Environmental and human risks of pesticide use in Thailand and Sri Lanka. Results of a preliminary risk assessment

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ABSTRACT

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Currently, a major difficulty facing the establishment of sustainable management plans in complex agricultural systems in the tropics, is the lack of sufficient relevant information on important ecological, hydrological and land-use processes that underpin the various values generated by natural resources. By applying baseline information from two study sites in Thailand and Sri Lanka, the MAMAS project aims to develop cost-effective tests and other environmental diagnostic tools that can ultimately be used in an Integrated Risk Assessment Model, leading to the development of policy guidelines for the management of agrochemical use in aquatic systems in Asian countries. The initial stage of the project involved a situation analysis which was followed by a preliminary risk assessment as described in this report. The preliminary risk assessment aimed to gather further information on the environmental characteristics of the study sites, in order to estimate potential risks (to both human health and the environment) through pesticide exposures. The information gathered within the MAMAS project was used to model the exposure concentration of the pesticides towards aquatic communities and residues present in food items. This exposure assessment was compared with estimated safe concentrations for the environment and human health. Both the environmental and the human health assessment indicated large potential risks. These risks were not only present for the farm channels located next to the crop but also for larger aquatic systems like cascade tanks present in Sri Lanka. The next phase of the project will consist of performing chemical measurements, bioassays and biomonitoring (the Triad approach). Data obtained will be used to validate the procedures used in the Preliminary Risk Assessment.

Keywords: pesticides, Sri Lanka, Thailand, tropics, environment, human health, risk assessment, aquatic ecosystems, fish

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Contents

Appendices

Preface

The Preliminary Risk Assessment (PRA) described in this report is part of the project: Managing Agrochemicals in Multi-Use Aquatic Systems (MAMAS). The MAMAS project is largely financed by the European Union INCO-DEV program. The Alterra contribution is also part of the DLO Research Programme International Co-operation (North-South program) sponsored by the Dutch Ministry of Agriculture, Nature Management and Fisheries. Additional support was obtained from the Department for International Development (DFID) Aquaculture and Fish Genetics Research Programme of the United Kingdom. The team consists of seven partners and is coordinated by the Institute of Aquaculture at the University of Stirling (UK). The other partners include: Alterra Green World Research (The Netherlands), University of Aveiro (Portugal), University of Peradeniya (Sri Lanka), Asian Institute of Technology (AIT, Thailand), Kasetsart University (Thailand) and National Aquatic Resources research and development Agency (NARA, Sri Lanka). The preliminary risk assessment was performed in November 2002 at Alterra, Wageningen, The Netherlands. All authors of this report contributed to this risk assessment, but without the input of the people participating in the project and performing the participatory community appraisals and household surveys conducting the assessment would have been impossible. The authors would like to thank Dave Little, Graeme Taylor, Donald Baird (University of Stirling), Theo Brock (Alterra), Amadeu Soares and António Nogueira (University of Aveiro), Sarath Kodithuwakku (University of Peradeniya), Amararatne Yakupitiyage (AIT) and Sunil Siriwardena (NARA) for their invaluable contribution to the report. We want to thank F. A. Cader (AbC), Sampath Abeyarathne (AbC), W. D. N. Wickramarchchi (NARA), M.M.S.D. Kumara (NARA), Kumudu Mahawatte (AbC), S.A.M Azmy (NARA), P.L.S. Panawala (NARA), Keola Soutthanome (AIT), Wijittra Sansud (AIT) and Rattanaporn Anantasuk (AIT) for their help with the participatory community appraisals and household interviews.

Abbreviations

ADI	Acceptable daily intake (mg/ kg body weight/ day)
ARfD	Acute Reference Dose
BCF	Bioconcentration Factor
DT50	Half-life for transformation
EC50	50% Effect Concentration. Concentration that causes an effect (e.g. immobilisation, reproduction) among 50% of the test organisms of a given species over a specified period.
HC5	Hazardous Concentration 5%. 5th percentile of a Species Sensitivity Distribution
Kd	Sorption coefficient (L/ Kg)
Koc	Sorption coefficient for organic carbon (L/Kg)
Kom	Sorption coefficient for organic matter (L/kg)
Kow	Octanol Water Partition coefficient
LC50	50% Lethal Concentration. Concentration that kills 50% of the test organisms of a given species over a specified period.
NEC	No Effect Concentration
NEDI	National Estimated Daily Intakes (mg/ kg body weight/ day)
NOEC	No Observed Effect Concentration. Highest concentration tested without observed effects on the individuals of a test.
OFC	Other Field Crops
PEC	Predicted Environmental Concentration (µg/L)
PRA	Preliminary Risk Assessment
S	Solubility (mg/ L)
SSD	Species Sensitivity Distribution
TER	Toxicity Exposure Ratio
TOXSWA	TOXic Substances in Surface WAters model

Summary

Currently, a major difficulty facing the establishment of sustainable management plans in complex agricultural systems in the tropics, is the lack of sufficient relevant information on important ecological, hydrological and land-use processes that underpin the various values generated by natural resources. By applying baseline information from two study sites in Thailand and Sri Lanka, the MAMAS project aims to develop cost-effective tests and other environmental diagnostic tools that can ultimately be used in an Integrated Risk Assessment Model, leading to the development of policy guidelines for the management of agrochemical use in aquatic systems in Asian countries. The initial stage of the project involved a situation analysis which was followed by a preliminary risk assessment as described in this report. The preliminary risk assessment aimed to gather further information on the environmental characteristics of the study sites, in order to estimate potential risks (to both human health and the environment) through pesticide exposures. The information gathered within the MAMAS project was used to model the exposure concentration of the pesticides towards aquatic communities and residues present in food items. This exposure assessment was compared with estimated safe concentrations for the environment and human health. Both the environmental and the human health assessment indicated large potential risks. These risks were not only present for the farm channels located next to the crop but also for larger aquatic systems like cascade tanks present in Sri Lanka. The next phase of the project will consist of performing chemical measurements, bioassays and biomonitoring (the Triad approach). Data obtained will be used to validate the procedures used in the Preliminary Risk Assessment.

1 Introduction

Environmental degradation of tropical ecosystems and its linkage to rapid economic growth and sustainable development has become a major focus for researchers and funding agencies alike. The relevance of this topic to the needs of the Asian region, home to the World's largest and most dense rural populations is clear. There is an urgent need to de-couple economic growth from environmental degradation in this fast-growing region of the World. Asia's wetlands are under particular pressure and their status is of concern to many national and international bodies and environment agencies (e.g. UNEP, EU) and conventions (RAMSAR). Although it is generally agreed that there is an urgent need for guidelines for good land-use practices that reduce or negate the use of pesticides and nitrate fertilisers, little is currently known of the status of their use or abuse and the fate and impact of the pollutants entering them. The MAMAS project (Managing Agrochemicals in Multi-Use Aquatic Systems) has a multidisciplinary approach to the issue of diffuse pollution from agrochemicals, the use of which is increasing as agriculture intensifies within the region. Vital deliverables of this project include information and approaches that can improve strategic planning, integrate sustainable management and tools at the catchment level, and these will be developed for two different but complementary areas of rural Asia.

Currently, a major difficulty facing the establishment of sustainable management plans in complex agricultural systems in the tropics is a lack of information on relevant ecological, hydrological and land-use processes that underpin the various values generated from natural resources. By applying baseline information from two study sites in Thailand and Sri Lanka, the MAMAS project aims to develop cost-effective tests and other environmental diagnostic tools that can ultimately be used in an Integrated Risk Assessment Model, leading to the development of policy guidelines for the management of agrochemical use in aquatic systems in Asian countries. The initial stage of the project involved a situation analysis which was followed by a preliminary risk assessment. An important part of the situation analysis was to identify the communities and institutions that are stakeholders in terms of policies and issues relating to pesticide use within the study areas or nationally. The preliminary risk assessment aims to gather further information on the environmental characteristics of the study sites, in order to estimate potential risks (to both human health and the environment) through pesticide exposures. After training, field deployments will commence to monitor effects. The information gathered will allow modelling of the distribution, persistence and bio-availability of contaminants, and effect monitoring to link fate with effects. The output will be a user-friendly decision-support system (DSS). The DSS, and its implications for decision making, will be discussed and disseminated at a participative workshop on completion of the project, following which a set of policy recommendations will be drafted. The report presented here gives an overview of the outline of the project together with the results of the preliminary risk assessment.

2 Background of risk assessment

2.1 Environmental risk assessment

Agricultural pesticides are, as the name indicates, chemicals deliberately released into the environment to control pests that harm crops. This mode of application implies that they may reach non-target areas. Aquatic ecosystems, for instance, have been reported to become contaminated by pesticides due to spray drift, drainage, run-off, atmospheric deposition and/or accidental spills (Capri and Trevisan, 1998). Since aquatic ecosystems include key species related to the target organisms of pesticides, undesirable side effects on aquatic plants and animals may ensue (Hurlbert, 1975; Hill et al., 1994). Consequently, authorities have set criteria to protect aquatic life from pesticide stress. As an example, the European Union adopted the Uniform Principles, a registration procedure for the placing of plant protection products on the European market in which also water quality criteria are incorporated (EU, 1997; see also Table 1). The basis of these principles is the adoption of a tiered approach. The risk assessment starts with a worst-case approach which can be followed by more realistic assessments when risks are indicated.

Tiered risk assessment approach

Ideally, when assessing the ecological risks of a new pesticide, one investigates its fate and effects under realistic field conditions, taking into account good agricultural practice and the spatial and temporal variability of the ecosystems potentially under stress. The time, costs and logistics necessary for this approach, however, make it impossible to evaluate all active ingredients and formulated products in this way. Therefore, a tiered approach has been adopted in Europe and elsewhere. The first, relatively simple, tier of aquatic risk assessment is based on the estimation of a PEC/NEC ratio. In this ratio, the calculated concentration of the pesticide in surface water (Predicted Environmental Concentration; PEC) is compared with the expected No Effect Concentration (NEC). If the PEC does not exceed the NEC, no effects of the pesticide on the aquatic community are expected.

Table 1. EU criteria as set for the impact of pesticides on non-target species

Tier	*Compartment* and organisms	Criteria
First tier	*Terrestrial*	
	Birds and other terrestrial non-target invertebrates	short-term PEC ≤ 0.1 x LD50 long-term PEC ≤ 0.2 x NOEC BCF ≤ 1 unless..
	Honeybees	maximum application rate ≤ 50 x LD50 unless..
	Beneficial arthropods	maximum application rate may not cause effects or death for more than 30% of test organisms in a laboratory test unless..
	Earthworms	short-term PEC ≤ 0.1 x LD50 long-term PEC ≤ 0.2 x NOEC unless..
	Soil micro-organisms	maximum application rate may not cause inhibition of nitrogen or carbon mineralization of larger than 25% after 100 days in the laboratory unless..
	Surface water	
	Fish, *Daphnia* and algae	Short-term PEC ≤ 0.01 LC50 or EC50 fish or *Daphnia* Short-term PEC ≤ 0.1 EC50 algae Long-term PEC ≤ 0.1 NOEC fish or *Daphnia* BCF ≤ 1000 for readily biodegradable active substances BCF ≤ 100 for not readily biodegradable active substances
Second tier		unless it is clearly established through an appropriate risk assessment that under field conditions no unacceptable impact on the viability of exposed species (predators) occurs - directly or indirectly - after use of the plant protection product according to the proposed conditions of use

The first tier PEC is calculated with the help of a simplified standard scenario for a standard freshwater system (stagnant; water depth 30 cm overlying sediment of 5 cm depth) on the basis of the recommended dose used for pest control and the expected drift percentage and runoff or drainage fractions (FOCUS, 2001). The NEC is based on concentration-effect relationships studied in the laboratory with a limited number of “standard” species, viz., an alga, *Daphnia* and fish (Figure 1). These species have been chosen because of their ease of handling and rearing in the laboratory. Their test procedures are highly standardised and well described in, for instance, OECD guidelines (Organisation for Economic Co-operation and Development; OECD, 1993). The standard test species are regarded as convenient surrogates for sensitive indigenous species of aquatic ecosystems, despite a general awareness of the uncertainty associated with the extrapolation from one species to another. To protect sensitive indigenous aquatic populations, the NEC is usually calculated by multiplying the toxicity value of the most sensitive standard test species by an assessment factor (e.g. a factor of 1/100 for acute EC50s or a factor of 1/10 for chronic NOEC’s in the uniform principles; for more details see Table 1).

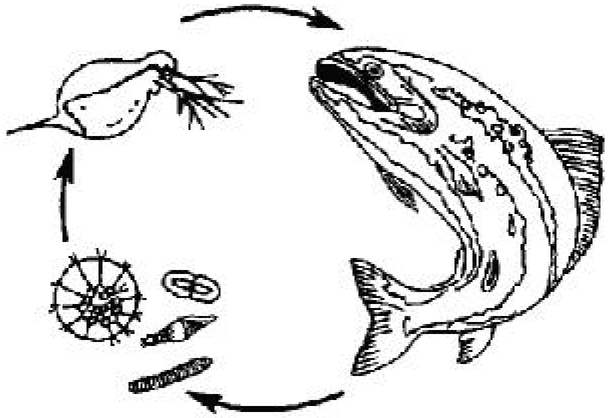


Figure 1. Standard test species as used for the aquatic risk assessment of pesticides

In the first tier, the PEC is based on an 'extreme worst case loading' scenario. If, based on this PEC compared with the NEC, the use is considered safe, no further risk assessment is required. If however, the result indicates that use is not safe, it is necessary to do a second tier assessment.

The above-mentioned first tier in the risk assessment procedure is considered conservative, partly because of the higher dissipation rate and the generally lower bioavailability of pesticides in the field compared with the standardised test conditions in the laboratory, and partly because of the worst case conditions adopted in the standard scenario to calculate the PEC. Therefore, if the first tier indicates potential risks it is possible to use more realistic exposure scenarios and include ecologically more relevant data in an advanced risk assessment procedure. This advanced risk assessment procedure can be regarded as the second tier, e.g. the "unless" procedure described in Table 1. The more realistic exposure scenarios take into account agronomic and climatic conditions relevant to the crop (FOCUS, 2001), for which simulation models are used to calculate the PEC. This second tier for effects does not consist of well-defined rules like the first one, but has to be tailor-made, depending on the degree of uncertainty in the risk remaining after the first tier. This may range from, for instance, more information on the susceptibility of indigenous species, a better estimation of the half-life of the chemical in water to a semi-field experiment using man-made ecosystems like microcosms and mesocosms (Campbell et al., 1999). Possible concepts and tools that can be used to calculate second tier NEC's are the Species Sensitivity Distribution concept (Posthuma et al., 2002), effect models like PERPEST (Van den Brink et al., 2002a) or results from semi-field experiments (Brock et al., 2000a,b). Experiments on an ecosystem level are frequently requested and performed to demonstrate that the actual risks of a particular pesticide are acceptable when used under normal agricultural practice.

