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Safety Evaluation and Regulatory Control of Pesticide Residues in Taiwan

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ABSTRACT

Because agricultural production in Taiwan depends heavily on the use of pesticides, much attention has been focused on pesticide contamination of food and on the effects of pesticide residues on human health. The Taiwan Agricultural Chemicals and Toxic Substances Research Institute (TACTRI) conducts tests to evaluate the safe usage of pesticides in Taiwan. In accordance with the Pesticide Control Act, minimum harvest intervals and tolerance levels for pesticides used on different crop groups are established before pesticides are approved for use in the field. The "tolerance" level of pesticides for different crop groups is determined on the basis of: i) the acceptable daily intake value of the pesticide; ii) the average daily consumption of each crop group by the Taiwanese people; and iii) the level of pesticide residues on different crops, estimated from supervised trials. Tolerance levels must be established before registrations can be approved.

Pesticide residues on vegetables and fruits are under heavy public scrutiny. Fifteen workstations for pesticide residue control have been set up by the TACTRI in different localities in Taiwan, and multi-residue methods are used for the analysis of these products. Pesticide residues commonly found on vegetables have now been identified. Educational programs for farmers have been devised, based on the analytical results obtained from these workstations. Risk assessments of dietary intakes of pesticides are carried out on a continuing basis. Results have shown that the dietary intake of pesticide residues by consumers is within safe limits.

Key words: Pesticide, Toxicity, Registration, Residue, Monitoring, Fruits and Vegetables, Risk assessment

INTRODUCTION

It is well known that weeds, plant diseases, and pre- and post-harvest pests are major factors causing reductions in potential crop yields. There are many ways to control diseases and insect pests, such as the application of pesticides, the breeding and cultivation of resistant crop varieties, biological control, etc.(3) Pesticides play an important role because they produce rapid and reliable results and are easy to use. Hence, the use of pesticides still remains as one of the most important control measures for plant protection. It is expected that this situation will continue in the future.

Although many methods, including integrated pest management (IPM), are being used in Taiwan for plant protection, Taiwan's agriculture is still heavily dependent on pesticide usage. Much attention has been focused on the regulatory control of pesticide residues to minimize contamination of food and any consequent effects on human health.

AGRICULTURAL CHEMICAL REGULATORY LAWS

The Pesticide Control Act, promulgated and implemented in Taiwan by the Government in 1973, prohibits the sale, distribution and use of any pesticide without governmental approval. This approval is given only after the submission of necessary data on the formulated pesticide's effectiveness, the satisfactorily evaluation of its physical and chemical properties under local environmental conditions, and the establishment of a residue tolerance level. On average, about 80 applications for registration of pesticides are received annually. Applications might be for new compounds, for new formulations of registered compounds, or for registered products manufactured by a producer other than the original registrant. The data required for registration include: physical and chemical properties which will help with the evaluations of the qualities of the chemicals; toxicity to mammals to ensure the safety of a pesticide product and to protect farmers' health; avian toxicity; toxicity to aquatic organisms and to natural enemies of pests, to minimize the impact of pesticide usage on the environment; the distribution and degradation in water and soil, to reduce the potential for environmental pollution; residue and metabolism data on crops, to minimize field application rates and to protect the consumers from harmful agricultural products; efficacy and phytotoxicity, to ensure the effectiveness of pest control and to avoid damages to treated crops(4). Field residue data and field efficacy data must be generated from local trials. Double-checking of the specifications of the pesticide by governmental laboratories is also necessary.

TACTRI is responsible for residue analysis, specification analysis and evaluation of the required registration data on the pesticides to make appropriate recommendations for approval. The registration procedure is shown in Figure 1.

The following sections summarize the residue control programs related to food safety in Taiwan.

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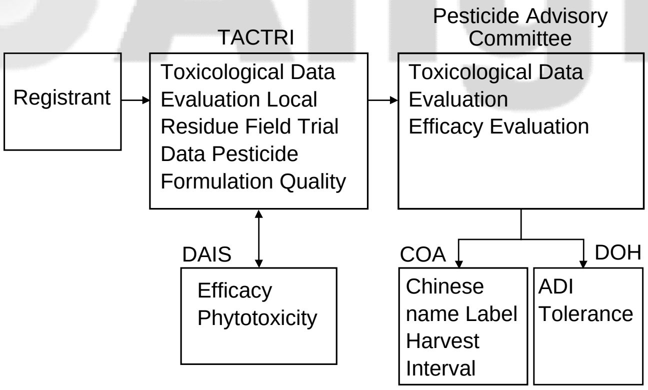


TACTRI = Taiwan Agricultural Chemicals and Toxic Substances Research Institute
DAIS = District Agricultural Improvement Station
COA = Council of Agriculture, Executive Yuan
DOH = Department of Health, Executive Yuan

Figure 1. Registration procedure in Taiwan

ESTABLISHMENT OF TOLERANCE LEVELS FOR PESTICIDES ON DIFFERENT CROPS

Before a pesticide is registered, supervised trials are conducted by TACTRI in cooperation with various agricultural research institutes and distinct stations. The pre- harvest intervals (PHI) are recommended by TACTRI by comparing residue data from supervised trials with the maximum tolerable residue limits established for a pesticide.

