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Persistence of granular endosulfan in padi-field water and its implications

(Kegigihan butiran endosulfan di dalam air sawah dan implikasinya)

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Key words: bioconcentration, endosulfan isomers and metabolites, endosulfan extraction and determination, padi-field water and fishes

Abstrak

Tahap sisabaki racun serangga endosulfan di dalam air sawah meningkat dengan cepatnya selepas penaburan butiran racun tersebut. Dari tahap 0.04–0.73 μg/L sebelum penaburan, pengeluaran racun dari butiran menyebabkan kepekatan di dalam air bertambah ke tahap 4.71–5.18 μg/L 21 hari selepas penaburan. Implikasi kegigihan racun serangga endosulfan di dalam air sawah dibincangkan dari segi kesannya terhadap ikan, pengambilan harian oleh manusia, keracunan akut dan kronik terhadap manusia sekiranya daging tercemar dimakan dan had sisabaki bagi ikan. Beberapa cadangan bagi mengubah reka bentuk sawah diusulkan supaya penternakan ikan di kawasan sawah dapat dilaksanakan. Apa pun reka bentuk yang diperkenalkan, penilaian semula perlu dibuat sebelum reka bentuk baru digabungkan dengan program pengawalan perosak semasa supaya kemujarapan pengawalan perosak dan hasil tanaman dapat dikekalkan atau ditingkatkan dengan pelaksanaan sistem baru ini.

Abstract

Endosulfan residues in padi-field water increased rapidly after granule application to padi plots. From a pre-application level of 0.04–0.73 μg/L, the movement of endosulfan from granules increased the concentration in water to 4.71–5.18 μg/L at 21 days after application. The implications of endosulfan persistence in padi-field water were discussed in relation to its known effects on fish, acceptable daily intake (ADI), acute and chronic human poisoning if contaminated fish were consumed, and finally, tolerance limit for fish. Several suggestions were proposed to alter existing padi-field designs if padi cultivation using endosulfan and fish culture were to be feasible in the same location. Whatever designs are to be introduced, re-assessment is needed for the incorporation of pest control programmes with the new designs to ensure that efficacy of pest control and crop yield are maintained or improved.

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Introduction

Granular endosulfan is one of the insecticides recommended in padi cultivation primarily for the control of padi stemborers. Its active ingredient consists mainly of two stereoisomers, alpha-endosulfan (70%) and beta-endosulfan (30%) (Anon. 1979), both of which are highly toxic to fish (Maier-Bode 1968). Consequently, its widespread use in padi-fields has brought about many undesirable effects especially large scale fish poisoning and decline in padi-field fishes. For example, contaminated padi-field water from affected area in Tanjong Karang often contained 0.001–0.03 mg/L of alpha-endosulfan, 0.001–0.012 mg/L of beta-endosulfan and occasionally small quantities of their metabolite, endosulfan cyclic sulfate, which ranged from trace quantity to 0.002 mg/L (Lim and Ong 1987). These isomers and their metabolite are of great concern to padi-field fish culture which provides cheap and valuable protein as well as additional income to padi farmers.

Although endosulfan is classified under the group of persistent pesticides known as the cyclodienes, the chemical is not as persistent as others in the same group such as dieldrin, heptachlor and chlordane. It is easily degradable because it has a cyclic sulphite ester which renders the compound liable to hydrolytic detoxification (Brooks 1974). Unlike many chlorinated hydrocarbon insecticides, endosulfan does not accumulate in fat or other tissues of fish (Maier-Bode 1968).