2.2 Human risk assessment

The risks for the human health effects of pesticide residue exposure due to dietary uptake consists of the comparison of some kind of exposure parameter with an intake amount considered safe. The exposure parameters are defined as IEDI

(International Estimated Daily Intakes) and NEDI (National Estimated Daily Intakes). These Estimated Daily Intakes are based upon a defined diet and calculated residue levels in these diets. The WHO defined 5 regional food diets based upon the FAO food balance sheets (Middle Eastern, Far Eastern, African, Latin American and European diet). Two intake amounts are used to describe the effect side of the equation, the ADI (Acceptable Daily Intake) and the ARfD (Acute Reference Dose). The ADI is defined as: "an estimate of the amount of a substance, expressed on a body weight basis, that can be ingested daily over a lifetime without appreciable health risk" and can be considered as a chronic threshold level. The ARfD is defined as: "an estimate of the amount of a substance in food and/or drinking water, normally expressed on a body weight basis that can be ingested in a period of 24h or less, without appreciable health effects" and can be considered as an acute threshold level. (Van Raaij, 2001; Van Raaij and Ossendorp, 2002). In this report we will calculate NEDI levels based upon a hypothetical diet representative for Thailand and Sri Lanka and the PEC's calculated within the environmental risk assessment. We will only consider intake due to exposure via the water into account (eating of fish and aquatic macrophytes and drinking of the water), no intake via the crops is considered. These NEDI values will be compared with chronic ADI and acute ARfD values to evaluate chronic and acute risks for human health.

3 Data gathered in Participatory Community Appraisal and House-Hold surveys relevant for Preliminary Risk Assessment

The initial stage of the project involved a situation analysis. An important part of the situation analysis is to identify the communities and institutions that are stakeholders in terms of policies and issues relating to pesticide use within the study areas or nationally. Participatory Community Appraisals (PCA) have been carried out in the sampled communities. The vulnerability context in each community is described in terms of trends, shocks and seasonality based on analysis of separate focus group interviews of men and women. Also wealth ranking is carried out in each community using a modified methodology described by Pretty et al (1995) to identify social groups. Timelines and historical profiles are used with focus groups to reconstruct the context, identify critical events and trace local and external activities over time. A small-scale sample survey of assets and strategies is carried out with a limited number of households in each community to establish their livelihoods profile.
Preliminary data on land-use, hydrology and types of surface water is collected by the research partners in Sri Lanka and Thailand in the target areas of concern. Special attention is paid to the crops present and the actual pesticide use in these crops (e.g. application rates and methods). This chapter will list all data from the Participatory Community Appraisals (PCA) and Household surveys (HH-surveys) carried out in Thailand and Sri Lanka, relevant to the Preliminary Risk Assessment (PRA)

3.1 Thailand

Taking into account the diversity of agricultural systems in Thailand, the Thailand MAMAS team selected two study sites; a commercial mono-crop of tangerines and a more diverse mixed vegetable farming area. Sarakru sub-district in Nong Sua District of Pathumthani province was selected for the mono-crop study site, and Kokprajadee sub-district in Nakornchaisri district of Nakhon Pathom province was selected for the mixed crop site. Three villages from each study site were selected for both PCA and household survey. Twenty households in each village were interviewed as part of the household survey, i.e. 60 households in each study site.

Mixed crop study site

Three villages were selected for investigation in Kokprajadee Sub-district of Nakhornchaisi District in the Nakhornpathom Province of central Thailand. Village selection was primarily based on a high proportion of households having diversified to intensive production of a wide variety of fruit and vegetables in the area and the use of canals and ponds as a source of food-fish through fishing and aquaculture.

The people in the communities are educated to primary level. Farm and general labouring, Government work, aquaculture, and farming are occupations evident in the area. In the case of the latter, farming can be split into livestock, fruit and vegetables of which the prominence of each varies between villages. The proportion of people involved in labouring and aquaculture also differs between village communities.

Various main canals in the area, with branching sub-canals, supply irrigation water to the farming systems. Water is frequently pumped from sub-canals to farm canal systems, which surround the crops, particularly outwith the rainy season. Water is however pumped from these farm systems back to the sub-canal systems during the rainy season to prevent flooding. A degree of water exchange between farms that share common same sub-canals is therefore expected. However within farms water supplies can be separate for fishponds and crops. Irrigation water supplies are variable, being dependent on rainfall, the tidal status and canal gate operations.

In the past, rice formed the main crop in the area however incomers introduced fruit & vegetable farming in the early 1980's and production of a variety fruit and particularly vegetables now predominates. Rice production has a minor contribution, whilst roseapple and longbean are prominent in selected areas of two villages.

Culture of the Giant Freshwater Prawn (*Macrobrachium rosenbergii*) was introduced but was suppressed due to resulting declines in water quality, however fish culture continued in two of the selected villages. One saltwater shrimp farm exists in the one of the villages. Fish are additionally caught from farm canals, sub-canals and main canals for personal consumption or small-scale local sale. Some other aquatic plants and animals are collected from local canals for consumption.

Canal and road improvements, electricity and tap water inputs and the introduction of government credit schemes have aided development business and livelihoods in the area. Small general stores and agriculture supply shops, a school and temple are present in the area.

Fruit and vegetables are sold at Talad Thai, Kokprajadee and Nakhonpathom Markets and to wholesalers in Bangkok, whilst cultured fish are sold at Saphapla Market, although some agricultural produce and caught fish are consumed within households. Food items are additionally purchased from informal markets and mobile traders that have become established in response to local development.

Mono crop study site

Three villages were selected for investigation in Salakru Sub-district of Nong Sua District in Pathumthani Province of central Thailand. Village selection was primarily based on the three villages' high production levels of tangerines within the District and the use of various canal systems in supplying food-fish, through both culture and fishing activities.

The majority of the community is educated to primary level and farming is the main occupation, followed by general labouring, aquaculture and government related work.

The Ni River is to the north of the study area and there are two main canals (Canals 13 and 33) from which various sub-canals branch to supply irrigation water to the farming systems. Water is frequently pumped from sub-canals to farm canal systems, which surround the crops, particularly out the rainy season. Water is however pumped from these farm systems back to the sub-canal systems during the rainy season to prevent flooding although in the case of tangerine farms this is commonly done frequently throughout the year for purposes of stimulation of crop development. Therefore a high degree of water exchange between farms that share common sub-canals is expected. A proportion of the drainage water collects in another main canal (Canal 32).

In the past, rice formed the main crop in the area however tangerine farming was later introduced from incomers and now forms the vast proportion of high intensity agricultural production in this area. Recently however, an unidentified disease has been having significant constraints on tangerine production. Longan, sweetcorn, mango and mushrooms are however additionally produced.

In one of the three villages pond fish culture has appeared whilst cage fish culture is apparent in Canal 13. Fish are however caught from farm canals, sub-canals and main canals for personal consumption. Some other aquatic plants and animals are collected from local canals for consumption.

Small general stores and agriculture supply shops, a school, public health office and temple are present in the area, whilst the development of the road network and other communication links over the years has improved business development.

Tangerines and other crops are sold in large markets which include Talad Thai, Si Mun Muang and Pak Klong and Nakhonpathom. Cultured fish are sold at large markets including Saphan Pla, Nongkar and Nakhonpathom and also the Kianthai Company. A small proportion of agriculture produce and fish cultured or caught are consumed within households. Small informal markets and mobile traders have become established and prospered in the area in response to development and are an additional source of food and other households consumables.

3.2 Sri Lanka

Two main research sites were selected within a large irrigation systems, Mahawelli H system, that is located in the North Central Province of Sri Lanka, in the dry zone of the country. They are Kalankuttiya and Meegalewa tanks. These two tanks are located along same cascade. Kalankuttiya tank is perennial tank and fed by both Mahaweli and drainage water whereas Meegalewa tank is fed by only drainage water. (See figure 2)

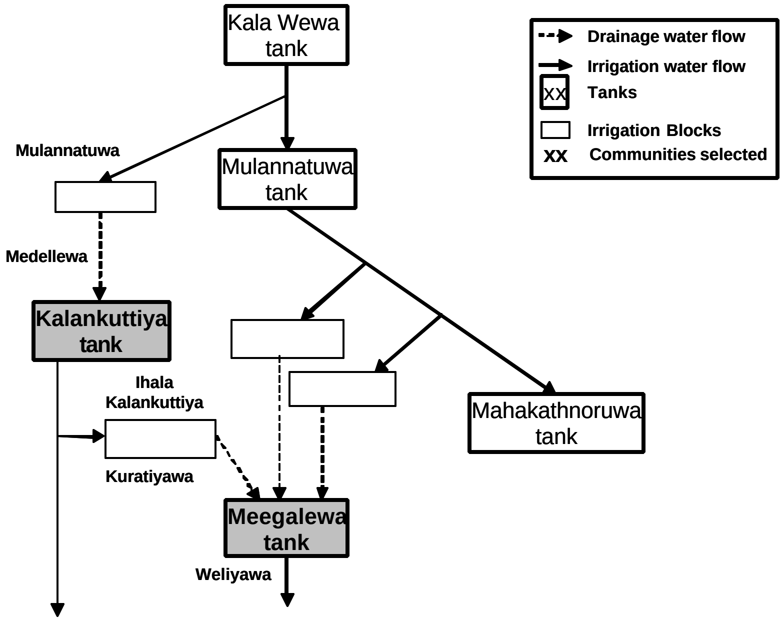


Figure 2. Overview of water flow of the two main research sites (Kalankuttiya and Meegalewa tanks) and selected communities for Sri Lanka.

Water drainage pattern was used as main site selection criteria. Cropping pattern, land use pattern and livelihood activities also considered for the site selection. Five communities were selected along the cascade representing both catchments and the command areas of the selected tanks (Appendix I, II and III). The selected communities for the research are :

1 Mulannatuwa – Located in the Kalankuttiya tank catchment area and away from the tank
2 Medellewa- Located in the Kalankuttiya tank catchment area and closer to the tank
3 Ihala Kalankuttiya- Located in between two tanks closer to Kalankuttiya tank
4 Kuratiyawa- Located in between two tanks closer to Meegalewa tank
5 Weliyawa – Located in the command area of the Meegalewa tank

The main income generation activity of all the communities is farming. Employment in the armed forces and in garment factories are some other major livelihood activities.

The major portion of drainage water of Medellewa and Mulannatuwa flows to the Kalankuttiya tank. Kalankuttiya tank provides water for the cultivation activities of Kuratiyawa and Ihala kalankuttiya. The major portion of these two communities' drainage water flows to Megalewa tank. Megalewa tank provides water for the cultivation activities of Weliyawa. Water is sufficiently available during the Maha season and hence the majority of the farmers cultivate paddy, which demands lot of water whereas water is not sufficiently available during the Yala season and hence some of the farmers cultivate Other Field Crops (OFC's) during the Yala season. Application of pesticides was found to be higher in cultivation of OFCs compare to paddy. However, more land was found to be under paddy cultivation.

Fish is one of the important animal protein sources of these communities. The major sources of fish consumed in these communities are the Kalankuttiya and Megalewa tanks. Consumption of aquatic plants was insignificant when compared with the other food items.

The majority of the farmers are aware of the safety methods of pesticide application. However, the majority of the farmers generally ignore safety procedures. Interestingly most of the farmers are aware of the hazardous nature of the pesticides. Most of the farmers are willing to reduce the total amount of pesticides that they apply.

4 Scenarios, pesticide entry assumptions and pesticide properties for the calculation of the Predicted Environmental Concentrations

To be able to calculate Predicted Environmental Concentrations (PECs) in the tiered approach the scenarios for each of the two tiers have to be defined. The scenario is a 'description' of the characteristics of the environment in each country within which pesticide concentrations in surface waters are to be determined. Furthermore, assumptions have to be made considering the entry of pesticides into the water body. For the 2nd tier calculations the pesticide properties are needed to simulate their fate in the water body.

4.1 Scenarios

For each country one scenario was developed for the first tier and two scenarios were developed for the second tier, all of them representative for the study sites.

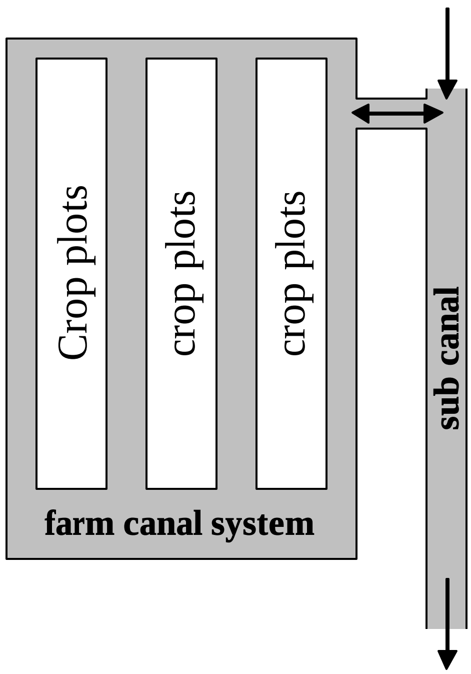
4.1.1 Thailand

There are 2 study locations in Thailand, one in each of Pathumthani and Nakhonpathom provinces In Thailand the Pathumthani site is characterised by monocrop, tangerine farm systems. The Nakhonpathom site is characterised by mixed produce, mostly vegetables and fewer fruits where season has little influence over the types of crops grown in each system. Similarities and differences in hydrological characteristics and cropping patterns of are further summarised in Table 2.

The Thai farming systems at both sites are characterised by strips of land on which crops are grown surrounded by water which itself either flows in or is pumped in from the main or sub-canals which canalises and supply the water ("ditch-and-dike systems", Table 2). The farm canal system is usually a closed water system and the water within the system is lost through transpiration, evaporation, surface and groundwater seepage, although during the rainy season water may be pumped back from these systems to the sub-canals to prevent flooding (Fig. 3). Additional to seasonal differences on hydrology, within the mono-crop sites water is additionally pumped to and from the farm during periods of the year for crop stimulation purposes (Fig. 3) which adds another degree of variation between these two study sites. The farm canal system and 20m sections of sub-canals themselves (approximate one farm width) were decided as the main focus of impact of pesticides in the aquatic environment due to both being sources of fish consumed locally, the former being the area of work and the latter being utilised for other domestic purposes such as washing clothes.

Table 2: Thailand site characteristics (2 sites), scenarios and basic assumptions

Characteristics	Site 1	Site 2
System type	Mono-crop Tangerine	Mixed crop Fruit and vegetables
Cropping pattern	3 tree stages. 3rd stage bears fruit 1-2 times / year	Continuous with short 1-2 month cycles
	Water supplied through main & sub-canals to farms	
Hydrology	Cyclical pumping in & out of farm – to stimulate tree development & crop production	Pump in during dry season & sometimes out during wet season to prevent flooding
Scenario	Scenario 1: Wet Season (both) Scenario 2: Dry Season (both)	
	Sub-canal impact zone 20m (distance between farms)	
Assumptions	Farm canal depth: (Wet) 0.75m ; (Dry) 0.5m	
	Soil & water temp. (Wet) 30 °C; (Dry) 33 °C	
	Simulation time (wet) 240 days. Simulation time (dry) 120 days	



Flows from farm canal system to sub canal:

Dry season scenario
- pumping into farm canal system (both sites)
- pumping out (mono-crop site only) to stimulate fruiting

Wet season scenario
- pumping out (both sites)

Figure 3. Diagrammatic representation of agricultural systems of the mono- and mixed cop study sites in Thailand. The farm canal system and sub canal are the areas of impact.