The requirements for setting tolerances involve both pesticide data and crop consumption data(5). The pesticide evaluation includes submission of data concerned with: product chemistry, acute and chronic toxicity, animal and plant metabolism, field residues and processing studies. The chronic toxicity data and the field residue data are the most important information. The actual levels of residues found on each crop group resulting from the application of the pesticide at recommended rates are obtained from the field residue data. The acceptable daily intake (ADI) of the pesticides is derived from the chronic toxicity data. The established ADI values of pesticides registered in Taiwan are listed in a book published by TACTRI(11). The MPI (maximum permissible intake) of a pesticide by Taiwanese people is calculated from the ADI using an average body weight of 60 kg.

The average daily consumption of each type of crop per person is obtained from large-scale survey data. For the survey and calculation, crops were classified into 19 different groups (Table 1), based on the edible parts of the plants, expected distribution of residues and residue accumulation patterns. Some examples of the daily consumption data are shown in Tables 2 and 3.

The tolerance level for each group of crops is set in accordance with the maximum amount of residue that should be present at harvest time. However, the total number of crop groups for which a pesticide is registered is limited by the MPI value. In other words, the total actual amount of pesticide residue on a crop group for which a pesticide had been registered could never exceed the established MPI value. Table 4 shows the tolerances established for benomyl

Table 1. Crop grouping for tolerance establishment

Group	Crop
1. Rice	Rice
2. Wheat	Wheat, Barley
3. Maize	Corn, Sorghum
4. Brassica vegetables	Cabbage, Cauliflower, Head lettuce, Leaf mustard, Head cabbage, Big stem mustard
5. Leafy vegetables	Pak-Choi, Field mustard, Chinese Kale, Celery, Lettuce, Garlic green, Spinach, Water convolvulus, Chinese chive, non-heading type Chinese cabbage
6. Root and tuber vegetables	Potato, Radish, Carrot, Bamboo shoot, Water oat, Onion, Ginger, Taro.
7. Fruiting vegetables	Eggplant, Green pepper, Tomato, Tomato, Hot pepper, Day lily
8. Curcubit vegetables	Cucumber, luffa, Pumpkin, Wax gourd, Rag gourd, Chayote
9. Legume vegetables	Kidney bean, String bean, Pea, Asparagus bean, Garden bean
10. Melon	Water melon, Yellow melon, Netted Melon, Pineapple melon
11. Small Berries	Grape, Guava, Mulberry, Carambola, Wax-apple, Strawberries.
12. Stone fruits	Logan, Mango, Lychee, Loquat, Persimmon, Kiwi fruit [kiwi fruit do not have stones. Like persimmons, they are normally considered large berries]
13. Pome fruits	Apple, Pear, [Peach, Plum, Apricot, Cherry, Jujube
14. Citrus fruits	Orange, Tangerine, Grapefruit, Pomelo, Lemon.
15. Large berries	Banana, Pineapple, Papaya, Mangosteen, Sugar apple, Pitaya
16. Pulse	Red bean, Soybean, Mung bean, Peanut.
17. Mushroom	Mushroom, Straw mushroom, Jew's ear
18. Sugarcane	Sugarcane
19. Tea	Tea

Table 2. The daily consumption data of vegetable groups

Crops	Daily Consumption(kg)	% Intake
Leafy vegetable	0.083	8.56
Brassica vegetable	0.066	6.74
Fruiting vegetable	0.022	2.28
Cucurbits	0.029	2.97
Legume vegetable	0.012	1.17
Root & tuber vegetable	0.050	5.16

Table 3. Crop consumption data of fruit groups

Crops	Daily Consumption(kg)	% Intake
Large berry	0.028	2.83
Small berry	0.041	4.26
Stone fruit	0.012	1.19
Pome fruit	0.030	3.01
Melon	0.056	5.71
Citrus	0.066	6.82

on different crops. The calculated intake is about 0.569 mg/person/day, which accounts for 47% of the MPI for benomyl. Thus, benomyl can be registered for use on some additional crops without exceeding the MPI. The sub-MPI, also known as the TMDI (mg/person/day) is equivalent to the tolerance times the daily consumption of crop groups. The SMPI is the sum of sub-MPI.

