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【Scientific note】

# 水田模擬生態系統評估農藥代謝之可行性【科學短訊】

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## Abstract

## 摘要

水稻是本省主要的糧食作物，品質的提高，產量的增加為當務之急，因此在有效的害蟲管制方法發展成功以前，農藥的使用仍為無可避免的。本省自1952年至1978年農藥的消耗額由每年二百萬元台幣增加至廿五億元台幣，如此大量的農藥投入農田中而其對環境的影響卻知之有限，這些問題極須加以研究則對農林保護及環境的安全均有相當意義。 1971年Metcalf首先創立模擬生態系統作為評估農藥安全度的方法。茲經修正其中生物相及理化因子以適合本省水稻田條件並利用放射性標誌之殺蟲劑施入模擬生態系統中，經過一段時間再分析食物鏈中，農藥代謝產物的分佈。食物鏈中包括：水稻(Oryza sativa indica)，小稻蝗(Oxya intri-cata)，褐飛蝨(Nilaparvata lagens)，狼蛛(Lycosa pseudoannul-ata)，藻(Oedogonium cardiacum)，浮萍(Spirodela polyrrhiza)，田螺(Cipangopaludina chinensis)，水蚤(Daphnia pulex)，蚊幼蟲(Culex P. fatigans)，大肚魚(Gambusia affinis) 藉這些生物對滴滴涕、靈丹、阿特靈、地特靈、在此模擬生態系統中進行檢定。其結果發現，有機殺蟲劑非常安定，具高度的生物蓄積作用及低度的生物分解指數。 (1)DDT於此生態系中代謝成之DDE佔57.8 %，DDD佔7.74 %，極性代謝物佔2.62 %，仍以原來形態存在的DDT佔32.47 %。魚體內所含之DDE佔全部DDE之42.91 %，DDD佔75.6 %。DDT於魚的生態加成值為(88,273.33)〉浮萍(36,363.33)〉田螺(36,173.33)〉水藻(21,672.67)〉蚊(10,139.33)。生物分解指數蚊(0.198927)〉浮萍(0.022103)〉大肚魚(0.015834)〉田螺(0.011066)。 (2)Aldrin於此生態系中代謝後Dieldrin佔83.76 %，僅有少部份之阿特靈11.3 %仍以原狀存在，9-Hydroxy-dieldrin佔0.86 %，9-ke-toaldrin佔0.71 %，二種未鑑識物之代謝物Rf = 0.62及Rf = 0.08共佔3.01 %，生態加成值大肚魚4,495.19〉水藻1,802.88〉田螺1,649.17〉浮萍841.35，生物分解係數田螺0.007499〉水藻0.001348〉浮萍0.001106〉大肚魚0.000223。 (3)79.82 %之Dieldrin仍保持原來形態，9-Hydroxydieldrin佔11.28 %，2.69 %轉變成9-Ketodieldrin，Rf = 0.4之一種未鑑定物佔5.15 %，生態加成值田螺(2,128.57)〉大肚魚(1,900.02)〉水藻(274.29)〉浮萍(240.00)。生物分解指數，浮萍(0.224792)〉水藻(0.01159)〉田螺(0.008437)〉大肚魚(0.001193)。 (4)γ-HCH主要代謝物是Pentachlorocyclohexane佔29.89 %，以原狀存在之γ-HCH有64.8 %，三種未鑑定物共佔2.749 %，生態加成值大肚魚(1,475)〉田螺(967.10)〉水藻(451.20)〉浮萍(0)。生物分解指數，浮萍(0.669924)〉水藻(0.045878)〉大肚魚(0.034529)〉田螺(0)。 (5)加保利於模擬生態系統結果分析中，發現2.22 %之加保利，3.39 %之4-Hydroxycarrbaryl，1.15 % 5- Hydroxycarrbaryl，2.39 %之N-Hydroxycarbaryl，1.12 %之5.6-Dihydroxycarbaryl及89.72 %之水溶性物質。生態加成值除於狼蛛及蟲外於所有生物中皆趨於零。生物分解指數：水藻(98.629032)〉浮萍(73.142857)〉田螺(4.425966)〉魚(1.507937)。 (6)治滅蝨於此模擬生態系統結果分析中，發現0.5 %之治滅蝨，0.59 %之3-Carboxyphenylcarbamate，0.29 %之3-Hydroxymethylphenyl-N-methyl carbamate，2.25 %之4-Hydroxy-3-methylphenyl-N-methyl carbamate0.4 %之3-Methylphenyl-N-hydroxymethyl Car-bamate及95.89 %之水溶性物質。生態加成值除於狼蛛及蟲外於所有生物中皆趨近於零。生物分解指數：水藻(180.464286)〉田螺(88.595041)〉浮萍(81.538462)〉魚(44.2607001)。 (7)巴拉松於此模擬生態系統結果分析中，發現33.94 %之巴拉松，20.7 %之p-Nitrophenol，2.4 %之Unknown 1 (Rf = 0.33)及1.62 %之Par-aoxon及41.26 %之水溶性物質。生態加成值：魚(37.7)〉浮萍(0.67)〉水藻(0.5)。生物分解指數：魚(0.914226)〉水藻(0.757576)〉浮萍(0.6)。 (8)馬拉松於此模擬生態系統中，結果分析發現22.53 %之馬拉松，33.65 %之Malaoxon，0.71 %之Malathion dicarboxylic acid 及43.11 %之水溶性代謝物質。除狼蛛及蝗蟲外於所有生物中其生態加成值皆趨近於零。生物分解指數：魚(60)〉水藻(2.45)〉浮萍(2.05)。 比較模擬生態系統中及田間的資料可知利用此水田生態模擬系統配合同位素技術以研究本省農藥在田間代謝情形及評估農藥的安全性是可行而且可靠。