Since endosulfan has low persistence and it hydrolyzes in water to the non-toxic diol (endosulfan alcohol) (Brooks 1974), it can be assumed that with the judicious use of endosulfan and a more integrated approach, there would be potential for padi cultivation and fish culture to be practised together. The persistence of endosulfan in aqueous system had been studied in the past with technical materials and non-granular products (Devi et al. 1981; Swarup et al. 1981), but these materials were studied at lower concentrations and did not reflect the real situations in which endosulfan is used in the country. Granular endosulfan, when applied under padi-field situation, is expected to release its active ingredient into the water at a much slower rate than the emulsifiable concentrate. Consequently, the active ingredient is likely to persist longer in the aquatic environment to pose bioconcentration problem to padi-field fishes. A study was thus initiated in early 1985 to determine the persistence of endosulfan in water of padi-field plots that had been treated with a single application of granules. The purpose was to investigate the possibility of cultivating padi and practising fish culture together by ensuring the appropriate timing of endosulfan application.

Materials and methods

Insecticide application and trial site

The trial was conducted using farmers' plots at three different locations in the Tanjong Karang padi area: Simpang Limau (Plot A), Sungai Leman (Plot B) and Sungai Burong (Plot C). The scheduled harvesting dates for the plots (A, B and C) were early April, mid-April and end of May respectively. Granular endosulfan *(Thiodan 5G)* was applied by hand broadcasting using the current recommended rate of 1.68 kg a.i./ha. Each plot measured approximately 1.21 ha. The three plots were treated at different dates in early 1985 to provide sufficient time for sample collection and to reduce the incidence of overlapping of sampling dates. Plot A contained direct seeded plants of 1 month old and had already been flooded with water. Plot B and Plot C contained plants that had been transplanted 1 month earlier. Water depth in the three plots varied from 30 cm to 90 cm.

Sampling of padi-field water
Padi-field water from each plot was sampled at several time intervals over a 21-day period. Samples were collected from each plot at 1 day before treatment and 1, 5, 7, 14 and 21 days after granule application. Water samples were collected from five points that had been marked earlier. From each sampling point, 2 x 2.5 L of water was collected using a clean amber glass solvent bottle of 2.5-L capacity. The sampling from Plot A began on 15.1.85, Plot B, on 23.1.85 and Plot C, on 14.2.85. Sampling ended on 6.2.85 for Plot A, 15.2.85 for Plot B and 8.3.85 for Plot C. The water samples were transported to Serdang for analysis. The distance between Tanjong Karang and Serdang is 120 km and the travelling time is 2 h. Immediately on arrival, all the water samples were kept in refrigerators until the next day when bulking of samples from each sampling point was carried out, and 2 x 1.0 L subsamples were taken for analysis.

Reagents and solvents
Throughout this study, analar grade hexane (MERCK) was used for extraction. Analar grade anhydrous sodium sulfate powder was used for drying the hexane extracts. Florisil (60–100 mesh size) purchased from Varian Instrument Service Centre was heated overnight at 130–135 °C and cooled before storage in a dessicator. A portion of it was taken out for deactivation with water before weighed amounts were transferred into the Florisil column.

Analytical standards
Alpha-Endosulfan, beta-endosulfan and endosulfan cyclic sulfate of purity >99.0% were obtained from Hoescht Malaysia. All the standard solutions were prepared using hexane as the solvent.

Chemical assay of granular endosulfan
Thiodan 5G was subsampled and analysed for total endosulfan content (both isomers) to ensure that the respective isomers of the active ingredient were present in the required quantity for corret rate application.

Extraction of endosulfan residues from padi-field water
Since endosulfan hydrolyses in water, it is expected that the water samples collected would contain the diol (endosulfan alcohol) in significant amounts. The diol, however, is not toxic to fish and was not included in the present study. Endosulfan sulfate was not expected in the water samples but because past monitoring of contaminated water from padi-fields demonstrated the presence of this metabolite (Lim and Ong 1987), its determination was included in the present study. All the water samples collected were, therefore, analysed for alpha-endosulfan, beta-endosulfan and endosulfan sulfate.