Tolerance levels for the pesticides registered in different crop groups have been proposed by the TACTRI[10]. Up to February 2000, tolerance levels for 290 pesticides on different crop groups have been accepted by the Department of Health and have been listed in the Food Hygiene Law for food safety control[1,2]. So far, 1149 tolerances have been set for different crops. All the tolerances have been compiled in a book entitled "Guide to Pesticides on Crops in Taiwan"[10].

RESIDUE ANALYSIS OF FIELD SAMPLES FOR FARMER EDUCATION

In order to enforce tolerances at the farmer's level, an inspection-education program has been set up by the extension agency and TACTRI (Fig.2). Fifteen working stations of TACTRI, in different locations in Taiwan, are responsible for the analysis of pesticide residues on vegetables and fruits, and also for farmer education based on the residue results obtained. From pesticide usage survey data, 77 commonly used pesticides are sought in each vegetable sample, and 24 to 42 pesticides are sought in each fruit sample, depending upon the type of fruit (Fig. 3). If results of these long-term and country-wide surveys indicate that a pesticide residue exceeded the tolerance level, then a follow-up investigation would be undertaken to uncover the possible causes, such as the usage of cultural methods and the technique of pesticide application. The development of the effectiveness of each pesticide against pests is also assessed. Farmer education follows after the problems have been solved. Approximately 15,000 samples are analyzed annually. Since the establishment of the inspection-education program, the number of vegetable samples, which have violated tolerances, has been greatly reduced (Fig.4). It has fallen from 15.4 % in 1979 to 1.8% in 1999. The summarized results of residue analysis during the fiscal year 1999 are given in Table 5[7].

RISK ASSESSMENT OF DIETARY EXPOSURE TO PESTICIDES

Public concern over pesticide residues on vegetables and fruits has been increasing in recent years. The risk to human health is due to pesticide residues in the edible parts

Table 4. The tolerances established for benomyl on in different crop groups
ADI = 0.1 mg/kg/day (WHO) MPI = 1.2 mg/person/day

Crop Group	Tolerance (ppm)	Daily Consumption (kg/day)	TMDI* (mg/day)	Residue (ppm)	Actual intake (mg/day)
Rice	0.2	0.148	0.030	0.02	0.003
Root vegetables	0.2	0.050	0.010	0.02	0.001
Fruit vegetables	1.0	0.022	0.022	0.29	0.060
Small berry	2.0	0.041	0.083	0.20	0.008
Tea	5.0	0.002	0.009	0.50	0.001
Pome fruit	3.0	0.029	0.088	2.79	0.081
Melon	2.0	0.055	0.110	1.61	0.088
Citrus	3.0	0.066	0.198	2.78	0.183
Large berry	1.0	0.028	0.028	0.01	0.003
SMPI			0.569		0.428

*TMDI: Theoretical maximum daily Intake

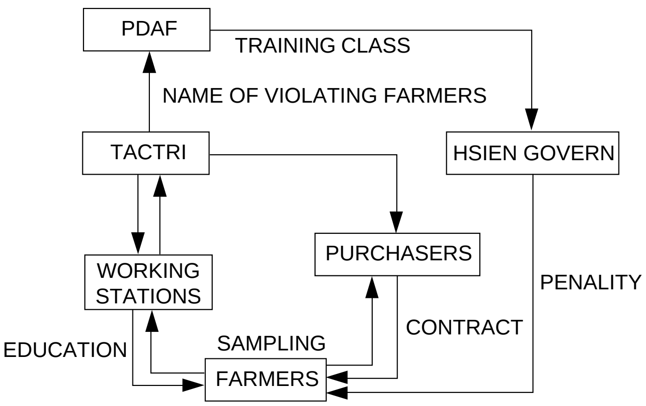


Figure 2. Working systems used to prevent pesticide residue problems on vegetables and fruits