Key words:
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# THE COMPATIBILITY OF A RICE PADDY MODEL ECOSYSTEM TO EVALUATE THE DEGRADABILITY OF THE PESTICIDES

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## ABSTRACT

Rice is the major crop plant in Taiwan, the maintaining of its quality and quantity is very important. For this reason, it is necessary to use chemical agents to control the rice pest before the other effective pest management method is established. For many years a huge quantities of pesticides have been introduced to the rice paddy field by farmers, but we are in ignorance of the fate of the pesticides in the rice paddy field. The value of pesticides used has risen from NT$2 million in 1952 to NT$2.5 billion in 1978. This enormous increase of pesticide consumption in Taiwan needs to be investigated to determine its effect on the quality of the environment.

The model ecosystem developed by Metcalf et al. (1971) was modified by changing organisms associated with the food chains to fit rice paddy conditions, and the fate of radiolabeled insecticides in the modified model ecosystem was examined. The radiolabled products were transfered through the food chains, e.g., rice (*Oryza sativa* indica), grasshopper (*Oxya intricata*), brown planthopper (*Nilaparvata lugens*), wolf spider (*Lycosa pseudoannulata*), alga (*Oedogonium cardiacum*), duckweed (*Spirodela polyrrhiza*), snail (*Cipangopaludina chinensis*), water flea (*Daphnia pulex*), mosquito fish (*Gambusia affinis*). The distribution and fate of eight 14C radiolabeled insecticides DDT, r-HCH, aldrin, dieldrin; malathion, parathion; carbaryl, MTMC were evaluated in a laboratory rice paddy model ecosystem.

1. The fate of DDT in this ecosystem, 57.8% of DDE, 7.74% of DDD, 2.62% of polar metabolites and 32.47% of unchanged DDT were found. 42.91%, 39.67%, and 75.6% of DDE, DDT and DDD of each were in fish/total metabolites. Ecological magnification: Fish (88,273.33) > Duckweeds (36,363.33) > Snail (36,173.33) > Algae (21,672.67) > Mosquito (10,139.33). Biodegradability index: Mosquito (0.198927) > Duckweeds (0.022103) > Fish (0.015834) > Algae (0.011335) > Snail (0.011066).
2. The fate of aldrin in this ecosystem, 83.76% of dieldrin, 0.86% of 9-hydroxydieldrin, 0.71% of 9-ketoaldrin, 3.01% of two unknown metabolites Rf = 0.62, 0.08 and 11.3% of unchanged aldrin were found. Ecological magnification: Fish (4,495.19) > Algae (1,802.88) > Snail (1,649.17) > Duckweeds (841.35). Biodegradability index: Snail (0.007499) > Algae (0.001348) > Duckweeds (0.001106) > Fish (0.000223).
3. The fate of dieldrin in this ecosystem, 79.82% of unchanged dieldrin, 11.28% of 9-hydroxydieldrin, 2.69% of 9-ketodieldrin and an unknown metabolite (Rf = 0.4), 5.15% were fond. Ecological magnification: Snail (2,128.57) > Fish (1,900.02) >

Algae (274.29) > Duckweeds (240). Biodegradability index: Duckweeds (0.224792) > Algae (0.01159) > Snail (0.008437) > Fish (0.001193).