The extraction method used was modified from the method of Zweig and Sherma (1972). Water sample was transferred into a 1-L separatory funnel. The side of the bottle was rinsed with 25 mL of hexane by shaking and rolling the bottle and the rinsate was transferred into the separatory funnel. The subsample bottle was rinsed twice. The separatory funnel containing solvent and water was vigorously shaken for 1 min. The contents were allowed to separate and the aqueous layer collected in a clean beaker. The remaining hexane layer was drained into a conical flask. Extraction of the aqueous layer was repeated twice and the hexane extract collected was passed through a sodium sulphate (anhydrous) column of 4.0 cm high. Rotary evaporation was used to concentrate the dried hexane to ca 10 mL and later by nitrogen stream evaporation to 2–5 mL after transferring from the conical flask to a graduated tube. The concentrated extract was transferred to a *Florisil* column for cleanup.

Florisil cleanup of hexane extract
The *Florisil* column contained 25 g of 4% deactivated *Florisil* topped with 1–2 cm of sodium sulfate, anhydrous.Transfer of *Florisil* and sodium sulfate was made using the slurry method. The column was rinsed with 50 mL of hexane before introducing the hexane sample extract. Three 2-mL portions of rinse from the sample extract container were also added onto the *Florisil* column.

Elution was performed using 200 mL of dichloromethane + hexane (20 + 80 by volume), followed by 200 mL acetonitrile + dichloromethane + hexane (0.35 + 50 + 50 by volumes). Each eluate was collected and concentrated by rotary evaporation to about 5–10 mL, and transferred to a graduated tube for dilution up to the 10-mL mark.

Gas-liquid chromatography analysis of endosulfan residues
The cleaned up samples were quantitatively analysed by a Varian 2100 gas-liquid chromatograph using a glass column packed with 4% SE-30 + 6% QF-1 on Chromosorb W A/W DMCS (80–100 mesh), with a Nickel-63 heated electron-capture detector. The gas-liquid chromatograph was operated under the following conditions: column temperature, 180 °C; injector temperature, 190 °C; detector temperature, 200 °C; carrier nitrogen gas flow rate, on flow meter scale, 18 divisions (ca 60 mL/min).

Confirmation of the endosulfan residues by qualitative analysis was carried out by using another glass column packed with 5% DC-200 on Chromosorb W A/W (60–80 mesh). Operating conditions used for this packed column were the same as those used for the SE-30 + QF-1 packed column.

Column temperatures of the two packed columns were varied between 175 °C and 200 °C to obtain data on retention times under different temperature conditions. The aim of varying the column temperature was to confirm further the endosulfan residues extracted.

Results

Active ingredient content in Thiodan 5G
The granular product contained 7.53–7.87% of endosulfan (both isomers). These values were higher than the stated value of 5%. Concentration of alpha-endosulfan varied from 5.50–5.63% while the beta-endosulfan from 1.90–2.37%. The ratio of alpha-endosulfan calculated was 3.6:1. No endosulfan sulfate was detected.

Efficiency of extraction and clean-up procedure
The modified method of Zweig and Sherma (1972) gave good recovery of endosulfan residues. Samples of untreated padi-water spiked at various concentrations encountered throughout the trial gave mean recoveries of 105, 95 and 97% for alpha-endosulfan, beta-endosulfan and endosulfan cyclic sulfate respectively.

Residue concentrations in padi-field water
Endosulfan residues present in padi-field water that were sampled over a 21-day period are presented in *Table 1* to *Table 3*. These residue values did not take into account residue loss during transportation from Tanjong Karang to Serdang. The total endosulfan residue values *(Table 1* to *Table 3)* represent the sum of alpha-endosulfan, beta-endosulfan and endosulfan sulfate residues, all of which are known to be toxic to fish.

Results from *Table 1* to *Table 3* demonstrated that endosulfan residues were present at very low levels in water at pre-application and these levels were unlikely to be detrimental to fish. Endosulfan residue levels in water were 0.05 ppb (parts-per-billion) in Plot A, 0.04 ppb in Plot B and 0.73 ppb in Plot C. The first two values were below the

Table 1. Endosulfan residues in padi-field water, Plot A+, Simpang Limau, Tanjong Karang, 1985