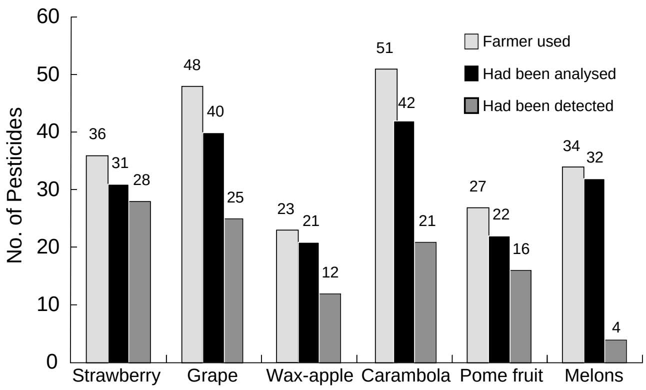


Figure 3. Survey of pesticides used on fruits

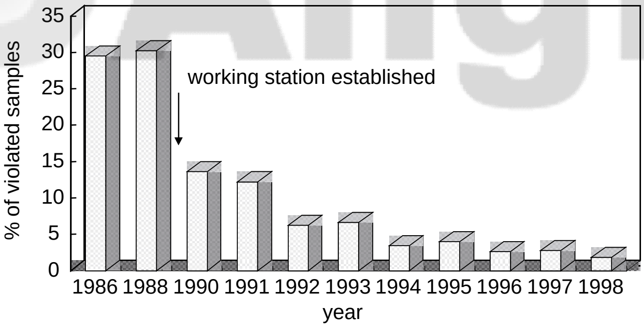


Figure 4. The percentage of samples exceeding tolerance levels before and after the establishment of working stations

Table 5. Summarized Results of Residue Analysis during the Fiscal Year 1999

Crops	Samples analyzed	Samples exceeding	Percentage (%)
Leafy vegetables	5058	150	3.0
Brassica vegetables	379	5	1.3
Fruiting vegetables	798	14	1.3
Cucurbits	1013	8	1.7
Legume vegetables	224	12	5.3
Root and tuber vegetables	956	1	0.1
Large berries	638	3	4.7
Small berries	1532	8	0.5
Stone fruit	825	19	2.3
Pome fruit	788	9	1.1
Melons	134	2	1.5
Citrus	1025	9	0.8
TOTAL	13,370	236	1.8

of the crop and the consequent daily intake of these residues.

Market basket surveys of pesticide residues in rice, vegetable, and fruit samples were carried out during 1992 to 1993. A total of 962 samples including 90 rice, 644 vegetables and 228 fruit samples were collected from markets at 11 different localities in Taiwan. Samples were analyzed using a multi-residue method (MRM). This method was used to search for 77 different pesticide residues. A total of 31 pesticides were found in various samples. Twelve pesticides were found in more than 1% of samples. Follow-up work calculated the toxicological risk by comparing the actual residue contribution (ARC) with the acceptable daily intake (ADI) for the same 12 pesticides(13). The results of this study are shown in Table 7. The actual residue contributions (ARC) were calculated using the following equation:

ARC = $\sum$ (Fi x Ri)/BW

Fi = the daily consumption of the crop group (kg/person/day)

Ri = the residue level of the pesticide found on the crop group (ppm = mg/kg)

BW = the average body weight of Taiwanese (60kg)

The risk assessment results are shown in Table 6. The results indicated that the ARC of the 12 pesticides consumed accounted for only 0.54 to 30.00% of their acceptable daily intakes(13).

Similar studies were carried out during the year 1999 to 2000(8,9). A total of 3262 samples, including 1064 rice, 1178 vegetables and 1202 fruit samples were collected from markets at different areas in Taiwan. Samples were analyzed using an improved multi-residue method. This improved method could be used to detect 113 pesticides on vegetables and 125 pesticides on fruits. A total of 65 different pesticides were detected on the vegetable samples, 44 on fruit and 29 on rice. Most of the pesticides detected were also commonly found on vegetables, fruits, and rice. The total number of pesticides detected was 69. After calculating the ARC of these 69 different pesticides, it was found that the ARCs of 16 pesticides were between 1.15% of ADI to 22.63% of ADI, 18 pesticides were between 0.12% to 0.97%, 24 pesticides were between 0.02% to 0.09%, and 10 pesticides were below 0.01% of ADI. Apparently, the risk posed by these pesticide residues to the consumers' health is very low. However, the ARC of EPN found in this study was about 124% of the ADI. This is because the ADI had been lowered to 0.00001 mg/kg/day. Further action will be taken on this finding. Table 7 gives a list of pesticides where the ARC value exceeded 1.15% of the ADI value.