4. The fate of r-HCH in this ecosystem, 29.89% of pentachlorocyclohexane, 2.749% of three unknown metabolites Rf = 0.28, 0.14, and 0.09 ; and 64.8% of unchanged r-HCH were found. Ecological magnification: Fish (1475) > Snail (967.1) > Algae (451.2) > Duckweeds (0). Biodegradability index: Duckweeds (0.669924) > Algae (0.045878) > Fish (0.034529) > Snail (0).
5. The fate of carbaryl in this ecosystem, 2.22% of carbaryl, 3.39% of 4-hydroxycarbaryl, 1.15% of 5-hydroxycarbaryl, 2.39% N-hydroxycarbaryl, 1.12% of 5.6-dihydroxycarbaryl and 89.72% of polar metabolites were found. 2.64%, 16.98%, 7.97%, 12.29% and 60.13% of 4-hydroxycarbaryl, 5-hydroxycarbaryl, N-hydroxycarbaryl, 5.6-dihydroxycarbaryl and 60.13% of each were in fish/total metabolites. Ecological magnification almost in all organisms are zero except wolf spider and grasshopper. Biodegradability index: Algae (98.629032) > Duckweeds (73.142857 > Snail (4.425966) > Fish (1.507937).
6. The fate of MTMC in this ecosystem, 0.5% of MTMC, 0.59% of 3-carboxyphenyl-carbamate, 0.29% of 3-hydroxymethylphenyl-N-methyl carbamate, 2.25% of 4-hydroxy-3-methylphenyl-N-methyl-carbamate, 0.4% of 3-methylphenyl-N-hydroxy-methylcarbamate and 95.89% of polar metabolites. Ecological magnification almost in all organisms are zero except wolf spider and grasshopper. Biodegradability index: Algae (180.464286) > Snail (88.595041) > Duckweeds (81.538462) > Fish (44.2607001).
7. The fate of parathion in this ecosystem, 33.94% of parathion 20.7% of *p*-nitrophenol, 2.4% of unknown I (Rf = 0.33), 1.62% of paraoxon and 41.26% of polar metabolites were found. 41.2%, 10.97%, 0.07% and 47.76% of parathion, p-nitrophenol, unknown I, paraoxon and polar metabolites of each were in fish/total metabolites. Ecological magnification: Fish (37.7) > Duckweeds (0.67) > Algae (0.5). Biodegradability index: Fish (0.914226) > Algae (0.757576) > Duckweeds (0.6).
8. The fate of malathion in this ecosystem, 22.53% of malathion, 33.65% of malaoxon, 0.71% of malathion dicarboxylic acid and 43.11% of polar metabolites were found. 1.49% and 98.36% of malaoxon and polar metabolites of each were in fish/total metabolites. Ecological magnification almost in all organisms are zero except wolf spider and grasshopper. Biodegradability index: Fish (60) > Algae (2.45) > Duckweeds (2.05).

Organochlorine insecticides were relatively stable under the rice paddy model ecosystem conditions and was bioconcentrated and stored over a 30-day period in the tissue of the organisms. The high values for ecological magnification and the low biodegradability indices for the organochlorine pesticides are in significant contrast to the low ecological magnification values and high biodegradability indices found with organophosphorus and carbamate insecticides.

The rice paddy model ecosystem technology, with the use of radiolabeled insec-

ticides, is the most convenient tool for studying the fate and environmental effects of pesticides to be used in rice paddies and this technology can be used in every laboratory.

# 水田模擬生態系統評估農藥代謝之可行性

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水稻是本省主要的糧食作物，品質的提高，產量的增加爲當務之急，因此在有效的害蟲管制方法發展成功以前，農葯的使用仍爲無可避免的。本省自1952年至1978年農葯的消耗額由每年二百萬元台幣增加至廿五億元台幣，如此大量的農葯投入農田中而其對環境的影響却知之有限，這些問題亟須加以研究則對農林保護及環境的安全均有相當意義。

1971年Metcalf首先創立模擬生態系統作爲評估農葯安全度的方法。茲經修正其中生物相及理化因子以適合本省水稻田條件並利用放射性標誌之殺蟲劑施入模擬生態系統中，經過一段時間再分析食物鏈中，農葯代謝產物的分佈。食物鏈中包括：水稻(*Oryza sativa indica*)，小稻蝗(*Oxya intricata*)，褐飛蝨(*Nilaparvata lagens*)，狼蛛(*Lycosa pseudoannulata*)，藻(*Oedogonium cardiacum*)，浮萍(*Spirodela polyrrhiza*)，田螺(*Cipangopaludina chinensis*)，水蚤(*Daphnia pulex*)，蚊幼蟲(*Culex P. fatigans*)，大肚魚(*Gambusia affinis*)藉這些生物對滴滴涕、靈丹、阿特靈、地特靈、在此模擬生態系統中進行檢定。其結果發現，有機殺蟲劑非常安定，具高度的生物蓄積作用及低度的生物分解指數。