The two sites do not differ in the most sensitive scenario parameters for the first tier scenario: water depth, and the second tier scenarios: flow rate (Westein et al., 1998). Therefore the scenarios defined here cover both sites. In the first tier one scenario is defined. In the second tier two scenarios are defined. One for the wet season and one for the dry season. The main scenario parameters differing between the seasons affecting the pesticide fate are the water depth and the temperature.

Tier 1 scenario

The first tier scenario comprises a stagnant water body with no sediment layer below is. The water depth is defined as 0.5 m; being a realistic low value for the ditches in the farming systems considered.

Tier 2 scenarios

The scenarios in the second tier are representative for both study sites. One scenario represents the conditions in the dry season, the other scenario represents the conditions in the wet season (Table 3). Both scenarios represent a stagnant water body, assuming that under worst case conditions the water in the ditch is not replenished during the season. The sediment layers in the scenarios represent sediments with low organic matter contents. These are worst case conditions regarding the low amount of organic matter available for sorption of pesticides. The low organic matter content has not been verified because data are not available.

Table 3. Scenario parameters for estimation of Predicted Environmental Concentrations (PECs) in the second tier risk assessment for Thailand.

Parameter	Dry season	Wet season
Water layer		
Flow rate (m/d)	0 (stagnant)	0 (stagnant)
Water depth (m)	0.5	0.75
Temperature (ºC)	33	30
Suspended solids (g/L)	50	50
Org. matter content suspended solids	0.5	0.5
Sediment		
Thickness (m)	0.05	0.05
Bulk density (kg/m3)	800	800
Porosity (-)	0.5	0.5
Tortuosity (-)	0.5	0.5
Mass ratio organic matter (-)	0.085	0.085

4.1.2 Sri Lanka

There are 5 study locations in the Mahaweli H system of Sri Lanka. In Sri Lanka the types of crops grown are largely rice, OFC's and vegetables, mostly comprising onion and chilli where seasonality and water availability have more influence on which crop and the area size on which the crops are grown. Additionally, the slope gradient is an important factor in the irrigation cascade system of the Sri Lankan sites influencing water availability and therewith affecting the potential accumulation of pesticides in tanks downhill. Similarities and differences in hydrological characteristics and cropping patterns of sites in each country are further summarised in Table 4.

The Sri Lankan farming system at each site is characterised by rice production on water-inundated land of no more than 1 hectare (2.5 acre) per household during the rainy season (Maha) and production of Other Field Crops on raised bed strips surrounded by water within the plot during the dry season (Yala) of around half an acre (Table 4). However rice may also be grown during Yala alongside OFC's if water availability permits. In each case, water is supplied from reservoirs or tanks via distribution channels and smaller field channels, which connect to plots. Water is issued to channels by the Mahaweli Development Authority and farmer organizations through the operation of gates although the amount of water issued is dependent upon its availability. During Yala water availability is reduced and is commonly issued to farmers for 3 days in every 10 days, which operates in a rotational pattern between plots. The farm plot canal system is usually a closed water system and the water within the system is lost through transpiration, evaporation, surface and groundwater seepage although seepage water also collects in drainage channels (Fig. 4). During Yala the tendency for farmers to pump and 'recycle' water from the drainage channels is increased due to scarcity. Drainage water eventually collects in downstream reservoirs / tanks (Fig. 4). The farm plot canals and tanks themselves were decided as the main focus of impact of pesticides in the aquatic environment due to the former being the area where farm workers operate and the latter being the main source of bathing water and fish consumed by local communities.

Table 4: Sri Lanka site characteristics (5 sites), scenarios and basic assumptions

Characteristics	Sites 1-5	
System type	Maha 'wet' season: rice, Yala 'dry' season: chilli, onion and vegetables	
Cropping pattern	Maha - rice (3 to 3 ½ or 4 months cycle)	Yala – chilli, onion)1-3 month cycle)
	1 ha cultivated per farm	½ ha cultivated per farm
	Water flow: distribution channels – farms – drainage channels	
Hydrology	Also pump from drainage channels to farm during dry season.	
Scenario	Scenario 1: Wet Season (all)	Scenario 1: Dry Season (all)
	Tank impact zone 20 ha & 1.5m deep	
Assumptions	Farm plot canal depth: 0.10 m (Wet & Dry)	
	Soil & water temp. 28 °C (Wet) & 30 °C (Dry)	
	Simulation time (Wet) 120 days & (Dry) 240 days	

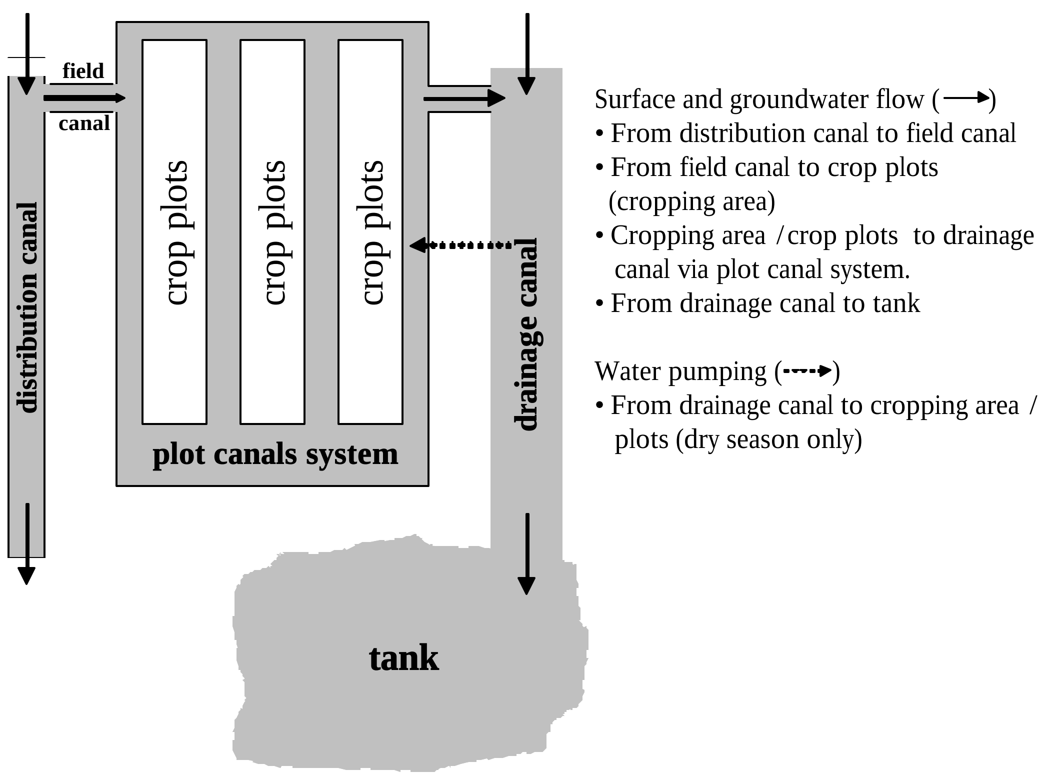


Figure 4. Diagrammatic representation of agricultural systems of the rice and OFC study sites in Sri Lanka. The farm canal system and tank are the areas of impact

In the first tier, a single scenario is defined. In the second tear two scenarios are defined, one for the wet season and one for the dry season. The main scenario parameters differing between the seasons affecting the pesticide fate are the water depth and the temperature.

Tier 1 scenario

The first tier scenario comprises a stagnant water body with no sediment layer below is. The water depth is defined as 0.1 m; being a realistic low value for the field drainage channels in the farming systems considered.

Tier 2 scenarios

One scenario represents the conditions in the dry season, the other scenario the conditions in the wet season. Both scenarios represent a stagnant water body, assuming that under worst case conditions the water in the field drainage channels is not replenished during the season. The sediment layers in the scenarios represent sediments with low organic matter contents. These are worst case conditions regarding the low amount of organic matter available for sorption of pesticides. The low organic matter content has not been verified because data were not available.

Table 5. Scenario parameters for estimation of Predicted Environmental Concentrations (PECs) in the second tier risk assessment for Sri Lanka.

Parameter	Dry season	Wet season
Water layer		
Flow rate (m/d)	0 (stagnant)	0 (stagnant)
Water depth (m)	0.1	0.1
Temperature (ºC)	30	28
Suspended solids (g/L)	50	50
Org. matter content suspended solids	0.5	0.5
Sediment		
Thickness (m)	0.05	0.05
Bulk density (kg/m3)	800	800
Porosity (-)	0.5	0.5
Tortuosity (-)	0.5	0.5
Mass ratio organic matter (-)	0.085	0.085

Dilution factor calculation for tank scenario in Sri Lanka

The second tier PECs of the Sri Lankan scenarios are also extrapolated to the tank or reservoir (see Figure 4). This Tank-PEC is used to calculate the PEC/NEC ratios and the human exposure for Sri Lanka.

The Tank-PEC can be calculated from the second tier PECfor the farm canal system using a dilution factor. So it is assumed that (part) of the water from the farm plots will enter the tank.

Only a scenario for the Yala season is defined, because then the dilution factors will be low. In the Maha (wet) season the dilution is higher because of the higher rainfall intensity, which will lead to lower PECs than calculated for the Yala season.

The following assumptions are made:

- The total land extent in this irrigation block is 1000 plots of 1 ha = 1 10^7 m^2.
- in Yala farmers are allowed to cultivate 0.5 ha (extent of cultivation depend on irrigation water availability), so total cultivatable area in this irrigation block during Yala season is 500 ha = 5 10^6 m^2
- the volume of water flowing from plots to the tank = 5 10^6 (cultivated area in m^2) *0.1 (water height) *0.1 (channel area) =5 10^4 m^3 (in the plot, bed area is 90% and cannel area is 10%)
- Via surface flow, only 1/3 of water in the plot ends up in the tank (due to evaporation, transpiration etc.). Hence, the volume of water entering the tank = 5 10^4 m^3 * 1/3 = 16667 m^3
- In the Yala season farmers get water 3 days out of 10 days. Therefore total water volume goes to the tank via surface ware flow is 16667 * 3/10 = 5000 m^3
- So farmers get water every 10 days and every 10 days a volume of 5000 m^3 goes to the tank from the 500 ha that is cultivated in Yala.
- therefore, the daily volume of water entering the tank = 5000 / 10 = 500 m^3
- from the 500 ha. cultivated area 60% is onion, 20% is chilli and 20% is rice and vegetables
- The size of the tank is 20 ha; the average tank depth is 1.5 m, so volume of the tank is 20000 m^2 * 1.5 m = 30.000 m^3
- The volume of water coming from different crop areas (m^3) is

- Onion: 60% * 500 m^3 = 300 m^3
- Chilli: 20% * 500 m^3 = 100 m^3
- Rice: 10% * 500 m^3 = 50 m^3
- Vegetable: 10% * 500 m^3 = 50 m^3

- Therefore dilution factor is = volume of water in the tank / the volume of water coming from the plot channel:

- DF_{Onion} = 30000 / 300 = 100
- DF_{Chilli} = 30000 / 100 = 300
- DF_{Rice} = 30000 / 50 = 1000
- $DF_{Vegetable}$ = 30000 / 50 = 1000

4.2 Pesticide entry assumptions

Pesticides may enter surface waters via spray drift, runoff, drainage or atmospheric deposition. In this preliminary risk assessment only the entries via spray drift are taken into account. For the other entry routes additional data on soils and field practices are needed, the data for which are not yet available. Also, spray drift is considered to be one of the main entry routes causing peak concentrations in surface waters. Point sources, e.g. via spills, are not considered in a risk assessment procedure because it is assumed that good agricultural practice is followed. Nevertheless, point sources are in the daily practice a main risk to be considered.

4.2.1 Thailand

Spray drift (% of pesticide and hence active ingredient, which directly reaches the surface water) was taken as 100% for boat application methods and 30% for knapsack spraying. The pesticide is diluted with irrigation water sprayed on the crops that are on the strips of land. The irrigation is done with a boat that sprays the water like a fan behind it, reaching land and water alike.

4.2.2 Sri Lanka

Spray drift was taken as 100% for applications by knapsack, because the small field canals are that close to the crop and are that small that the water surface is sprayed fully.

4.3 Defining pesticide characteristics

In the Tier 2 calculations pesticide properties are needed. Transformation, sorption and volatilization are the main processes affecting the fate of pesticides in surface waters. The parameters needed to simulate these processes with TOXSWA are listed here. It is indicated how the values have been obtained. Appendix IV lists the parameter values of the pesticides considered in this study.

(A) Transformation

1. Half-life for transformation in water at 20 °C (days)
2. Half-life for transformation in sediment at 20 °C (days)
3. Activation energy for transformation (J/mole)

The half-life estimates used for the simulations with TOXSWA model, were obtained from Tomlin (1997), Arthur et al. (1996) and Tomlin (2000). When available, the DT50 of the water-sediment study was used, but if the data were not available, the hydrolysis, photolysis and degradation times in water at pH 7 were used. As a last choice the DT50 of soil was used. If soil DT50 was not available, a value for DT50 water and sediment of 10,000 days was used. Using molar enthalpy the transformation rate can be calculated for the temperature considered in the scenario. For the activation energy of transformation, the default value of 55,000 J/mole was used for all pesticides (Beltman et al., 1999).

(B) Sorption

4. Suspended Solids
- Sorption coefficient, K_{om} (organic matter) (L/kg)
- Freundlich exponent (-)

5. Sediment
- Sorption Coefficient, K_{om} (organic matter) (L/kg)
- Freundlich exponent (-)

The sorption coefficient K_{om} for suspended solids and for sediment were both taken from the sorption coefficient for soil from the three references listed under (A). If not available the K_{om} was calculated from the K_{oc} using the equation below,

$K_{om} = 1.7 * K_{oc}$

If both K_{om} and K_{oc} were unavailable, the default value of 1,000 L/kg was used. The Freundlich exponent was set at the default value of 0.9.

(C) Volatilisation Part:

6. Saturated gas pressure
- Saturated gas pressure (Pa)
- Temperature at which the saturated gas pressure is measured (°C).
- Molar enthalpy of vaporization (J/mole).

Saturated gas pressure was obtained from the three main references (A). The conversion from m Hg to Pa is 1 m Hg = 133322 Pa and 1 mm Hg = 133.322 Pa. If the references did not have a value for saturated gas pressure, the value was set at 1 E-15 Pa. The temperature at which the saturated gas pressure was measured is needed as well. With this temperature and the molar enthalpy the saturated gas pressure can be calculated for the temperature considered in the scenario. For the molar enthalpy of vaporization the default value of 95,000 J/mole was used (Beltman et al., 1999).