The average daily intake of crop groups by Taiwanese

Table 6. Risk assessment of dietary exposure of pesticides

Pesticide	ADI(mg/kg/day)	ARC(mg/kg/day)	%ADI
EBDCs	0.05	0.00568	11.35
Chlorothalonil	0.03	0.00044	1.47
Methamidophos	0.004	0.00035	8.75
Acephate	0.03	0.00044	1.47
Monocrotophos	0.0006	0.00018	30.00
Chlorpyrifos	0.01	0.00023	2.32
Permethrin	0.05	0.00098	1.96
Cypermethrin	0.05	0.00030	0.60
Carbofuran	0.01	0.00036	3.60
Ethion	0.002	0.00031	15.50
Formetanate	0.037	0.00020	0.54
Carbendazim	0.05	0.00031	3.10

Table 7. Risk assessment of dietary exposure of pesticides (year 2000)

Pesticides	ADI	ARC	% ADI
EPN	0.00001	0.0000124	124.00
Ethion	0.002	0.0004525	22.63
Prothiofos	0.0001	0.0000099	9.90
Methidathion	0.001	0.0000697	6.97
Carbofuran	0.002	0.0001270	6.35
Monocrotophos	0.0006	0.0000358	5.97
Dithiocarbamates	0.03	0.0016581	5.53
Methamidophos	0.004	0.0001909	4.77
Hexaconazole	0.005	0.0001433	2.87
Chlorpyrifos	0.01	0.0002453	2.45
Carbendazim	0.03	0.000576	1.90
Carbaryl	0.003	0.0000520	1.73
Profenofos	0.01	o.0001589	1.59
Metalaxyl	0.03	0.0004470	1.49
Phorate	0.0005	0.0000072	1.44
Flusilazole	0.001	0.0000118	1.18
Omethoate	0.002	0.0000230	1.15

ARC (Actual Residue Contribution) = (F*i* x R*i*)/ BW people for risk assessment during the year 2000 has been recalculated according to a 24-hour recall data file. This data file was derived from a 5-year Nutrition and Health Survey in Taiwan (NHSIT) from 1993 to 1996[6]. The project was initiated by the DOH. The sample number was 9,962 persons, in the range 4 to over 65 years of age. Owing to the unreliable recall data for people below 13 and over 64 years old, the reduced sample size was 5,834. TACTRI has categorized hundreds of items into crop groups as shown in Table 2. A summary of the recalculated results is shown in Table 8[11].

Another purpose for the risk assessment of dietary exposure to pesticides is to evaluate the suitability of the established tolerances in pesticide regulations. The evaluation is based on MPI, Sub-MPI and SMPI.

Taking the dietary intake risk assessment of cyhalothrin as an example (Table 9), cyhalothrin is registered to be used on rice, brossica vegetables, leafy vegetables, small berries, and pome fruit. The SMPI calculated from the tolerances and the daily consumption of these crop groups is about 0.260 mg/person/day. It was found during the study that the tolerance for cyhalothrin on leafy vegetable, originally set at 1.0 ppm, was below the maximum actual residue of 1.32 ppm. Therefore, the tolerance for cyhalothrin on leafy vegetable was adjusted from 1.0 ppm to 2.0 ppm. This is acceptable because after the adjustment, the SMPI (0.426 mg/person/day) was still below the MPI (1.2 mg/person/day) for cyhalothrin. Another example is dicofol (Table 10). All tolerances of dicofol must be adjusted or the use of dicofol must be restricted.

Table 8. Average daily intake of Taiwanese

Crop group	Crop sub-group	Average daily intake (g/person/day)	% of intake
Main food	Rice	178.45	20.42
	Wheat	80.82	9.25
	Pulse	65.29	7.47
	Maize	17.75	2.03
Subtotal		**342.31**	**39.18**
Fruit	Large berries	25.86	2.96
	Small berries	37.79	4.32
	Pome fruits	32.98	3.77
	Stone fruits	12.52	1.43
	Melon	27.10	3.10
	Citrus	58.70	6.72
Subtotal		**194.95**	**22.31**
Vegetable	Broccoli vegetables	63.62	7.28
	Leafy vegetables	143.34	16.41
	Fruit vegetables	12.35	1.41
	Cucurbit	41.41	4.74
	Mushroom	1.82	0.21
	Root & stem vegetables	61.68	7.06
Subtotal		**336.52**	**38.51**
Total		**873.77**	**100.00**

MULTI-RESIDUE METHOD

Based on pesticide usage survey data, 165 pesticides were selected for investigation to establish multi-residue analysis methods for vegetables, fruits and rice (Table 11). Three multi-residue methods were developed for the analyses. One could detect 145 pesticides and their metabolites, another could detect 19-triazole pesticides and their metabolites, and the third one is used to detect pesticide residues on rice[8,9,12]. The results for dithiocarbamate fungicides were generated using a modified Keppel method. A brief flow chart of the first multi-residue method is shown as figure 5. Vegetable samples are extracted with acetone. Clean-up is performed by liquid partitioning from aqueous solution to petroleum ether and dichloromethane, followed by a Florisil column chromatography. The extracts are analyzed by temperature-programmed gas chromatography (GC) with FPD and ECD, HPLC with OPA post-column reaction and

