crops, malformation of crop seedlings occurred, and it was found that such plant injury could be attributed to pentachlorobenzoic acid and tetrachlorobenzoic acid produced from pentachlorobenzyl alcohol and its derivatives. The production and application of new fungicides containing pentachlorobenzyl alcohol and its derivatives were rapidly discontinued. Afterwards, another type of rice blast fungicide was developed, and tetrachlorophthalide (4,5,6,7-tetrachlorophthalide) was registered in 1970 and has been extensively applied to the control of rice blast disease.
8. 2,4,5-T: Tetrachloro-p-dioxine resulting from the synthesis of 2,4,5-T is teratogenic, and the registration of 2,4,5-T became invalid in 1973.
9. α-naphthaleneacetic acid: This compound was used as citrus thinner and for prevention of apple fruit shedding, but its registration became invalid in 1976. At present, it is very difficult to find another compound fitting the above mentioned purposes.
10. Rice paddy herbicides, with emphasis on the control of perennial weeds: Rice paddy herbicides have been actively developed by pesticide companies, and thiobencarb and simetryn were registered in 1969, followed by molinate, oxadiazon, butachlor, chlormethoxynil, bentazon, dimuron, dimethametryn, piperophos, methoxyphenone, naproanilid and pyrazolate.
11. Rice blast fungicides for paddy water application: Isoprothiolane (diisopropyl 1,3-dithiolan-2-ylidenemalonate) and probenazole (3-allyloxy-1,2-benzothiazole 1,1-dioxide) were registered in 1974, and rice blast control by paddy water application of fungicides has been achieved by the use of these fungicides and IBP. Recently, tricyclazole applied in the nursery beds of

rice seedlings has been registered for the control of rice blast disease.

12. DCV: Preparation containing insect virus of pine caterpillar (*Dendrolimus spectabilis* Butler) was registered for the control of pine caterpillar in 1974.
13. Soybean lecithin: This compound is effective for the prevention of powdery mildew of various vegetables, and the compound is a food additive which can be applied until harvest time of vegetable crops without the risk of crop contamination by pesticide residues. Registration was made in 1976.
14. Sodium alginate: This compound which is effective for the prevention of TMV was registered in 1976.
15. Litlure: Synthesized sex pheromone of the common cutworm, *Spodoptera litura* was registered in 1977.
16. Adjuvants: d-Sorbit, a diluent when a pesticide is applied with a fog machine was registered in 1976. Sodium polyacrylate is used for aerial application with ULV. It prevents the evaporation of water on spray particles, and was registered in 1978.

Discussion

Morallo Rejesus, B. (The Philippines): Could you explain on what basis you classify pesticides in Japan with regard to mammalian toxicity.

Answer: The classification is based on both acute oral and acute dermal toxicity.

Mochida, O. (IRRI): In Japan, if I am right, there are standards for human and fish toxicity.

Ishikura, H. (Japan): In Japan there is the Poisonous and Deleterious Substances Act that refers to pesticides and industrial chemicals. The classification of pesticides based on acute oral and dermal toxicity is as follows: 1. Specified poisonous substances (toxicity: less than 10 mg/kg); 2. Poisonous substances (10 to 30 mg/kg); 3. Deleterious substances (30 to 300 mg/kg); 4. Ordinary substances (above 300 mg/kg). These figures refer to oral toxicity only.