7. Solubility
- Solubility in water (g/L).
- Temperature at which the solubility is measured (°C).
- Molar enthalpy of solution (J/mole).

Solubility in water was obtained from the three main references as listed under (A). With the temperature at which the solubility is measured and the molar enthalpy the solubility can be calculated for the temperature considered in the scenario. For the molar enthalpy of solution, the default value of 27,000 J/mole was used (Beltman et al., 1999).

8. Molecular mass (g/mole).

Molecular mass was also found in the three main references (see (A)). When not available the molecular mass data was set at 100 g/mole.

The results of determining the pesticide parameters for all pesticides that are were found in the Household surveys of Thailand and Sri Lanka are listed in Appendix V. The values are used in calculation of the second tier PEC.

5 Procedures for the calculations of the Predicted Environmental Concentration, No Effect Concentration and Dietary Exposure Risk assessment

5.1 Predicted Environmental Concentration

All calculations are done for all combinations of crop and pesticide that were found in the household surveys held in Thailand and held in Sri Lanka.

5.1.1 First tier PEC calculation

This involved a preliminary estimation of the risks posed by each pesticide to the aquatic environment. The total use of each pesticide on each crop during the crop cycle is used to very simply calculate a first tier PEC. These PECs allow the identification of pesticide-crop combinations that may cause the highest risks.

$$PEC = \frac{\text{Dose} * \text{Number of applications} * \text{Drift fraction}}{10 * \text{Volume of water body}}$$

PEC ($mg/m^3 = \mu g/L$)
Predicted Environmental Concentration calculated from instantaneous input of accumulated pesticide loading during the crop cycle.

Dose (g a.i. /ha)
The recommended dose is used assuming good agricultural practice by the farmer. By using the recommended dose we exclude effects of temporal (between years) and spatial variation (between farms) on the risk assessment. The loading of active ingredient for one application is calculated from the recommended dose of the formulated product accounting for the % of active ingredient of the pesticide product. (concentrations of active ingredients of solid form were provided as an expression of weight per weight (W/W) whilst liquid forms were expressed as weight per volume (W/V), where in the latter case 1% = 10g / 1000 mL therefore this was taken into consideration in calculations.

The actual field doses applied by farmers were used for Thailand because recommended doses were not available, whereas recommended doses were used in the calculations for Sri Lanka.

Number of applications (-)
For Thailand the highest number of applications in a crop during its crop cycle, found in the Household survey is used. For vegetable crops a crop cycle of 45 days was assumed, for fruit also periods of 45 days were assumed. By using the highest

values, we consider the worst case situation that may occur. For Sri Lanka, the results of the Houshold survey were not available yet, the number of applications is based on expert judgement. A crop cycle takes 120 days.

Drift fraction (-)
These are the drift percentages indicated in Section 4.2 divided by 100. The drift fraction depends on the application method used in the crop.

10
This factor is added to change from g/ha to mg/m^2.

Volume of water body (m^3)
The volume is calculated assuming a length of 1 m, a width of 1 m and a water depth depending of the country that is considered. For Thailand it is 1 m x 1 m x 0.5 m = 0.5 m^3. For Sri Lanka it is 1 m x 1 m x 0.1 m^3 (see Section 4.1).

The first tier PECs calculated for Thailand and Sri Lanka are listed for each crop-pesticide combination in Appendix VI.

5.1.2 Second tier PEC calculation

The second tier PEC was calculated to obtain a more realistic estimate of the concentrations of pesticide in surface waters. The first tier PEC was calculated assuming all loadings enter instantaneously the water body, causing a peak concentration that is the PEC. In calculation of the second tier PEC the processes that determine the fate of the pesticide in surface water are taken into account and a realistic application scheme is considered. The difference between the first tier PEC and the second tier PEC was due to the dissipation processes between applications resulting in lower PECs. The second tier PEC was the result of stacking the individual applications. For the calculations the TOXSWA model was used.

Second tier PEC calculations for the risk assessment involved the input of data relating to pesticide use, pesticide properties and various environmental parameters to the TOXSWA model. For Thailand only the pesticide-crop combinations from the first tier assessment which revealed the highest PEC values were selected for calculation of a second tier PEC. For Sri Lanka for all pesticide-crop combination a second tier PEC was calculated. From the second tier PEC of the farm canal system in Sri Lanka also a second tier PEC for the tank was calculated using a dilution factor, calculated as described in Section 4.1.2.3.

As described, two scenarios were developed for each country, representing the dry season and wet season. However, for calculation of the second tier PEC the dry season scenarios were chosen as the worst case scenarios for both Thailand and Sri Lanka. Calculations for the wet season have not been done. Concentrations will be highest in the dry season because the water depths are smallest and in reality in the dry season the replenishment of the water is minimal. The values entered for each parameter in TOXSWA for Sri Lanka and Thailand are shown in Appendix IV. The parameter values used for the pesticides used in TOXSWA are given in Appendix V. The drift deposition on the water surface for each application is calculated with:

Drift deposition on water surface (mg/m^2) =
Dose (g a.i./ha) * Drift fraction (-) / 10

For explanation of Dose, Drift fraction and the factor 10 see Section 5.1.1.

The number of applications and the time interval between applications are extracted from the Household surveys. For Thailand a period of 45 days is simulated, being the crop cycle period in which the series of pesticide applications occur. For Sri Lanka a period of 120 days is simulated, being a realistic period for the crops grown there.

The second tier PECs for Thailand and Sri Lanka are listed in Appendix VI. For Sri Lanka also the tank-PECs (see Section 4.1.2.3) calculated from the second tier PECs are presented.

5.2 No Effect Concentration

The preliminary risk assessment is based on the estimation of a PEC/NEC ratio. For the calculation of the ratio the second tier PEC's calculated according to the procedures as described in the previous paragraph were used. The procedure for the NEC calculation is addressed below.

5.2.1 First tier NEC calculation

The calculation of the NEC is based on laboratory toxicity data (LC50/ EC50/ NOEC's) gathered for a limited number of 'standard species': viz. algae, *Daphnia* and fish. These species have been chosen because of their ease handling and rearing in the laboratory. A list of standard test species was derived from the OECD (1993, Table 6).

Table 6. Standart test species (OECD, 1993)

Crustacea	*Daphnia magna*
	Daphnia sp
Algae	*Chlorella vulgaris*
	Scenedesmus subspicatus
	Selenastrum capricornutum
Macrophytes	*Lemna minor*
	Lemna gibba
Fish	*Brachydanio rerio*
	Cyprinus carpio
	Gasterosteus aculeatus
	Lepomis macrochirus
	Oncorhynchus mykiss
	Oryzias latipes
	Pimephales promelas
	Poecilia reticulata

The toxicity data for the standard test species listed above were obtained from the quick-search Ecotox database of the US-EPA (internet reference 1). Only toxicity data from laboratory tests were used. Furthermore, values obtained from laboratory tests with non-reported endpoints or endpoints that were not considered relevant were excluded (Table 7). Toxicity values from laboratory tests with a duration that is considered out of range were also deleted (Table 7).

Table 7. Relevant endpoints and duration for laboratory toxicity tests

Species group	Toxicity measure	Relevant endpoints	Relevant duration of test (days)
Daphnia / fish	EC50	Mortality	1 - 4
		Behaviour	
		Intoxication	
	NOEC	See EC50+	> 4
		Reproduction	
Macrophytes	EC50	Growth	2-14
		Population	
	NOEC	See EC50	> 8
Algae	EC50	Growth	1 - 4
		Population	
	NOEC	See EC50	1 - 4

When more than one EC50 or NOEC values were found for the same species, the geometric mean was calculated. If no EC50 or NOEC data was available within one of the three species groups, the database of the RIVM was used (De Zwart, 2002). If toxicity values were still missing for the most relevant species groups for a certain pesticide (i.e. insecticide and acaricide: *Daphnia* and fish; herbicide and plant growth regulator: algae and macrophytes; fungicide: *Daphnia*, fish, algae and macrophytes), the Pesticide Manual (Tomlin, 2000) was checked. For all pesticides a NOEC or EC50 value was obtained for at least one species within the most relevant species group(s). Because of the uncertainties associated with the extrapolation from one species to another and to protect sensitive indigenous aquatic populations, the NEC is calculated by multiplying the toxicity value by an assessment factor (EU, 1997. Table 8).

Table 8. Assessment factors for extrapolation of toxicity values for standard test species to NEC (EU, 1997)

Short term exposure
0.01 x acute EC50 fish, *Daphnia*
0.1 x acute EC50 algae and macrophyte
Long-term exposure
0.1 x chronic NOEC fish, *Daphnia*, algae and macrophyte

After application of the assessment factors, the lowest NEC for each pesticide was taken and listed in Appendix VII.

5.2.2 Second tier NEC calculations

The NEC calculation in the first tier of the risk assessment procedure is often considered conservative because of the limited amount of species tested and the lack of ecological realism Brock et al., 2000a;b). Therefore, if the first tier indicates potential risks, European guidelines offer the possibility to include more ecologically relevant data in a higher tier risk assessment procedure.

For the type of risk assessment proposed here, using SSD (Species Sensitivity Distributions) or models, e.g. PERPEST, are useful tools for estimating a more realistic NEC (Campbell et al., 1999).

The SSD concept is based on the assumption that the sensitivities of a set of species can be described in a statisical distribution (Posthuma et al., 2002). The available ecotoxicological data for all species tested are considered as a sample from this distribution and are used to estimate the parameters of the SSD. The variance in sensitivity among the test species and the mean are used to calculate a concentration expected to protect most species (e.g. 95%). This concentration (HC5, Hazardous Concentration 5%) is supposed to prevent effects on ecosystems and is validated for a limited number of compounds (Versteeg et al., 1999; Van den Brink et al., 2002a; Schroer et al., 2003). By including more species and taking into account the (modelled) sensitivity between them, a more realistic NEC can be calculated.

The PERPEST model is a model that predicts the ecological risk of herbicides and insecticides in freshwater ecosystems by using relevant (toxicity) characteristics of the compound and the results of all microcosm and mesocosm experiments published in the open literature (see Brock et al., 2000a;b for the review). PERPEST searches for analogous situations in the database allowing the model to predict effects of pesticides for which no effects on a semi-field scale have been published (Van den Brink et al., 2002b). By using this model, an (modelled) ecological more realistic NEC can be obtained.

The second tier NEC was calculated for substances having a PEC/NEC ration higher than 10.000 using the RIVM data base (De Zwart, 2002). HC5 values were based on toxicity values of arthropods for insecticides and acaricides, primary producers for herbicides and plant growth regulators and all available data for fungicides (Maltby et al., 2002). Since EC50 values are far more available than NOEC's, the first were used for the HC5 calculation. A safety factor of 10 was used to extrapolate the HC5 based on EC50 data to a NEC. HC5 values were only calculated when at least 6 toxicity values were available. When less than 6 toxicity values were available, the PERPEST model was used.

5.3 Dietary Exposure Risk assessment

In predicting pesticide residue intake, long term food consumption habits should be taken into account, to permit valid comparisons with the Acceptable Daily Intake (ADI). The ADI is an estimate of the amount of a substance, expressed on a body weight basis, that can be ingested daily over a lifetime without appreciable health risk. The ARfD (Acute Reference Dose) is an estimation of the amount of pesticide that can be ingested in 24 hours without health risk. For the human risk assessment, the ADI and ARfD of the pesticides were compared to the NEDI's (National Estimated Daily Intakes) based on the three main entry routes: drinking water, eating fish and water-plants. This comparison was made to estimate acute and chronic health risks. Consumers are considered to be adequately protected providing the intake of pesticide residues does not exceed the acceptable daily intake (ADI) and/or Acute Reference Dose (ARfD).

The calculation of the pesticide intake (NEDI`s) for the three entry routes are described below. In calculating the NEDI, it is necessary to convert the consumption to mg (pesticide) /Kg (body weight) /day. Therefore it is assumed that a person weighs on average 60 kg, as is stated on the web-page of the World Health Organisation (WHO, internet reference 2). The assumptions are based on an average person and not a worst-case.

Drinking water
The daily amount of pesticide intake via drinking water was calculated by multiplying the second tier PEC with the average daily consumption of water. Therefore, it was assumed that all water that's consumed is taken from the surrounding agricultural water (worst case). On the web-page of the South-East Asia regional office of the WHO (internet reference 3), it is stated that the average consumption of water in Thailand is 5 litres per day. Because no other values (for Sri Lanka) could be found, this amount was used for further calculations.

Eating fish
The amount of pesticide consumed via eating of fish was calculated by multiplying the amount of fish eaten per day with the concentration of the pesticide in the fish. The amount of fish eaten per day was obtained from the 'far eastern' diet of the GEMS/Food regional diets on the WHO web-page (internet reference 4). In this calculation the amount of fish and meat eaten a day were added to get a realistic worst-case diet (e.g. people just eat fish, which is quite common in Asia). It was assumed that a person eats 81.7 g fish a day (34.7 g fish + 47 g meat). The concentration of the pesticide in the fish was calculated using second tier PEC´s and bio-concentration factors (BCF) values for the different pesticides:

concentration in the fish = concentration in the environment (PEC) * BCF

The BCF´s were calculated from the Kow using the following relation as determined by Weith et al. (1979):

log BCF = 0.85 Kow – 0.70

Kow values were obtained from the pesticide manual (Tomlin, 2000). When they were not available in the manual, they were obtained from the Environmental Science web-page (internet reference 5) or The Alternate crops & systems Lab web-page of the USDA (United States Department of Agriculture; internet reference 6).

Eating macrophytes

The amount of pesticide consumed via eating of macrophytes was calculated by multiplying the amount of macrophytes eaten per day with the concentration of the pesticide absorbed to the macrophytes. The daily consumption of macrophytes was estimated from the 'far eastern' diet of the GEMS/Food regional diets (internet reference 4) by assuming that half of the vegetables eaten a day consists of macrophytes (i.e. 179/2 = 89.5 g/ person/ day). The concentration of pesticides absorbed to waterplants was calculated from the following formulas:

concentration of pesticide absorbed to plants = concentration in the environment (second tier PEC) *Kd

The relation between solubility and Kd as estimated by Crum et al. (1999) was used to calculate the Kd:

Kd = 3.20 – 0.65 log S

The Solubility (S) were taken from the pesticide manual (Tomlin, 2000). As the concentration of pesticide absorbed to plants is given in Kg (pesticide) /Kg (macrophytes dry weight) and the amount of macrophytes eaten per day is given in wet weight, a weight conversion factor had to be found. Based on the work of Van Lieverloo (2002) it was assumed that dry weight is 8.33% of the wet weight.