Table 9. Dietary intake risk assessment for cyhalothrin
ADI: 0.02 mg/kg bw/day (FAO, 1984)
MPI: 1.2 mg/person/day (ADI x 60kg)

Crop Group	Tolerance (PPM)	Daily Consumption (kg/day)	Estimate Intake (mg/day)	Actual Residue (ppm)	Actual Intake (mg/day)
Rice	0.5	0.148	0.074	0.004	0.001
Brassica vegetables	0.5	0.066	0.033	0.42	0.027
Leafy vegetables	1.0(2.0)	0.083	0.083(0.166)	1.32	0.110
Small berries	1.0	0.041	0.041	0.311	0.113
Pome fruit	1.0	0.029	0.029	0.61	0.001
SMPI			0.260(0.426)		0.252

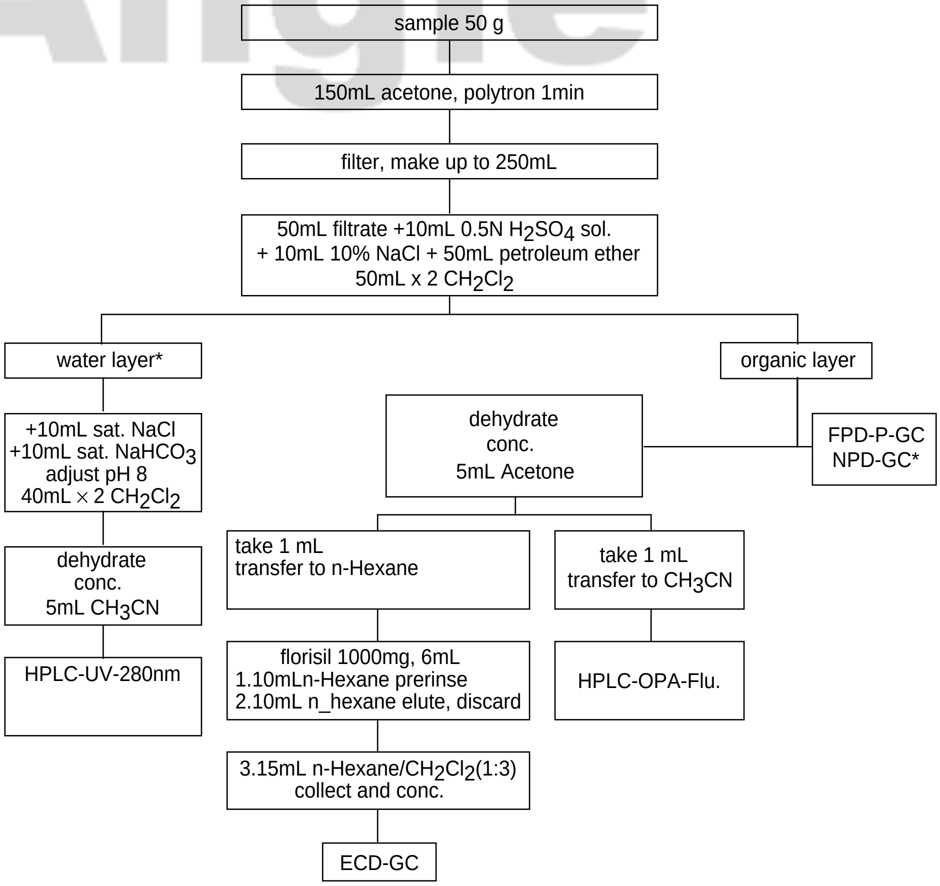
Table 10. Dietary intake risk assessment of dicofol
ADI : 0.002 mg/kg bw/day (FAO, 1992)
MPI: 0.12 mg/person/day (ADI x 60kg)

Crop Group	Tolerance (ppm)	Daily Consumption (kg/day)	Estimate Intake (mg/day)	Actual Residue (ppm)	Actual Intake (mg/day)
Pulses	0.5	0.084	0.042	0.05	0.004
Legume Vegetables	5.0	0.011	0.057	0.5	0.006
Citrus	3.0	0.066	0.198	2.4	0.159
SMPI			0.297		0.169