Days after application (DAA)	Concentration in water μg/L (ppb)‡						
	alpha-Endosulfan		beta-Endosulfan		Endosulfan cyclic sulfate		Total
	Mean	Range	Mean	Range	Mean	Range	
−1	0.015 ± 0.018	ND−0.042	0.010 ± 0.015	ND−0.034	0.02 ± 0.04	ND−0.08	0.05
1	0.49 ± 0.59	0.06−1.51	0.08 ± 0.08	ND−0.17	0.02 ± 0.03	ND−0.07	0.59
5	2.73 ± 3.76	0.04−9.20	0.74 ± 0.09	0.03−2.40	0.69 ± 0.77	0.12−2.0	4.16
7	0.99 ± 0.62	0.16−1.75	0.39 ± 0.19	0.11−0.63	0.79 ± 0.36	0.32−1.30	2.17
14	1.12 ± 0.87	0.03−2.35	0.57 ± 0.48	0.04−1.30	1.34 ± 1.27	0.04−3.41	3.03
21	2.30 ± 2.24	ND−5.25	0.69 ± 0.72	0.35−1.70	1.72 ± 1.46	ND−3.43	4.71

+Plot size is 1.21 ha
‡Values expressed as average of 10 analyses from 5 sampling points
ND = not detectable

Table 2. Endosulfan residues in padi-field water, Plot B+, Sungai Leman, Tanjong Karang, 1985

Days after application (DAA)	Concentration in water μg/L (ppb)‡						
	alpha-Endosulfan		beta-Endosulfan		Endosulfan cyclic sulfate		Total
	Mean	Range	Mean	Range	Mean	Range	
−1	0.01 ± 0.02	ND−0.06	0.01 ± 0.029	ND−0.06	0.02 ± 0.05	ND−0.11	0.04
1	4.98 ± 3.11	1.43−8.35	3.03 ± 1.59	1.02−4.80	0.52 ± 0.27	0.27−0.95	8.53
5	4.23 ± 2.21	1.29−6.67	2.99 ± 1.46	1.10−4.38	2.35 ± 1.43	0.50−3.78	9.57
7	2.46 ± 1.46	0.63−4.16	2.09 ± 1.29	0.62−3.32	3.36 ± 2.63	0.15−5.77	7.91
14	1.24 ± 0.84	0.34−2.60	0.59 ± 0.38	0.18−1.18	3.15 ± 1.36	1.74−4.90	4.98
21	1.06 ± 0.62	0.28−1.85	0.99 ± 0.55	0.35−1.75	3.11 ± 1.95	0.48−6.0	5.16

+Plot size is 1.21 ha
‡Values expressed as average of 10 analyses from 5 sampling points
ND = not detectable

Table 3. Endosulfan residues in padi-field water, Plot C+, Sungai Burong, Tanjong Karang, 1985

Days after application (DAA)	Concentration in water μg/L (ppb)‡						Total
	alpha-Endosulphfan		beta-Endosulfan		Endosulfan cyclic sulfate		
	Mean	Range	Mean	Range	Mean	Range	
−1	0.65 ± 0.54	ND−0.43	0.08 ± 0.17	ND−0.34	Trace	ND−trace	0.73
1	5.18 ± 1.30	3.35−6.75	3.03 ± 0.89	2.13−4.0	1.98 ± 1.08	0.38−3.05	10.19
5	2.76 ± 0.73	1.60−3.38	1.97 ± 0.42	1.25−2.25	4.11 ± 1.79	2.25−6.20	8.84
7	2.25 ± 1.54	0.53−4.42	1.59 ± 1.03	0.70−3.20	6.19 ± 2.39	2.93−8.75	10.03
14	1.39 ± 0.99	0.18−2.70	1.03 ± 0.42	0.56−1.55	5.77 ± 2.36	3.44−9.50	8.19
21	1.05 ± 0.81	0.35−2.25	0.93 ± 0.39	0.38−1.38	3.20 ± 1.14	1.56−4.68	5.18

+ Plot size is 1.21 ha
‡ Values expressed as average of 10 analyses from 5 sampling points
ND = not detectable

0.00009 mg/L (or 0.09 ppb) level, a permissible level calculated from the 96-h LC50 value of 0.009 mg/L (Ong 1981) using a safety factor of 100 (Anon. 1968). The LC50 value was determined in aquarium using the common padi-field fish, Sepat Ronggeng, *Trichogaster trichopterus* (Pallas) under static flow conditions.