Sum of NEDI´s and comparison with ADI´s and ARfD's

Important to note that for all calculations, the numbers had to be recalculated taking into account the body weight (dividing the result by 60 Kg) so the of the NEDI could be expressed in mg/kg body weight / day. The 3 NEDI´s calculated (drinking water, fish and macrophytes) were summed and compared with the ADI and ARfD's for each pesticide. The ADI's and ARfD's were obtained from the JMPR (Joint Meeting of the FAO Panel of Experts on Pesticide Residues in Food and the Environment and the WHO Core Assessment Group on Pesticide Residues) reports as published on their web-site (internet reference 7). If not available, the ADI list as provided by the Commonwealth of Australia (internet reference 8) was consulted, after that the pesticide manual was checked. If still not available chronic US-EPA RfD values as found on (internet reference 9) were used as ADI's. For fenobucarb no entry was found for the ADI and the 5% lower limit of the log-normal distribution fitted through all available ADI's was used as a worst case estimation. Only for 6 chemicals an ARfD could be found. The others were estimated using the 95% log-normal upper limit of the 6 ADI to ARfD extrapolation factors available.

The 95% upper limit of this distribution was 47 so an extrapolation factor of 47 was used to convent ADI's to ARfD's

6 Results of first and second tier environmental risk quotients

6.1 Predicted Environmental Concentrations

6.1.1 Thailand

The PEC's for the Thailand scenario are listed in Appendix VI. For each pesticide, the pesticide-crop combination yielding the highest first tier PEC, also a second tier PEC was calculated. From the Appendix it is clear that PEC varied highly between crops (e.g. for methamidophos between 123 and 28929 µg/L and for carbendazim between 41 and 1125 µg/L. In most cases the second tier assessment lowered the PEC considerably, for profenofos even up to a factor of 10.

6.1.2 Sri Lanka

The PEC's calculated for the farm canal system varied little between pesticides (Appendix VI). For carbofuran the lowest first tier PEC was calculated (120 µg/L), for carbaryl the highest one (2250 µg/L). The second tier PEC's differed even less between pesticides (120 µg/L for carbofuran and 1078 µg/L for carbaryl). The differences between the first and second tier PEC's as calculated for the Sri Lanka scenario were relatively small. The largest difference of a factor of 2.4 was calculated for the carbaryl – chilli combination. For no pesticide – crop combination was an increase in PEC recorded between the first and second tier assessment.

6.2 No Effect Concentration

The NEC values of all pesticides are listed in Appendix VII. The magnitude of the NEC varies from <0.1 ng/L (fenoxycarb) to >1 mg/L (gibberellic acid). In general, the insecticides / acaricides were most toxic to aquatic life, followed by fungicides and herbicides / plant growth regulators

6.3 Environmental risk quotients

6.3.1 Thailand

The risk quotients calculated from the second tier PEC and the first tier NEC indicate a potential risk for all pesticides in the Thailand scenario (Appendix VIII). The highest potential risks are indicated for various insecticides and the fungicide carbendazim, the lowest ones for the herbicide glyphosinate and the fungicides propineb and metalaxyl. On a crop level, Chinese kale, guava, drumstick moringa and rose-apple were the crops posing the highest risks.

6.3.2 Sri Lanka

For the farm channel system of the Sri Lanka scenario it was indicated that, as for Thailand, the concentrations of all pesticides exceed the NEC (Appendix VIII). Especially the risks posed by insecticides carbaryl, chlorpyrifos and dimethoate were very high (> 10000 risk quotients were calculated) while for the herbicide glyphosate a relatively low one was calculated (3.4). Even for the larger tank system, for most pesticides risks are indicated with highest values for the onion crop because for this crop the lowest dilution factor was used (§5.1.2.4)

7 Results of dietary exposure risk assessment

7.1 ADI and ARfD levels

Appendix IX lists the ADI and ARfD levels used for the dietary exposure risk assessment. For most chemicals an ADI could be found in the annual reports of the JMPR. For all compounds except fenobucarb an ADI could be found in one of the literature sources, the one for fenobucarb was estimated to be the 5% level of the log-normal distribution of all ADI values found (worst case estimate). Only for 5 chemicals an ARfD could be found, for all other chemicals the ARfD was calculated using an extrapolation factor.

7.2 Results dietary exposure risk assessment

7.2.1 Thailand

Appendix X displays the results of the human risk assessment due to dietary exposure via water and food (fish and aquatic macrophytes). For three chemicals an extremely high exceedence (> 10000) of the ADI by the NEDI is indicated (chlorfenapyr, prothiofos and dicrotophos). For all three pesticides the source is different: chlorfenapyr exposure is high due to macrophyte intake, exposure to prothiophos is high due to fish intake and dicrotophos exceeds the ADI because of exposure through drinking water. For a number of chemicals the NEDI also exceed the ARfD, indicating acute risks of the defined diet. The highest exceedences are indicated for the same chemicals as above although one should keep in mind that the ARfD levels of these chemicals are all based on extrapolation. For fipronil and mevinphos risks are indicated based on ARfD levels as set by the JMPR (Appendix X).

7.2.2 Sri Lanka

Also for the Sri Lankan scenario a high exceedence of the ADI is indicated for some pesticides although the absolute value is always below 1000 (Appendix X). The highest exceedence is indicated for fenobucarb, alachlor and chlorpyrifos. It must be noted that the ADI of fenobucarb is based on a worst case extrapolation from all other available ADI's so a large uncertainty of the actual risks remains. Chlorpyrifos is the chemical with the largest exceedence of the ARfD level that is set by the JMPR, indicating acute risks from the defined diet. When the tank is considered as a source for fish, macrophytes and water all NEDI levels drop below the (extrapolated) ARfD levels (Appendix X) and only few exceed the ADI (alachlor, fenobucarb and chlorpyrifos).

8 Discussion, conclusions and recommendations

The data gathered in the Participatory Community Appraisal (PCA) and House Hold (HH) surveys were used to support the Preliminary Risk Assessment (PRA). Data on pesticide dosage, application intervals, system characteristics and composition of diet were sufficient for the purposes of the PRA. The difference between Thailand and Sri Lanka was the source of the pesticide dosages. For Thailand the PECs were calculated with dosages obtained from HH surveys, for Sri Lanka the recommended dosages were used. The variation in applied dosages between farmers was sometimes very high (e.g. the amount of carbendazim used in tangerine differed by a factor 32 between the lowest and the highest dose). The major drawback of these applied dosages was that it was not verified whether those amounts were really applied on the fields. For the risk analysis the use of a standard dose approach is therefore recommended e.g. the dose recommended by the company or extension services or used for the registration of the pesticide on the local market. When doing so, the variations between years and between farmers does not influence the results and a risk assessment of the pesticide given the dose used in normal or good agricultural practice is obtained. The data from the HH surveys can be compared with the recommended dose, to quantify the degree and give insight into the reasons for overdosing. For Sri Lanka data on pesticide use as indicated in the HH surveys were not available at the time of study, but will be gathered in future to allow this comparison.

Another major source of uncertainty of the current PRA was that the pesticide properties used for the assessment were obtained from databases originating from Europe and North-America. It is questionable whether these are representative for Asian circumstances. It can be argued that the breakdown of the pesticide is different under warmer and eutrophic conditions compared to the sediment water system used to establish the DT50 for registration purposes in Europe. The same can be argued for the toxicity of the chemicals towards tropical species although Maltby et al (2002) could not demonstrate differences in sensitivity between temperate and tropical species for a few pesticides (chlorpyrifos, fenitrothion and carbofuran). Brock et al. (2000a; 2000b) also could not find any systematic differences in threshold levels derives from semi-field experiments performed in temperate and more warmer conditions although the extent and types of secondary effects caused by exceedence of these safe threshold levels may be influenced considerably by temperature (Van Wijngaarden et al., 2003). It is important, however, that more insight is obtained in the differences in fate and effects of pesticides under temperate and tropical conditions, e.g. using microcosm or mesocosms.

In Thailand, for all active ingredients, the highest second tier PECs as calculated for the farm canal exceed the first tier NEC (Appendix VIII). The highest TER was calculated for the use of mevinphos in the drumstick tree, the crops rose-apple, guava and Chinese kale generally yielded the highest TERs. When using the second

tier NECs the TERs were lowered by maximum a factor of 25 (methamidophos) but the PEC still exceeded the NEC considerably (Appendix VIII).
For Sri Lanka the same results are reported for the farm channels; for all active ingredients, the highest second tier PECs as calculated for the farm canal exceeded the first tier NEC (Appendix VIII). For the tank for several cases the highest second tier PECs as calculated for the tank did not exceed the first tier NEC (e.g. Glyphosate). Even when compared with the second tier NEC, however, the second tier PEC considerably exceeded the safe concentrations for some compounds (carbaryl, chlorpyrifos and dimethoate). In general, the highest TERs were reported for all three major crops (onion, chilli and rice)

The environmental PRA for sites in both countries indicates that significant effects of pesticide exposure could be expected on aquatic life. The predicted effects are so large that it is to be expected that the species inhabiting the local aquatic ecosystem present in the farm channels and tanks are highly resilient to high pesticide exposure or have a large opportunity to reinvade the systems rapidly. The biomonitoring programme performed later in this project will give further consideration to these ideas.

The human risk assessment indicated that for sites in Thailand the ADI is likely to be frequently exceeded, even up to a factor of 36000 times. These high exceedence values again indicate significant risks of pesticide exposure via the diet leading to problems for human health. It is worth noting that no single food item causes the exceedences and that the risk is not associated with a single crop. The PCA indicated that in both the mono-crop and the single-crop sites, fish and aquatic macrophytes are regularly obtained from the farm channels for human consumption. This indicates that while the assumptions made in the human risk assessment may be unrealistically worst-case for water consumption, this is not true for the consumption of fish and macrophytes.
Compared to Thailand, lower exeedences of the ADI are reported (up to a factor of 1000) for Sri Lanka. The exceedence of the ADI is caused by the consumption of water and fish, rather than by consumption of macrophytes, which are rarely eaten in Sri Lanka (Appendix II). Even when dietary items are obtained from the tank, the ADI of a few pesticides could be exceeded. This is of particular importance because the fish caught in the tanks are a more important part of the protein source of their diet for poorer people within the districts studied.

For both countries high risks of pesticide use are indicated both for the environment and human health. These indicated risks are extremely high for farm channels but also exist for the Sri Lankan tank scenarios. These risks were also reflected by farmers, with most expressing a belief that pesticides are harmful to both the environment and human health (Appendix I). It is, however, essential for the formulation of the Decision Support System, that the results from this Preliminary Risk Assessment are validated using chemical measurements, bioassays and biomonitoring (the Triad approach).

For this biomonitoring programme it is recommended that scenarios are defined for worst case conditions, e.g. no flow of water. By monitoring it should be possible to gain insight into realistic worst case conditions, e.g. what is a realistic low value for replenishment of the water bodies? In other words, are the scenarios as described in Chapter 4 fully reflective of the Thai and Sri Lankan situations? By performing chemical analysis, a degree of validation of the PECs as calculated with TOXSWA using these scenarios can be obtained. In this way a more refined risk assessment can be carried out after the monitoring programme. On the other hand, possible effects indicated by the PRA can be validated using bioassays and biomonitoring. It is important that these bioassays and sampling of invertebrates are carried out in a systematic standardised fashion. To validate dietary risk assessment, the formulas describing sorption of pesticides to the food items as stated in Section 5.3 should be verified by actual measurements of pesticides in fish and aquatic macrophytes present in the systems of concern. Also the composition of the diet itself needs to be refined using approaches that reveal seasonal and intrahousehold variation.

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Appendix 1 Summary Report of Participatory Community Appraisal (PCA) findings and outputs from Thailand and Sri Lanka

Thailand, Nakhon chaisi (mixed crop site)

	VILLAGE 2	VILLAGE 3	VILLAGE 4
Village Map			
Village Characteristics	Surrounded by 2 Canals	4 canals in village flow to main canal	3 canals supply water to the village
	Water flows around the village	Water flows generally north-south but direction changeable; rainfall, tidal status and gates operation.	
Land Use	Main land use: fruit and vegetable farming (more vegetables produced) and pond-fish culture.		
	Rose-apple and long-bean are prominent in some areas.		Crops & fishponds are equal land areas.
	More fish culture.	Rice production has minor contribution. One saltwater shrimp farm.	
Education Status	Most people educated to primary class 4		
	Higher % of higher educated people		
Occupation Status	Most do general & farm labouring followed by farming and government work.	1/3 of communities are vegetable farmers. Some rice farmers, cow and pig farmers, labourers and government work.	
		More fish culturers	More fruit farmers
Timeline	Rice was the main crop however low prices. Newcomers introduced fruit & vegetable farming (early 1980's). *M. rosenbergii* culture lasted short time due to pollution and fish culture succeeded. Canal and road improvements, credit schemes, tapwater & electricity connections made.		
Well-being Ranking	Most households within worse-off group and least in better-off group	Approx. equal proportions in each well-being group	Most households in middle well-being group and equal proportion in better and worse-off groups
	Better-off group: own more land, higher incomes and more occupations. Worse-off own less or no land, less income and mostly on & off-farm labour work		
Activity Matrix			
Better-off groups	Males and females mainly involved in farm management and going to markets. Males do more social type of activities and females have less activities including housework & assisting neighbours on farms		Better-off & worse-off group comparison not possible. Males involved in agricultural related work and social activities. Females involved in housework, purchasing food & farm management
Worse-off groups	Males and females share activities; visiting markets, farm management, labour work. Women mainly do labour and household work		
Seasonal Calendar			
Weather	Summer: Feb-April / Rainy Season: May-Oct / Winter: Nov-Feb		
Hydrology	High water flow and turbidity in rainy season and lowest during summer		
Vegetable production	Vegetables grown throughout the year, 1-2 month cycles, crop rotation		
		Highest vegetables prices: May-Oct (but crops more vulnerable to damage)	Highest veg prices: March-May & Oct & highest pesticide application May-Nov.
Fruit production	Main fruit: Guava, mango & roseapple, frequent harvesting. Highest price & labour use in Aug. Most pests Feb-April.		Main fruit: Guava & roseapple, frequent harvesting. Pesticide applied every 10 days. Highest price & labour use in Aug.
Fish Culture	Fish are cultured extensively in farm canal systems for personal consumption		