Table 11. Pesticides analyzed by multi-residue method

	Pesticide name	group	Pesticide		Pesticide name
O.P.	Acephate	Orgeno-	Profenophos	Aromatic nitro	Butachlor
	Azinphos-methyl	phosphorus	Propaphos	compound	Captafol
	Bromophos*		Propaphos-SO		Captan
	Bromophos-ethyl		Propaphos-SO2		Carbendazim
	Cadusafos		Prothiofos		Carpropamid
	Carbophenothion		Pyraclofos		Chinomethionat
	Chlorfenvinphos		Pyrazaphos		Chlorothalonil
	Chlorpyriphos*		Pyridaphenthion		Dichlorfluanid
	Chlorpyrifos-methyl		Quinalphos		Dicloran
	Chlorthiophos		Terbufos		Dicofol
	Cyanofenphos*		Tokuoxon		Dinocap
	Demeton-s-methyl		Triazophos		Endosulfan
	Dialiphos		Trichlorfon		Fenarimol
	Diazinon		Vamidothion		Flufenoxuron
	Dichlorvos	Synthetic	Allethrin		Fluroxypyr
	Dicrotophos	pyrethroid	Alphacypermethrin**		Fthalid
	Dimethoate*		Beta-cyfluthrin		Haloxyfop-methyl
	Dyfoxon		Bifenthrin		Hexaflumuron
	Edifenphos*		Cyfluthrin		Iprodione
	EPN		Cyhalothrin		Isoprothiolane
	Ethion		Cypermethrin		Kresoxim-methyl
	Ethoprophos		Deltamethrin		Linuron
	Etrimfos		Fenpropathrin		Metalaxyl
	Fenamiphos		Esfenvalerate		Metolachlor
	Fenamiphos-sulfon		Fenvalerate		Nuarimol
	Fenchlorphos		Flucythrinate		Oxadiazon
	Fenitrothion		Fluvalinate		Pendimethalin
	Fensulfothion		Permethrin		Procymidone
	Fenthion		Tetramethrin		Pyridaben
	Fonofos		Tralomethrin		Pyrifenox
	Formothion	Triazole	Azafenidin		Teflubenzuron
	Fosthiazate		Bromuconazole		Tetradifon
	Iprobenfos		Cyproconazole		Thiabendazole
	Isazofos		Difenoconazole		Trifluralin
	Isofenphos		Epoxiconazole		Vinclozolin
	Isoxathion		Fenbuconazole		1-naphthal
	Leptophos		RH9129	Carbamate	3-Keto Carbofuran
	Malathion*		RH9130		3-OH Carbofuran
	Mephosfolan*		Flusilazole		Aldicarb
	Methamidophos*		Hexaconazole		Aldicarb sulfone
	Methidathion*		Imibenconazole		Aldicarb sulfoxide
	Mevinphos		Myclobutanil		Bendiocarb
	Monocrotophos*		Paclobutrazole		Butocarboxin
	Naled		Penconazole		Carbaryl
	Omethoate*		Propiconazole		Carbofuran
	Parathion		Tebuconazole		Fenobucarb
	Parathion-methyl*		Tetraconazole		Isoprocarb
	Phenthoate*		Triadimefon		Methiocarb
	Phorate		Triadimenol		Methomyl
	Phosalone	Aromatic nitro	Alachlor		Metolcarb
	Phosdiphen	compound	Aziprotryne		Promecarb
	Phosmet		Bifenox		Propoxur
	Phosphamidon		Bromopropylate		Thiodicarb
	Phoxim		Bupirimate		XMC
	Pirimiphos-methyl		Buprofezin		

fluorescence detection, and HPLC with UV absorption detection. 2-benzimidazole and 4-organonitrogen compounds were subject to extra clean-up steps for fruit samples, before using HPLC-UV. For the triazoles, multi-residue method is shown as a flow chart in Figure 6. Samples are extracted with acetone under basic conditions. The clean-up procedure is the same as used for the first method. The extracts are analyzed by temperature-programmed gas chromatography (GC) with NPD and ECD. A flow chart of the method for pesticide residues on rice is