(1) DDT於此生態系中代謝成之DDE佔57.8%，DDD佔7.74%極性代謝物佔2.62%，仍以原來形態存在的DDT佔32.47%。魚體內所含之DDE佔全部DDE之42.91%，DDT佔39.67%，DDD佔75.6%。DDT於魚的生態加成值爲(88,273.33)＞浮萍(36,363.33)＞田螺(36,173.33)＞水藻(21,672.67)＞蚊(10,139.33)。生物分解指數蚊(0.198927)＞浮萍(0.022103)＞大肚魚(0.015834)＞水藻(0.011335)＞田螺(0.011066)。

(2) Aldrin於此生態系中代謝後Dieldrin佔83.76%，僅有少部份之阿特靈11.3%仍以原狀存在，9-Hydroxy-dieldrin佔0.86%，9-ketoaldrin佔0.71%，二種未鑑識物之代謝物Rf＝0.62及Rf＝0.08共佔3.01%，生態加成值大肚魚4,495.19＞水藻1,802.88＞田螺1,649.17＞浮萍841.35，生物分解係數田螺0.007499＞水藻0.001348＞浮萍0.001106＞大肚魚0.000223。

(3) 79.82%之Dieldrin仍保持原來形態，9-Hydroxydieldrin佔11.28%，2.69%轉變成9-Ketodieldrin，Rf＝0.4之一種未鑑定物佔5.15%，生態加成值田螺(2,128.57)＞大肚魚(1,900.02)＞水藻(274.29)＞浮萍(240.00)。生物分解指數，浮萍(0.224792)＞水藻(0.011159)＞田螺(0.008437)＞大肚魚(0.001193)。

(4) r - HCH 主要代謝物是 Pentachlorocyclohexane 佔 29.89 %，以原狀存在之 r-HCH 有 64.8 %，三種未鑑定物共佔 2.749 %，生態加成值大肚魚（1,475）＞田螺（967.10）＞水藻（451.20）＞浮萍（0）。生物分解指數，浮萍（0.669924）＞水藻（0.045878）＞大肚魚（0.034529）＞田螺（0）。

(5)加保利於此模擬生態系統結果分析中，發現 2.22 % 之加保利，3.39 % 之 4-Hydroxycarbaryl，1.15 % 之 5-Hydroxycardaryl，2.39 % 之 N-Hydroxycarbaryl，1.12 % 之 5.6-Dihydroxycarbaryl 及 89.72 % 之水溶性物質。生態加成值除於狼蛛及　蟲外於所有生物中皆趨於零。生物分解指數：水藻（98.629032）＞浮萍（73.142857）＞田螺（4.425966）＞魚（1.507937）。

(6)治滅蟲於此模擬生態系統結果分析中，發現 0.5 %之治滅蟲，0.59 %之 3-Carboxyphenylcarbamate，0.29 %之 3-Hydroxymethylphenyl-N-methyl carbamate，2.25 % 之 4-Hydroxy-3-methylphenyl-N-methyl carbamate 0.4% 之 3-Methylphenyl-N-hydroxymethyl Carbamate 及 95.89 % 之水溶性物質。生態加成值除於狼蛛及蟲外於所有生物中皆趨近於零。生物分解指數：水藻（180.464286）＞田螺（88.595041）＞浮萍（81.538462）＞魚（44.2607001）。

(7)巴拉松於此模擬生態系統結果分析中，發現 33.94 %之巴拉松，20.7 % 之 *p*-Nitrophenol，2.4 %之 Unknown 1（Rf＝0.33）及 1.62 %之 Paraoxon 及 41.26 %之水溶性物質。生態加成值：魚（37.7）＞浮萍（0.67）＞水藻（0.5）。生物分解指數：魚（0.914226）＞水藻（0.757576）＞浮萍（（0.6）。

(8)馬拉松於此模擬生態系統中，結果分析發現 22.53 %之馬拉松，33.65 %之 Malaoxon，0.71 %之 Malathion dicarboxylic acid 及 43.11 % 之水溶性代謝物質。除狼蛛及蝗蟲外於所有生物中其生態加成值皆趨近於零。生物分解指數：魚（60）＞水藻（2.45）＞浮萍（2.05）。

比較模擬生態系統中及田間的資料可知利用此水田生態模擬系統配合同位素技術以研究本省農葯在田間代謝情形及評估農葯的安全性是可行而且可靠。