	Pond culture throughout the year (commercially mainly & personal consumption) harvest every 8-10 months. Prices lowest Aug-Sept & highest Oct-Dec.		
Sub / Main canal fishing	Rarely catch fish	Fish caught in main and sub-canals	Fish rarely caught but are available all year
Health	Colds & Dengue fever occur sometimes during the year		
Consumption Matrix			
Main food items	Main foods: Rice, eggs, freshwater fish, fruit, vegetables (Chinese cabbage / kale). Mainly purchased from informal markets. Fish also from farm & sub-canals. Other aquatic animals collected.	Main foods: Rice, freshwater fish & vegetables (Chinese kale / cabbage). Fish mainly from farm & sub-canals & ponds. From informal markets, mobile traders & groceries.	Main foods: Rice, meat, freshwater fish & vegetables. Vegetables (Chinese cabbage / kale, water mimosa & long bean) from own farm, groceries & informal markets. Fish purchased and caught from canals.
Bio-resource Maps	Mostly either crop or fish producers.	Most have fruit, vegetable farms & fish ponds.	
	Fruit & vegetable farmers pump water into their farms but don't usually pump out. Those with fishponds pump out when harvesting (once/yr).	Water is pumped from canals and sometimes flows out the farm system. Crops are sold at similar markets or wholesalers (Bangkok) who also provide agro-inputs. Waste vegetables are fed to fish.	Water pumped in from canals but only pumped out during rainy season.
	Fruit & veg sold at Talad Thai, Kogphajadee & Noakhonpathom markets. Fish sold at Saphapla market. Some produce is consumed within the household. Agrochemicals purchased locally (village 2) are applied to crops. Water supplies can be separate for fishponds & crops. Most food items are purchased.		
Agricultural Input Costs	Almost all crops were both sold and consumed		
	Labour & farm management & pesticides (particularly worst-off) were highest costs	Perceptions of cost distribution varied between groups.	Males thought fertiliser as the highest cost and females, labour & management. Pesticides were considered a higher cost by males than females
	Chinese kale & cabbage were indicated as having the highest costs of pesticide use		
Agrochemical Use Level	Chinese kale was indicated to receive the highest amounts of agrochemicals. Also high applications to Guava, rose-apple, Chinese cabbage & long bean		
	Additionally Grape	Additionally Mango & celery	Taiwan cabbage
Decisions & Responsibilities in Agrochemical Use	Both male & female household heads took decisions and carried out activities relating to agrochemical purchase, storage, preparation & application	*Better-off group:* male & female household heads take decisions but male head does the activity. Labourers also do spraying *Worse-off group:* Male HH head takes decisions, male & female heads do activity.	Both male & female HH heads take decisions, but also worse-off group sons & daughters. Decisions relating to application taken by HH heads. Heads mainly responsibility for doing activities but also sons & daughters.
Perceptions of Agrochemical Use			
Necessity	Over 50% claimed pesticides were important but also claimed other pest prevention methods were useful.		
Health & Environment	Over 50% thought pesticides were not harmful to health or environment if used correctly.		All females & some males thought pesticides harmful to environment & health indicating concern.
Desired Outcome	Most wanted to continue with present level of use if affordable & cost was main factor for those who wanted to reduce application	50% wanted to continue with present level of use if remaining affordable (both groups). Some better-off people wanted to increase pesticide use.	All wanted to reduce pesticide use with human health given as the main reason.

Thailand, Nong Saeo (mono-crop site)

	VILLAGE 6	VILLAGE 7	VILLAGE 1
Village Map			
Village Characteristics	Main canal 13 flows through centre of the village from North to South. Village 2 is to the north and east and village 4 is to the south.	Main canal 13 is to the north of the village and canal 33 to the east. Sub-canals from canal 33 feed water to farms. Village 2 is to the south and village 10 to the east	Canal 33 irrigates farms through sub-canals, which then drain into canal 32 to the east. The Ni River is to the north side. Village 7 is to the north and village 2 to the east.
Land Use	Main land use ion each village is tangerine farming		
	Longan and sweetcorn also produced	Mango and Mushrooms also produced	Longan and mushroom also produced
	Pond-fish culture is prominent and cage culture in canal 13.	Few fish ponds apparent.	The presence of fish farming was not established.
	Groceries, public health office, temple, school and agricultural supplies shop are also present.	A temple is also present in the village.	A factory is also present in the village.
Education Status	Most people educated to primary class 4 and below, followed by middle school grades 1-3. Few people have Bachelor degrees.	Most people educated to primary class 4 -6, followed by middle school grades 1-3. Few people have Bachelor degrees.	
	Little difference in education status between villages		
Occupation Status	Most are involved in farm work, followed by general labouring, aquaculture and gov't related work.	Most (49%) of the community are tangerine farmers, followed by labourers on and off tangerine farms, chicken farmers, gov't work, mat making and only 1% mushroom farming and fish farming. onl1/3 of communities are vegetable farmers. Some rice farmers, cow and pig farmers, labourers and gov't work.	Most are tangerine farmers, followed by labourers on tangerine farms, general labouring,
Timeline	Rice was the main crop however low prices. The canal system was constructed, rice production intensified, incomes increased. Fish losses occurred in the canals. Roads were constructed and incomers introduced tangerine farming. Sub-canals were constructed and farmers started pumping water from them. Fish stocks declined thought due to increased agrochemical use. Rice farming declined and aquaculture increased. Disease in tangerines is now causing economic loss and relocation. Government has introduced a loan system.		
		Drought in canal 33 – water taken from canal 13. Mobile food & agriculture supply shops started & became important resources.	Tangerine business spread from village 10
Well-being Ranking	Most households lie between the worse-off and better-off groups.		
	Better-off group: own more land, tangerine farmers, lease land, higher incomes and have more income sources. Worse-off own less or no land, less income and mainly do on & off-farm labour work		
Activity Matrix			

Better-off groups	Government work or responsibilities only applied to better-off males & cockerel fighting more prominent activity for them. Females work on tangerine farms, do housework & prepare food mostly.	Well-being comparisons were not possible from the data available however for males religious activities, visiting markets, farming & sending children to school were most important. Females indicated managing own farms, housework and visiting markets as most important.	Better-off males mainly managed own farms, laboured, housework and visiting markets. Females main activities similar including cooking and excluding labour work. For males own tangerine farm work, religious activities & carpentry were the main activities. Females did on and off farm work, housework and market visits were main activities.
Worse-off groups	Worse-off males revealed a greater number of main activities and additionally are involved moreso in other off-farm labour. Female activities similar to better-off but have a greater number of major activities, including other labour and feeding fish.		
Seasonal Calendar			
Weather	Summer: Feb-April / Rainy Season: May-Oct / Winter: Nov-Feb		
Hydrology	High water flow & turbidity in rainy season and lowest during summer		
Tangerine Production	3 phases planting & budding, flowering and fruiting. Year 1: land preparation (Jan-April), planting (May-Aug), plant maintenance, fertilising, pesticide application by spraying every 7-10 days. Year 2: Maintenance and spraying frequency continues, water pumped in and out of farm periodically to promote tree maturation. Year 3: Maintenance less frequent, pesticide spraying continues and harvesting sometimes twice per year (Nov-Dec & Feb-March). High prices Feb-March & Aug.		
Other Crop Production	Leaf curl: Jan-Feb. Insecticide & nematicides applied (every 10 days July-March, every 7 days May-June). Pesticide granules applied Sept-March. Highest labour use: Jan, June & Oct-Nov. High production costs April & Aug.	Long-bean & cucumber planted when higher rainfall & soil Ph increases.	Fungus problem July-Feb & leaf disease (insects & worms), May-June.
Fish Culture	Fish are cultured extensively in farm canal systems for personal consumption		
	Cage fish nursing March-June. Stock fingerlings to tangerine canals (Feb-April & Sept-Oct). Cage & pond tablefish culture & sales all year.	No mentioned	No mentioned
Sub / Main canal fishing	Fishing more important to worse-off group. Fish caught in main canal in rainy season (abundant), sub-canal throughout the year,Fish easier caught from sub-canal & main canal during summer low water levels.	Fish caught in canals throughout the year, although which canals, not distinguished.	Fish easier caught from sub-canal & main canal during summer low water levels but very few people do this due to having no time.
Health	Colds & diaorreahia occur sometimes during the year	Few health issues except colds during rainy season	No specific health issues.
Consumption Matrix			
Main food items	Main food items indicated were rice, vegetables, aquatic plants, fish and fruit.		
	Fruit had a higher status of importance amongst the better-off group in comparison with the worse-off group. Vegetables and meat were also important to all other than worse-off males. Both groups purchased these items from traders and markets but also caught fish and collected plants from the wild. Aquatic plants were collected from tangerine canals and the local environment. Vegetables were	Distinguishes between better-off and worse-off groups were not made. Morning glory, Ivy gourd, Chinese kale (males), cabbage & long-bean (females) were important vegetables some of which came from own farms and canals. Fish (snake head, catfish, Nile tilapia, Silver barb) came from informal	Markets, groceries & mobile shops were the main food sources. Egg plant, water mimosa and morning glory were taken from farm canals. Markets, mobile shops and farm canals were sources of fish. Durian, tangerine, santol, mango, jackfruit & rose apple

	purchased by both groups although being less important to the worse-off group. The better-off group tended towards purchasing and females tended to be more involved in food collecting.	markets, farms canals or irrigation canals. Guava, cocnut & rose-apple were fruits from own farms.	were fruits taken from own farms. Freshwater snails, turtles & frogs were collected from the local environment.
Bio-resource Maps	Mostly either crop or fish producers.	Fruit, veg & fish farmers	Tangerine & fish farmers
	Farmers pump water into & out of farms. Tangerine & longan (sold at Talad Tait market) are the main crops grown but other fruit & vegetables are grown (own consumption). Agrochemicals and fertilisers are commonly applied to tangerines, longan, sweetcorn and vegetables of which some of these foods are consumed within the household. These agricultural inputs are mostly obtained from the from local and distant sources are stored in outbuildings or within the household. Fish come from a variety of sources including markets, mobile traders, local pond or cage aquaculture or from catching in either of the main, sub, or farm-canal systems. 'Talad Tai' market, 'Nongkar' market and the Kianthai company were common places for taking and selling cultured fish. Commercial farm canal and pond aquaculture, was most apparent amongst better-off groups whilst cage aquaculture in the main canal was most apparent for worse-off groups, however fish cultured from all types of systems were both sold and consumed.	Water sometimes exchanges between farm canals and fishponds in farms. Fish cultured in ponds are sold at Saphan Pla & Nakhonpathom markets, fruit (mango, rose-apple) & vegetables grown are sold at Pak Klong, Nakhonpathom & Si Mun Muang markets, although both also consumed. Fish grown in farm canals are consumed. Pesticide from village 2 is applied to vegetables. Water / fish from main & sub-canals is used in households. Farm vegetable & household waste is fed to fish.	Tangerines are sold at Talad Tai, Si Mun Muang markets & consumed. Other fruits are grown & fish which are consumed. Pesticide is applied to tangerines & mushrooms. Water / fish from main & sub-canals is used in households. Farm vegetable & household waste is fed to fish.
Agricultural Input Costs	Almost all crops were both sold and consumed		
	Between all groups, overall for all crops grown pesticide was the lowest input cost however for tangerines alone pesticides and fertilisers were indicated to be the highest input costs. Input costs were more evenly distributed amongst seed, fertilizer and labour and management inputs by the better-off male group.	Fertiliser and pesticide were attributed the highest input costs overall for all crops by males and fertiliser and labour and management costs by females.	Seed was the highest input cost for each group except for better-off males who indicated pesticide as the highest cost. For tangerine alone fertiliser and pesticide had the highest input costs.
Agrochemical Use Level	Tangerine was indicated all groups as having the highest pesticide input, by far, of all crops produced.	Tangerine was not indicated by either group, however Chinese kale was the crop indicated to receive the most pesticide.	Tangerine was indicated all groups as having the highest pesticide input, by far, of all crops produced.
	Longan, long-bean and banana also received high levels of pesticide.	Long-bean and Taiwan cabbage were also indicated to receive much pesticide (females) and guava and rose-apple (males).	Longan, long-bean, cucumber and mushroom were indicated to receive high levels of pesticide.

Decisions & responsibilities in Agrochemical Use	Male household heads or farm owners undertake the majority of decisions on the purchase, storage and preparation of agrochemicals, and when and where they should be applied. Better-off females indicated other family members involvement in these decisions. Decisions on how often crops should be sprayed with agrochemicals, varied between groups and included agrochemical salespeople, Tangerine Farmers' Association members, neighbours and other family members but worse-off males indicated male household heads to take decisions on frequency of pesticide use. Either male or female household heads were involved pesticide activities, however better-off groups noted other family members and labourers involvement.	Both better-off and worse-off groups indicated male and female household heads to share decision making and undertaking of activities related to pesticides.	Worse-off group indicated mainly male and female household heads to make decisions and undertake activities related to pesticides and occasionally labourers. Within the better-off groups additionally more family members were involved in pesticide decision making and activities.
Perceptions of Agrochemical Use			
Necessity	Most claimed pesticides were important but also claimed other pest prevention methods were useful.		
Health & Environment	Most participants claimed pesticides to be harmful to both health, expressing concern.		
Desired Outcome	The majority of participants future desires were to reduce their level of pesticide use for reasons given below:		
	Reasons for desired strategies were firstly adverse health effects followed by environment and costs.	Reasons for desired strategies were firstly adverse health effects followed by costs and environment.	Reasons for desired strategies were firstly costs followed by adverse effects on health and the environment.

Sri Lanka

Characteristic	**Variations among Five Communities**				
	Medellewa	**Mulannatuwa ***	**Kuratiyawa**	**Ihala Kalankuttiya**	**Weliyawa**
Location of the community	Kalankuttiya catchment Closer to Kalankutiya tank	Kalankuttiya catchment Away from Kalankutiya tank	Sharing Kalankuttiya command area and Megalewa catchment. Closer to Meegalewa tank	Sharing Kalankuttiya command area and Megalewa catchment. Closer to Kalankuttiya tank	Megalewa command area Closer to Meegalewa tank
Irrigation water flow	From Kalawewa - Mulannatuwa main cannel 304 (D2)	From Kalawewa - Mulannatuwa main cannel 304 (D2)	From Kalankuttiya Tank 308 (D2 and D3)	From Kalankuttiya Tank 308 (D1)	From Meegalewa Tank 309 (D2)

Drainage water flow	To Kalankuttiya tank	To Kalankuttiya tank	To Megalewa tank	To Megalewa tank	To Rajangana tank
Drainage water reuse / re-pumping	Not practiced	Not practiced	Practiced	Practiced	Not practiced
Water availability	High in *Maha* low in *Yala*	Low	High in *Maha* low in *Yala*	High in *Maha* low in *Yala*	Available throughout the year
Cropping pattern	*Maha* – Paddy *Yala* – OFC, Paddy	*Maha* – Paddy and OFC to a higher degree *Yala* – OFC	*Maha* – Paddy *Yala* – OFC, Paddy	*Maha* – Paddy and OFC to a lesser degree *Yala* – OFC, Paddy	*Maha* – Paddy *Yala* – Paddy
Major Income generation activities	Farming	Farming	Farming	Farming and fishing	Farming
Farming as major income generation activity	64%	61%	78%	56%	70%
Availability of other income generation activities	High	High	High	High	Low
Major secondary income generation activity	Government and private sector employments	Animal husbandry	Government and private sector employments	Trading and shop keeping	Government and private sector employments/ labour works
Animal husbandry	Not much practiced	Broiler chicken	Broiler chicken and cattle	Broiler chicken	Cattle
Crop marketing facilities	Easy access to town centre	Poor access to town centre	Poor access to town centre	Easy access to town centre	Easy access to town centre
Educational status	Majority schooled up to grade 08	Majority schooled up to grade 08	Majority schooled up to grade 08	Majority schooled up to grade 08	Majority schooled up to G.C.E. O/L
Well-being ranking	Most households belongs to worse off group and some are belongs to better off group				
Seasonal calendar	All most all the farmers cultivate during main two cultivation seasons (i.e. *Yala* and *Maha*). Majority of the farmers cultivate paddy during *Maha* season and OFC (Chilli and Onion etc.) during the *Yala* season.				
	OFC cultivation is low (compare with the other communities)	OFC cultivation is high (compare with the other communities)	OFC cultivation is low (compare with the other communities)	OFC cultivation is high (compare with the other communities)	OFC cultivation is very low (compare with the other communities)
Consumption matrix	Rice is the staple food				
	Bread and vegetable are the second most important food	Bread and vegetable are the second most important food	Bread is the second most important food	Bread is the second most important food	Bread and vegetable are the second most important food
Bio resource map	Paddy, Chilli, Onion and Vegetable are cultivated in all the communities. All those crops are cultivated for the purpose of consumption and selling. Pesticide is the most important input need for cultivation of Chilli and Onion.				
Activity matrix	Visit to paddy field is the most important primary activity of all the communities. Female tend to do more household activities than males.				