* Fruit samples only

Figure 5. Multi-residue analysis methods- Applied on fruits and vegetables

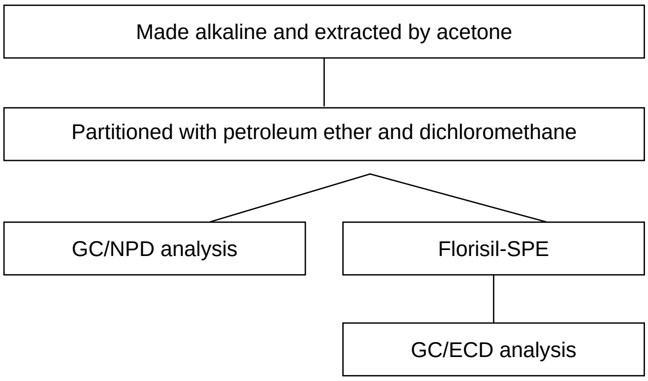


Figure 6. Multi-residues analysis method for triazole pesticides

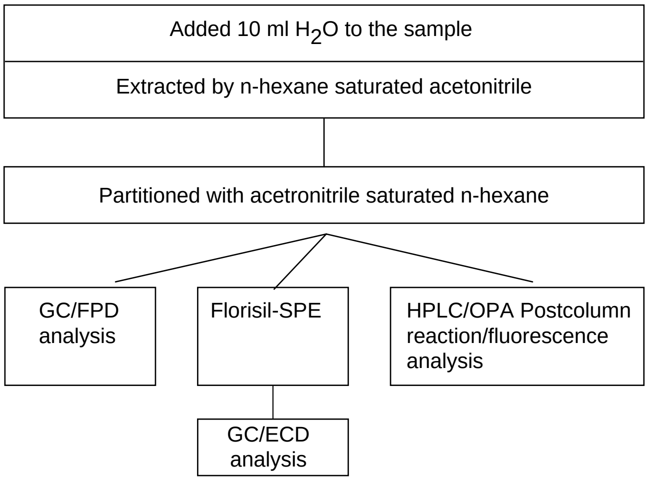


Figure 7. Multi-residue analysis method for rice

shown in Figure 7. Samples are grounded and distilled water is added. The mixed samples are extracted with n-hexane and mixed with acetonitrile. Clean-up is performed using acetonitrile with n-hexane to remove the fat. This is followed by additional clean-up using a Florisil column. The extracts are analyzed by temperature-programmed gas chromatography (GC) with FPD and ECD, and HPLC with OPA post-column reaction.

The average recoveries of 90% of the pesticides studied were in the range of 60% to 120%. The average recoveries of the remaining 10% of the pesticides investigated are below 60%. The detection limits of these pesticides were between 0.001 to 0.5 ppm.

These multi-residue methods are suitable for rapid screening of pesticide residues in a majority of field or market samples. It takes less than four hours to complete the analysis. One person is able to analyze 8 to 10 samples in a batch, quantitatively and qualitatively.

In Taiwan, these three multi-residue methods are the only methods recommended by the authorities for the screening of pesticide residues on crops. The classification of commonly detected pesticides on crops, based on their chemical groups, is shown in Table 12. No other methods, such as ELISA or other enzyme-based methods are suitable or effective for screening a large number of pesticide residues on fresh commodities.

Table 12. Summary of pesticides detected

Commodity	OP*	PY	AN	CA	TR	DT	Total
Rice	6	1	2	7	0	0	16
Fruit	20	10	9	12	13	1	65
Vegetable	14	7	5	8	9	1	44
Total	23	10	10	12	13	1	69

* OP = organophosphorus, PY = synthetic pyrethroid, AN = aromatic nitro compound, CA = carbamate, TR = triazole, DT = dithiocarbamate.

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台灣農藥殘留安全性評估及管制

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摘　要

農藥的使用在維護台灣農業的生產上佔相當重要的地位，農藥殘留對食物的污染及對人體健康的影響因而極受重視。農業藥物毒物試驗所負責推動各項試驗以作為農藥使用的安全評估之依據。根據農藥管理法，農藥准許在田間使用前，該農藥在使用後至作物採收時之間隔時間（最短採摘期）及該農藥在作物上之殘留容許量必需先建立。農藥殘留容許量係依據i) 農藥每日可接受攝食量ii)台灣人民各種作物每天平均取食量及iii) 由田間農藥消退試驗所估算出來採收時作物上的農藥殘留含量等三類資料來綜合研判訂定，農藥殘留容許量必須在准許登記前建立。

蔬果中農藥的殘留受到大眾相當的矚目，農業藥物毒物試驗所在台灣不同地區設立十五個農藥殘留管制工作站，並以多重農藥殘留分析法進行蔬果產品中農藥殘量分析，目前經常在蔬菜中發現的農藥殘留種類已能掌握。農民輔導計畫係依據這些分析結果設計並付諸實施。國民經由農產品之農藥攝食量的風險評估也在持續的基礎下進行，結果顯示消費大眾的農藥殘留攝食量都在安全限量之內。

關鍵詞：農藥、毒性、登記、殘留、監測、水果及蔬菜、危害評估