In areas where prawns and shrimps were to be cultured, permissible levels have to be lower than the 0.09 ppb limit as these organisms are more sensitive to endosulfan than Sepat Ronggeng. In the U.S.A., authorities recommended that environmental levels of endosulfan in fish areas may not rise above 0.05 μg/L (0.05 ppb). This value was calculated using a safety factor of 100, based on the assumption that endosulfan is acutely toxic to wildfile organisms including shrimps at concentrations of 5 μg/L (Anon. 1968). In padi fields, permissible levels can be raised if more tolerant species are introduced for culture.

Residues that were present in water at pre-application may have originated from applications on crop cultivated in the previous season. These values probably represent the overall situation of water in padi-fields in Tanjong Karang at pre-application.

Contamination of water by endosulfan after granular application appeared to be rapid *(Table 1* to *Table 3)*. From a pre-application level of 0.04−0.73 ppb, residues in water increased rapidly to 0.59−10.19 ppb at 1 day after application (DAA). With increasing DAA up to 21 DAA, total endosulfan residues in water did not decline significantly. At 21 DAA, endosulfan level was still at 4.71 ppb in Plot A, 5.16 ppb in Plot B and 5.18 ppb in Plot C. Water from Plot B and Plot C appeared to exhibit a declining residue trend for both isomers but the same trend was not noticeable in Plot A where concentration levels of both isomers were

maintained throughout the trial. Data indicated that endosulfan sulfate levels increased immediately after application. Towards the end of the 21 DAA, there was evidence that levels were starting to decline as demonstrated by Plot B and Plot C. However, in Plot A, the overall flower residue levels possibly indicated that these levels were in the flat portion of the degradation curve which explained why the decline in endosulfan isomers and endosulfan sulfate was not apparent.

Overall results indicated that endosulfan when applied as granules did not distribute uniformly in water. The wide variation in residue concentrations at designated sampling points were demonstrated by high standard deviation values *(Table 1* to *Table 3)*.

At 21 DAA, total endosulfan levels in water were still in the 4.71–5.18 ppb range and had not declined to the pre-application level of 0.04–0.73 ppb. The slow disappearance of endosulfan residues after granular application implied that fish species introduced are likely to be exposed to its toxic action.

Discussion

Based on theoretical considerations, endosulfan sulfate should not be present in padi-field water as endosulfan was known to decompose through slow hydrolysis when exposed to water, forming sulfur dioxide and non-toxic endosulfan alcohol (Brooks 1974). However, results from the present study showed that toxic endosulfan sulphate was present, giving rise to speculation that mild oxidation of endosulfan must have occurred. This observation confirmed the previous findings when endosulfan sulfate was occasionally found to be present in padi-field water (Lim and Ong 1987) after endosulfan application by farmers using emulsifiable concentrates. However, the levels of endosulfan sulfate, whenever detected, were lower than levels detected in this study. It is difficult at this stage to identify factors that contribute to oxidation of endosulfan but the rapid appearance of endosulfan sulfate in water implied that chemical oxidation played an important role.Since the pH of water from the trial plots were in the range of 4.0 to 5.9, the aquatic environment must be indicative of oxidizing conditions (Ponnamperuma 1972, 1977), exhibiting redox potential values (Eh) in the range of 80 to >265 mV (Ahmad, A. R., MARDI, Serdang, pers. comm. 1988). Consequently, it can be assumed that transient oxidants, especially free radicals ($RO_2^{\cdot}$) and singlet oxygen ($^1O_2$) must have been formed from humic materials under photolytic conditions (Mill et al. 1980) to chemically oxidize endosulfan to endosulfan sulfate at the sulfite position. Transient oxidants are very reactive and support the proposition that endosulfan is transformed to the sulfate through chemical oxidation rather than photoxidation (Maier-Bode, 1968; Archer et al. 1972; Putnam et al. 1975). Enzymatic action of microbes could contribute to the transformation to endosulfan sulfate (Martens 1976), but the process is too slow to explain the rapid appearance of endosulfan sulfate (Miles and Moy 1979). Nevertheless, microbes are an important factor as they are capable of transforming endosulfan to the sulfate under both aerobic and anaerobic soil conditions (Martens 1977). As oxygen is being removed for oxidation, the redox potential of soil and water would decline and the aquatic environment becomes more alkaline to encourage hydrolysis (Martens 1976; Miles and Harris 1978; Rao and Murty 1980) to the diol and eventually to endosulfan alpha-hydroxyether (Martens 1976). Since water in the trial plots is always flowing, anaerobic conditions are not likely to arise.