Farmers perception on the necessarily of agrochemicals on plant protection	None of the farmers indicated that there is no effect of agrochemicals on environment and human health. Farmers in all the communities indicated that they are willing to reduce the total amount of pesticides that they apply.

***** In this community, the agricultural fields are located in the Mahaweli system H and settlements are located outside Mahaweli system H.

Appendix 2 PCA Data from Thailand and Sri Lanka of relevance to PRA (E - Environmental Risk Assessment; H - Human Health Risk Assessment)

Thailand

Data Type	Risk Type	Study Sites and Data Results	
		Nakhon chaisi (Mixed crop site)	Nong saeo (mono-crop site)
Hydrology	E	Water flow direction in main and sub-canals is variable being dependent upon rainfall, tidal regime and irrigation gate operation. Water is pumped from sub-canals to farms throughout the year and usually only pumped out of farms during the wet season to prevent flooding. Water may seep from farms back to sub-canals.	Main Canal number 13 flows in a southerly direction through one of the three villages supplying irrigation water to farms whilst main Canal number 33 supplies irrigation water to the other two villages through feeder sub-canals. Irrigation and effluent water commonly mixes in sub-canals which act as irrigation supplies and drainage ditches. Village farm drainage water was indicated to eventually collect in Canal numbers 13 and 32.
Cropping Pattern & Land Use	H & E	Many different types of vegetables and few fruits are grown through the year, which have 1-2 month production cycles. Pesticides applied every few days throughout the year, insecticides more in summer, fungicides in wet season & herbicides all year. More fish culture in one village and shrimp farming in another.	Tangerine is the primary crop grown in each village, although mushroom, longan, sweetcorn, longbean, cucumber & mango are also grown amongst villages. Tangerine production follows 3 phases: planting & budding, flowering and fruiting, although all stages are apparent on farms simultaneously. Year 1: land preparation (Jan-April), planting (May-Aug), plant maintenance, fertilising & pesticide application every 7-10 days. Year 2: Maintenance and spraying frequency continues & water pumped in and out of farm periodically to promote tree maturation. Year 3: Maintenance less frequent, pesticide spraying continues and harvesting, sometimes twice per year (Nov-Dec & Feb-March). Leaf curl, insects, fungus & nematodes cause pest problems at stages of the year. Extensive fish culture occurs in farm canals although cage and pondfish culture extits.
Occupations	H	Farming is the main occupation whilst worse-off people are more involved in farm labour work. Village 2 has more fish culturers.	Largest proportion of communities is involved in farming, followed by on and off-farm labouring. Additionally Government, craft, livestock farming & aquaculture work exist.
Activities & Pesticides	H	Both males and females do farm work whilst farm labour work is most significant for worse-off groups. 'Pesticide related' decision-making and activities lie mainly with male & female household heads & occasionally sons & daughters. Farm labourers also undertake pesticide related 'activities'.	Within better-off groups variation occurs between male and female activities although activities are both on and off-farm, work and social. Worse-off groups revealed more activities and labour work including fish husbandry in both genders. Pesticide related decision-making mostly lies with household heads although other family members may be involved. In aspects of application other advisors may be involved. Those involved in handling pesticides varied although family members and labourers are involved.

Consumption & Pesticide Use	H & E	Rice, vegetable (Chinese kale / cabbage, Longbean), water plants (water mimosa) & freshwater fish are major food items. Some fish and aquatic animals taken from farm / sub-canals. All crops produced are both consumed and sold. Vegetables sometimes fed to farm canal fish. Chinese kale / cabbage, guava & roseapple have highest pesticide applications. Pesticide is a relatively high cost to farmers.	Main food items indicated were rice, vegetables, aquatic plants, fish and fruit although fruit & vegetables were less important to the worse-off groups. Markets groceries and mobile shops were common food sources, although fish and other aquatic fauna and flora were also obtained from local canals and ponds.
Education, Awareness & Pesticide Use	H & E	Largest % of communities have the lowest education level. Most think that pesticides are important but they also use other pest control methods. Most perceive that pesticides pose no health or environmental risk if use 'correctly', whilst some think they are harmful nevertheless. Males show less awareness & concern than females of potential adverse environmental & health effects of pesticides. Economics is an important factor in decision making over pesticide use as most want to continue with the present use level if affordable. However all Village 4 participants wanted to reduce levels for human health reasons.	Larger proportions of the communities are educated to primary school level, where community proportion declines with increasing education level. Most participants claimed pesticides to be harmful to health and environment expressing concern. The majority of participants also wanted to reduce their pesticide use for reasons of which priorities varied between villages although overall health, followed by economics and environment were the apparent priorities. It would appear that the majority deem pesticides as important in crop protection but that other pest control methods are additionally used

Sri Lanka

Data Type	Risk Type	Study Sites and Data Results Kalankuttiya and Meegalewa tanks
Hydrology	E & H	Water is scared resource for the most of the selected communities for both domestic and irrigation purposes. For They depend on the Mahaweli scheme* and rainfall. Generally the community members are depending on ground water for drinking purposes (Wells, tube wells) and they use surface water for irrigation purposes. Multi-use of the water is prominent in these communities such as drinking, bathing, laundry, cooking and washing food, cleaning houses and vehicles, animal husbandry purposes and home garden irrigation and irrigation purposes. Since the study site is a part of the cascade, irrigation water is used continuously.
Water	H & E	The community members are depending on following ground water sources for their drinking water consumption. About 55.1%of them use own wells whereas another 43.3% use open access private wells as their drinking water source. Both Mahaweli water and rainwater are used for farming depending on the availability. Most were dependants on Mahaweli water for irrigation. The majority (92.6%) of the community members uses the distribution channel as the main source of irrigation water. Other water sources were seasonal tanks, perennial tanks and main channels.
Cropping Pattern & Land Use	H & E	Depend on rainfall pattern and water availability there are two main cropping seasons. They are Yala (May to September) and Maha (October to April) seasons. Water availability and the rainfall intensity is high in the Maha compare to Yala and farmers face water scarcity problems in this season. Cropping pattern and land use vary with the main cropping seasons.

		Rice is mainly grown in the Maha season and less in the Yala. About 91.8 %, and 75.3% the community members cultivate paddy in Maha and Yala seasons respectively. Other field crops (OFC), Vegetables, Chilli and onion are the mostly grown crops in the Yala season. About 13.4% of the community members cultivated Chilli and about 33 % of the community members cultivated big onion in Yala. Comparatively rice consumes less pesticide whereas Chilli and onion need lot of pesticides.
Occupations	H	Farming is the main occupation in the study site. Lot of part time farmers in the study sites together with pluriactive community members.
Activities & Pesticides	H	Though male and female are involved in farming mainly male farmers are involved in pesticide spraying. Almost all the farmers use sprayers to apply pesticides.
Consumption & Pesticide Use	H	The staple food in this area is rice and most of the farmers grow their requirement in their fields. Flour based food products are also popular. Other field crops (OFC), Vegetables, Chilli and onion are the mostly grown crops in the Yala season. Most of the cases they grow crops for both to sell and to consume.
Education, Awareness & Pesticide Use	H & E	Almost all the respondents (93.8%) were aware of recommended pesticide dosages. However only 55.7% practiced recommended levels. A considerable portion of the respondents used more than recommended pesticide amounts (35.1%). The reasons for deviating from recommended dosages are: over dosages reduces the risk (23.7%), profit would increase with over dosage (5.2%) and as a preventive method (6.2%). Most of the respondents (91.8%), were aware of safety methods of pesticide application. However only (27.8%) practice them. The majority (78.4%) cleaned equipments used in pesticide application, by rinsing the tank several times with water on land. However, another 14.4% cleaned their equipments by immersing and rinsing the tank in farm ditches. Few farmers immersed their equipments in tanks and drainage channels. Most of the farmers threw their empty bottles into the field (41.2%) and another considerable portion of the farmers brought them home (38.1%) thinking that they can reuse them for domestic purposes. Few farmers (2.1%) threw them into the water bodies. Most farmers them (44%) indicated that application of agrochemicals was the only method of controlling pests. Another 39% stated that pesticides and other methods could be used effectively for pest management. Only 17% respondents' viewpoint was pesticides are not needed for controlling pests. An interesting finding was that most of the farmers (49%) were willing to reduce the total quantity of pesticides. Another 40% would continue to apply agrochemicals if they remain affordable. Few respondents' (7%) willingness was to apply more agrochemicals if cost would be manageable. Interestingly every farmer knew that agrochemicals have bad effects on environment and human health. Half of the respondents said pesticides cause health and environment hazards. Another 45% were said that better management of agrochemicals would not cause health and environment hazards. Though the farmers were aware of health and environmental hazards caused by agrochemicals, some respondents' (5%) viewed that farmers are careless when they apply agrochemicals.

Appendix 3 Type of Household (HH) data collected in Thailand and Sri Lanka.

Thailand

HH Category	Data Type
General Info	HH ID, Respondent name, HH member ID, village & house No., well-being rank & average income.
Profile	Age, education level & occupation.
Activities	HH member ID, activity type
Consumption	Food type, Collection (where, method, who, when, frequency & quantity).
Water Use	Purpose, who, frequency & source.
Crops Grown	Species, farm area, inorganic & organic fertiliser (type, quantity) organic fertiliser origin, production quantity, product destinations & percentages.
Aquatic Animal Production	Species type & source, water source, water area, feed type & quantity, No. Cycles / year, production quantity, destinations of product & percentages.
Farming / Fishing Calendars	*Mixed crops:* (Species, activity type, month of occurrence & frequency). *Perennial Crops:* (Species, No. Cycles / year, activity type, month of occurrence & freq.). *Aquaculture & fishing:* (species, activity, month of occurrence & frequency).
Farm Canal Water Volume	Water system, farm canals (ID, length, width & depth)
Water Management & Irrigation	Water system, farm size, canal ID, high water depth, low water depth inside and outside the farm, sediment removal & frequency)
Pesticide Application	Crop type & area, pesticide use, period of application and frequency, interval between application & watering crops and application strategy (crop specific or whole farm)
Type of Pesticide & Dosages	Crop type, pesticide ID, dose (liquid or solid), application method, application strategy (crop specific or whole farm), storage duration before use.
Pesticide Application Strategy	Apply curatively, preventatively or both.
Pesticide Purchase	Where from and what type of facility.
Pesticide Application Criteria	Reasoning behind application (fixed, depending on pest density, weather dependent & other).
Pesticide Equipment Cleaning	Rinse, immerse or other.
Pesticide Storage & Preparation	Pesticide ID, place of storage, place of preparation, place of accidental spills, use of left over pesticide.
Pest Identification	Description of methods used for identifying pests.
Farmer Training & Knowledge	Training (formal, informal, who received, topic, provider, duration, when & frequency)
Health	Symptoms, who, frequency of occurrence, protective measures, type of treatment received.
Testing & Treatment for Pesticide Poisoning	Who
Suicide Attempts Using Pesticide	Who
Animal / Plant deaths from Pesticide Poisoning	Where (canal, pond), when (year) & cause (pesticide or not sure)
Stakeholder Relations	Stakeholder type & description of relationship.
Information Sources	Information type, source & rank of usefulness.
Pesticide Advertising Influence	Type of advertising & rank of the influence it has over choice of purchase.
Farmer Organisations	Membership of farmer organisation & rank of benefit.
Choice of Pesticide Supplier	Ranking of factors influencing choice of pesticide supplier (convenience, stock variety, price, reliability, advice, discount or other).
Choice of Product	Ranking of factors influencing choice of pesticide product (efficiency of product, discount, brand name, advertising, advice or other).
Pesticide Supplier's Terms & Conditions	Description of pesticide supplier's terms & conditions.
Poor Quality Pesticide Products	Product type & details, crop type, pest type, when used & where purchased from.
Aims, Goals & Needs	Future aims, need for information & type.