The wide variation in endosulfan residue levels at any one sampling time implied that after granular application,

the movement of endosulfan from granules to water did not occur uniformly. The overall results appeared to show that endosulfan was released into water slowly after an initial rapid increase in endosulfan concentration in padi-field water. The slow release must have resulted in the residue levels being maintained at about the same level throughout the 21 days. Either the low water solubility of endosulfan (20 mg/L) or the continuous water flow existing in the padi plots or both in combination (Brooks 1974) may have contributed to endosulfan residues being maintained at levels not exceeding 10.2 ppb.

If endosulfan residues persist in padi-fields in the same manner as encountered in the trial, bioconcentration problem in fish will arise. Residues from the aquatic environment will be taken in rapidly through their gills from water and bioconcentrated to reach toxic levels in tissues resulting in mortality. Bioconcentration of endosulfan residues had been observed in a local species of padi-field catfish after endosulfan application to a padi crop using emulsifiable concentrates (Lim and Ong 1987). The catfish known to farmers as 'Ikan Lundu' are capable of bioconcentrating alpha-endosulfan and beta-endosulfan from water very rapidly. Fish samples taken from an affected area revealed that alpha-endosulfan and beta-endosulfan were bioconcentrated 423.6 and 275.0 times respectively (Lim and Ong 1987). Chemical assay of contaminated water indicated 0.01 mg/L of alpha-endosulfan and 0.0056 mg/L of beta-endosulfan (Lim and Ong 1987). The metabolite endosulfan sulfate was occasionally detected up to a level of 0.002 mg/L. In whole fish collected just before mortality occurred, residues determined were alpha-endosulfan, 4.66 mg/kg, ww (wet weight) and beta-endosulfan, 1.54 mg/kg, ww (Ong 1982).

In aquarium studies with 'Sepat Ronggeng', exposure to water containing 0.00375 mg/L of endosulfan resulted in bioconcentration 0.23 mg/kg of alpha-endosulfan and 0.16 mg/kg of beta-endosulfan in whole fish tissues (Lim and Ong 1987) sampled from fish collected just before mortality occurred. The same tissues were found to contain 0.26 mg/kg of endosulfan sulfate metabolite, giving a total endosulfan residues of 0.65 mg/kg. The ratio of total endosulfan residue level in whole fish:water was determined to be 173.3. 'Sepat Ronggeng' is generally considered more tolerant to endosulfan than 'Ikan Lundu' and 'Sepat Siam', *Trichogaster pectoralis* (Regan), another food species. Thus, this implies that padi-field fishes under field conditions tolerated a heavier dosage before mortality occurred.

The average level of endosulfan residues in water from padi-field plots in this study was 5.02 μg/L (ppb) at the end of 21 DAA. Assuming that the residue ratio in whole fish:water is the same (i.e. 173.3), it can be deduced that 'Sepat Ronggeng', if introduced into the trial plots, would accumulate 869.97 μg/kg (or 0.87 mg/kg) of endosulfan residues. At this concentration, 'Sepat Siam', would either suffer mortality or lethargy. Studies with the carp, *Channa punctata*, demonstrated that exposure to endosulfan (technical) at as low a concentration range of 3.5–6.5 μg/L in water led to decrease in protein, glycogen and lipid concentration in tissues (Murty and Devi 1982). Significant biochemical changes induced by pesticides may be more hazardous and could reduce growth rate and fecundity. Assimilation of food and survival of eggs and embryos will be affected and consequently the behaviour of fish thus rendering the species more susceptible to attack by predators.

It is possible that endosulfan contaminated fish which survived are harvested by farmers for food or sold in

the market. It is important to evaluate this by taking into consideration the acceptable daily intake (ADI) of 0.008 mg/kg recommended by FAO/WHO (Anon. 1985). Assuming a normal person weighs 70 kg and consumes 1 kg of endosulfan contaminated fish a day, his acceptable intake would be 0.56 mg endosulfan per day. Dead padi-field fish from endosulfan poisoning have been found to contain 6.00–7.29 mg/kg of endosulfan residues (Ong 1982) and if 1 kg of this contaminated meat is consumed, the endosulfan intake would be in the range of 6.00–7.29 mg/day. This level of intake would far exceed the level of 0.56 mg recommended by FAO/WHO. However, the chances of acute and chronic human poisoning resulting from consumption of contaminated meat are small when toxicological data such as 'no-toxic effect' levels and LD50 values are considered. The 'no-toxic effect level' for endosulfan is 2.5 mg/kg per day in rats and 0.75 mg/kg per day in dogs (Anon. 1985). The acute oral LD50 level in rat is 80–110 mg technical (in oil)/kg (Anon. 1979) which implies that a great deal of meat need to be consumed to reach toxic levels. However, a 0.2 mg/kg tolerance limit for endosulfan in fish is stipulated in the U.S.A. and this mandates that anyone selling fish containing in excess of this limit will be liable to prosecution.

As demonstrated by the data from *Table 1* to *Table 3*, the present design for padi cultivation would present problems for farmers who intend to keep fish in their padi plots. Existing design needs to be altered if padi cultivation using endosulfan and fish culture are to be carried out in the same place. Several systems are possible to overcome the toxic action of endosulfan. The first system can comprise padi plots which are made deeper (up to 4–5 feet) to provide more water for dilution. It is necessary for this system to incorporate the use of taller padi varieties that adapt quickly to changing water levels. The adoption of this design may present problems as granules had been known to be ineffective against insect pest under situations when water level is high (Lim, G. S., MARDI, Serdang, pers. comm. 1989), suggesting that other chemicals or formulations need to be evaluated for use. The second system would require the construction of fish ponds or ditches near to padi plots to separate fish from contaminated areas to avoid exposure to toxic action of endosulfan. The third design would be to make use of faster flow in padi plots to dilute and remove contaminants quickly. When endosulfan residue levels are expected to be high, fish can be transferred using water flow to a temporary pond. When residues have dropped to acceptable levels, the fish are re-introduced into the padi plots. This strategy is likely to increase insecticide loss which may decrease the efficacy of insecticide application. Additionally, the implementation of this change requires a great deal of labour input which may not be attractive to farmers. Of the three strategies considered, the second alternative appears to be more promising.

In adopting new designs, further research is needed to study their influence on the efficacy of present insect control procedures. New recommendations on insecticide usage are needed if current control programmes become less effective.

As endosulfan is easily biodegraded in fish tissues, contamination of fish at the tolerance limit of 0.2 mg/kg may be acceptable at the farm level if the degree of contamination does not affect fish yield negatively. Harvested fish can be transferred to a specially built pond containing clean water for a specified period to allow endosulfan in fish tissues to decline before their despatch to the market. If this is feasible, more tolerant species could be selected for culture and market sized fish could be transferred to a

clean pond for dissipation of endosulfan residues to ensure that residues in fish tissues are below the specified tolerance limit before they reach the market. Endosulfan residues in fish tissues were known to decline rapidly when contaminated fish were transferred into clean water (Schimmel et al. 1977).

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