Sri Lanka

HH category	Data type
General Info	Respondent name, Well being Group, Well being Number, Household Number, Village, Irrigation block, Settler / Non settler, Generation
Profile	Relationship to Household head, Age, sex, education level, Ethnic group, Religion, Employment status (Local, Foreign), Average Income Per month
Activities	Farmer organisations and benefits getting from it.
Consumption	Type of Food (Rice, Vegetables, Fruits, Tin fish, Dried fish, Inland Fish, Marine fish, Meat Aquatic Plants Other) Buy or Grow / Catch (who, where, how much, how often)
Water Use	Accessibility and Distance to Water Resources –Type of Water Sources (Agro well, Open Access private well, Tube well, Own Well, Pipe (Tap) water Public, Common Well, Canal Tank) Accessibility and Distance to Water Resources (Drinking Water, Other Domestic purpose, Farming), Ownership, Access, Distance from house, Distance from Farm, Water availability problem (Describe the severity of the scarcity) Water quality problems (Describe the type of pollution) When does the problem occur (months or season) Domestic Usage - Washing clothes, Washing food, Cleaning house, vehicles, Household surroundings, Giving water to animals, Washing animals, Bathing, Cooking, Drinking, Home garden irrigation, (Who does it, Water Source Period, How often) Irrigation Water Usage- Water Source (Seasonal Tank, Perennial tank Main Canal, Distribution canals, Agro wells, Drainage cannel, other), Name of the water source, Farm size (cares) Water Pumping, Natural Water Distribution, Water Availability Severity of the water availability problem- severity, When occurs, Reason
Crop Grown	Crops Cultivation (*Maha* / *Yala*) - Type of Crop (Paddy, chillies, Big Onion), Area, Tenure, Yield, Production Level, Total Produced, Quantity Consumed, Sold, Average market Price
Aquatic Animal Production	Type of the fisherman, Full time fisherman / Part time Fisherman / Full time farmer Part time farmer Average catch per month (Kg- all species or-distinguish between species if possible)
Farming/ Fishing Calendars	Type of Crop: Management practice (Land preparation, Seeds / Sowing, Weeding Operations, Insecticide application, Herbicide application, Fungicide application, Fertilizer application, Irrigation (Water Use), Harvesting, Threshing, Winnowing, Drying, Transport)
Livestock information	Type of Animals (Cattle, Buffalo, Goats, Poultry, Swine, Sheep) Type of Products, For Market or Home Consumption, Water Source, Food Source.
Agricultural Inputs Pesticide Application Type of Pesticide & Dosages Pesticide Application Storage Pesticide Purchase Pesticide Application Criteria Pesticide Equipment Cleaning Pesticide Storage & Preparation Pest Identification	Fertilizer, Buying place, Quantity, Advise on fertilizer use, reasons, Source of the advice. Awareness of the recommended level, Dosage, Actual dosage, Reasons Ways of the improvement of fertilizer supply (Quality, Affordability, Credit, Availability Pesticide usage: _ Pest identification, Buying place, Paying methods, Volume, Quantity, Advise on pesticide use, reasons, Source of the advice. Awareness of the recommended level, Dosage, Actual dosage, Reasons Ways of the improvement of fertilizer supply (Quality, Affordability, Credit, Availability Factors influencing the purchasing decision of Pesticide Criteria used to select Pesticide Product Pesticide application for different crops (Pest type, Pesticide common name, Brand name, Company, Type (Organic or inorganic) Active ingredient Storage duration before application, Time of application, Safety period Pesticide Storage, Preparation & Disposal, Where, How Biological factors Influencing the Application of Pesticide Awareness, Label information, Colour code, Safety method (Awareness and practice) Cleaning of pesticide applicator Actual dilution by farmer, Field dosage, Application method, Frequency,

	Interval between application and watering,
Farmer Training & Knowledge	Type of training, Where, what, how often, how long and duration
Health	Pest Pesticides poisoning, Protective measure, Symptoms & treatments
Testing & Treatment for Pesticide Poisoning	Examination for Pesticide Poisoning, Treatment for Pesticide Poisoning, Suicide Attempts by Pesticide Poisoning,
Suicide attempting Using Pesticide	Suicide attempting Using Pesticide
Animal/Plant deaths from Pesticide Poisoning	Type of animals/plants, place of found and time

Appendix 4 TOXSWA scenario parameters for Thailand and Sri Lanka

	Country	Sri Lanka		Thailand		Comments
	Location	Farm Canals		Farm Canals		
	Crop Type	OFC's	Rice	Mixed Fruit & Vegetables		
	TOXSWA Scenarios Parameters	Scenario1: Yala (Dry)	Scenario 2: Maha (Wet)	Scenario 1: Dry Season	Scenario 2: Wet Season	Worse case scenarios considered in each case
	Slope	0.0001 (lowest value)	0.0001	0.0001	0.0001	Assumed vertical slope
	Bottom width	1 m	1 m	1 m	1 m	For 1 m^3 water
	Suspended solids					
	- concentration (g/m^3)	50	50	50	50	Assumed from local knowledge
	- mass ratio organic matter	0.5	0.5	0.5	0.5	Assumed to be low
	Water Layer Segments					
	- length water body (m)	1	1	1	1	For 1 m^2 water surface
	- No. segments	1	1	1	1	Insignificant
	Macrophytes	0	0	0	0	Assumed worst case
	Sediment Segments	1	1	1	1	Assumed 1
	- thickness (m)	0.05	0.05	0.05	0.05	Assumed depth
	- bulk density (kg/m^3)	800	800	800	800	Assumed low bulk density
	- porosity	0.5				Default – insignificant
	- tortuosity	0.5				Default – insignificant
	- mass ratio	0.085	0.085	0.085	0.085	Assumed low organic matter
Hydrology	Flow velocity water body	0	0	0	0	Assumed no flow
	Water depth water body (m)	0.10	0.15	0.50	0.75	Assumed lowest from expert judgement
	Temp. (water & sediment °C)	30	28	33	30	Assumed average of seasonal temp.
	Dispersion coefficient in water (m^2/d)	1	1	1	1	Dummy value when flow is zero
	Dispersion length in sediment (m)	0	0	0	0	Assumed no dispersion in sediment
	Upward seepage & concentration of pesticide in incoming water					
	- seepage (mm/d)	0	0	0	0	Assumed no upward seepage
	- conc. (mg/L)	0	0	0	0	Assumed no upward seepage
	Initialisation					
	Segments	Water layer	Water layer	Water layer	Water layer	Assumed pesticide stays in water
	- position (m)	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	Insignificant
	- initial conc. (µg/L)	0	0	0	0	

Simulation	Total time	120	120	45 or 180 days	45 or 180 days	Depending on length of crop season
	Calculation time step	600 seconds	600 seconds	600 seconds	600 seconds	Default
	Output time	0.5 days	0.5 days	0.5 days	0.5 days	Default
	Segment	1 selected	1 selected	1 selected	1 selected	Assumed only 1 segment
	Position (m)	0.00-1.00	0.00-1.00	0.00-1.00	0.00-1.00	1 m depth in segment
	Output	Choose 'Áll'	Choose 'Áll'	Choose 'Áll'	Choose 'Áll'	Default

Appendix 5 Pesticide properties for calculation of second tier PEC

Active ingredient name	Molecular Mass (g/mole)	Psat (mPa)	Temp. Psat (°C)	S (g/L)	Temp. S (°C)	DT50-water (d)	DT50-sedim. (d)	*K_{om} (L/kg)
Abamectin	873.1	2E-07	22.5	0.005000	20	56	10000	2860
Alachlor	269.77	1.90E-03	25	0.240000	22.5	149	22	117
Azoxystrobin	403.4	1.10E-10	25	0.006000	20	213	10000	246
2,4-D sodium salt	221	1.00E-03	20	0.890000	25	10000	10000	26
Benomyl	290.3	1.00E-08	25	0.002000	25	0.1	10000	1000
Captan	300.61	1.10E-05	25	0.005100	22.5	1	1	75
Carbaryl	201.23	1.60E-04	24	0.120000	30	14	14	34
Carbendazim	191.19	6.50E-08	20	0.008000	20	90	10000	76
Carbofuran	221.25	8.00E-05	22.5	0.351000	25	50	50	13
Carbosulfan	380.5	4.10E-05	25	0.000300	25	7.6	10000	1000
Chlorfenapyr	407.6	1.00E-15	20	1.000000	20	10000	10000	1000
Chlorfluazuron	540.7	1.00E-08	20	0.000010	20	42	10000	1000
Chlorpyrifos	350.62	2.70E-03	25	0.001400	25	1.5	94	3470
Cypermethrin	416.3	1.90E-07	20	0.000004	20	14	10000	2137
Dicrotophos	237.2	9.30E-03	20	1.000000	20	20	20	1000
Difenoconazole	406.3	3.30E-08	25	0.015000	25	145	10000	1000
Diflubenzuron	310.69	1.20E-07	25	0.000080	20	10	10000	104
Dimethoate	229.2	1.10E-03	25	23.800000	20	21	10000	17
EPN	323.3	4.10E-05	23	0.00000092	24	15	10000	96700
Fenobucarb	301.3	1.70E-06	25	0.006000	22.5	75	16	571
Fipronil	437.2	3.70E-07	25	0.001900	25	28	10000	1000
Glyphosat	169.1	1.00E+00	25	12.000000	25	30	10000	3200
Lufenuron	511.2	4.00E-06	25	0.000060	25	70	10000	22
Malathion	330.3	5.30E-03	30	0.145000	25	1	10000	1000
Mancozeb	330	1.00E+00	25	0.006000	25	70	10000	1143
MCPA	200.6	2.30E-05	25	0.734000	25	35	10000	29
Metalaxyl	279.3	7.50E-04	25	8.400000	22	56	10000	27
Methamidophos	141.1	2.30E-03	20	200.000000	20	23.5	10000	5
Methomyl	162.2	6.70E-03	25	58.000000	25	30	10000	12
methyl parathion	263.2	2.00E-03	20	0.060000	25	58	10000	141
Mevinphos	224.15	1.70E-02	20	600.000000	22.5	20.5	10000	17
Omethoate	213.2	3.30E-03	20	1000.000000	25	4	10000	13
Paraquat dichloride	186.3	1.00E-05	25	620.000000	20	7	10000	10000
Profenofos	373.6	1.24E-04	25	0.028000	25	8	10000	13965
Propanil	218.1	5.33E-03	25	0.130000	20	1	10000	149
Propineb	289.8	0.0001	22.5	0.010000	20	1	10000	1000
Prothiofos	345.2	6.00E-04	22.5	0.000070	20	280	10000	1000
Tetradifon	356	3.20E-08	20	0.000078	20	52	10000	455
Zineb	275.8	1.00E-05	20	0.010000	22.5	37	10000	571

* K_{om}, sorption coefficient for organic matter, can be used for sorption to suspended solids and for sorption to sediment.

Appendix 6 First and second tier PEC's for crop-pesticide combinations in Thailand and Sri Lanka.

PEC's of crop-pesticide combinations are based on dosages collected in household surveys in case of Thailand and on recommended dosages in case of Sri Lanka. The second tier PEC is only calculated for pesticide-crop combination yielding the highest first-tier PEC.

Thailand (mixed crop site)

Pesticide name	Crop name	Load	Number of applications	Application Interval	Spray drift	1st tier PEC	2nd tier PEC
		g a.i./ha.		days	-	µg/L	µg/L
Abamectin	Chinese leek(Kui chai)	9.1	6	7	1	11	
Abamectin	Chinese leek(Kui chai)	12.5	6	7	1	15	
Abamectin	For all crops	12.7	6	7	1	15	
Abamectin	Amaranth (Pak Khom)	10.9	9	5	1	20	
Abamectin	Chinese cabbage (Kwang tung)	9.0	15	3	1	27	
Abamectin	Lettuce (Pak kad horm)	13.5	15	3	1	41	
Abamectin	Chinese kale (Ka na)	18.0	15	3	1	54	
Abamectin	For all crops	78.9	6	7	1	95	
Abamectin	Chinese kale (Ka na)	208.3	9	5	1	375	195
Carbendazim	Holy basil	68.5	3	14	1	41	
Carbendazim	Chinese cabbage (Kwang tung)	187.5	15	3	1	563	
Carbendazim	Roseapple	500.0	6	7	1	600	
Carbendazim	Lettuce (Pak kad horm)	281.3	15	3	1	844	
Carbendazim	Roseapple	753.3	6	7	1	904	
Carbendazim	Chinese kale (Ka na)	375.0	15	3	1	1125	734
Carbendazim	Guava	992.1	5	10	1	992	
Carbendazim	Guava	1250.0	5	10	1	1250	841
Carbendazim	Roseapple	95.5	6	7	1	115	
Carbosulfan	Roseapple	100.8	6	7	1	121	24.0
Chlorfenapyr	For all crops	48.4	6	7	0.3	17	
Chlorfenapyr	For all crops	70.7	6	7	1	85	
Chlorfenapyr	Amaranth (Pak Khom)	60.4	9	5	1	109	99
Chlorfluazuron	Lettuce (Pak kad horm)	10.6	2	24	1	4.2	
Chlorfluazuron	For all crops	16.7	9	5	1	30	14
Cypermethrin	Roseapple	19.1	6	7	1	23	
Cypermethrin	Roseapple	100.0	5	10	1	100	
Dicrotophos	For all crops	233.4	6	7	1	280	
Dicrotophos	For all crops	1157.9	6	7	1	1389	
Dicrotophos	Chinese kale (Ka na)	1432.3	9	5	1	2578	740
Difenoconazole	For all crops	88.4	6	7	1	106	80
Diflubenzuron	Roseapple	100.0	5	10	1	100	24
Dimethoate	Roseapple	2260.8	6	7	1	2713	984
Fipronil	Amaranth (Pak Khom)	30.2	9	5	1	54	20
Glyphosate	For all crops	2891.6	6	7	0.3	1041	428
Glyphosate	Grass	393.4	1	183	0.3	24	
Glyphosate	Grass	761.9	1	365	0.3	46	

Glyphosate	Grass	1326.7	1	243	1	265	
Lannate (methomyl)	Drumstick Moringa (Ma rum)	133.3	3	15	1	80	
Lannate (methomyl)	Chinese kale (Ka na)	578.7	9	5	1	1042	
Mancozeb	Lettuce (Pak kad horm)	50.8	2	24	1	20	
Mancozeb	Chinese leek(Kui chai)	60.9	6	7	1	73	
Mancozeb	Roseapple	100.8	6	7	1	121	61
Mancozeb	Amaranth (Pak Khom)	72.4	9	5	1	130	60
Malathion	Guava	5389.6	6	7	1	6468	1067
Metalaxyl	For all crops	1096.5	6	7	1	1316	788
Methamidophos	Holy basil	205.5	3	14	1	123	
Methamidophos	angled gourd	480.0	6	7	0.3	173	
Methamidophos	Roseapple	229.2	6	7	1	275	
Methamidophos	Roseapple	565.2	6	7	1	678	
Methamidophos	Roseapple	800.0	5	10	1	800	
methamidophos	Guava	3600.0	5	10	1	3600	
methamidophos	Guava	3896.1	6	7	1	4675	
Methamidophos	Roseapple	24107.1	6	7	1	28929	11040
Methomyl	For all crops	116.3	6	7	0.1	14	
Methomyl	Roseapple	20.2	6	7	1	24	
Methomyl	Guava	82.8	5	10	1	83	
Methomyl	Roseapple	160.0	5	10	1	160	
Methomyl	Guava	396.8	5	10	1	397	
Methomyl	Roseapple	400.0	6	7	1	480	
Methomyl	Guava	500.0	5	10	1	500	
Mevinphos	Drumstick Moringa (Ma rum)	533.3	3	15	1	320	142
Phosphorus acid	For all crops	1754.4	6	7	1	2105	
Profenofos	For all crops	242.2	6	7	0.3	87	
Profenofos	For all crops	166.7	9	5	1	300	
Profenofos	For all crops	333.3	6	7	1	400	
Profenofos	For all crops	1204.8	6	7	0.3	434	
Profenofos	Chinese cabbage (Kwang tung)	250.0	15	3	1	750	
Profenofos	Lettuce (Pak kad horm)	375.0	15	3	1	1125	
Profenofos	Chinese kale (Ka na)	500.0	15	3	1	1500	166
Propineb	Drumstick Moringa (Ma rum)	136.1	3	15	1	82	
Propineb	For all crops	233.3	6	7	1	280	
Propineb	Roseapple	933.3	5	10	1	933	184
Prothiofos	Guava	892.9	5	10	1	893	710

Thailand (mono-crop site)

Pesticide name	Crop name	Load	Number of applications	Application Interval	Spray drift	1st tier PEC	2nd tier PEC
		g a.i./ha.		days	-	µg/L	µg/L
Abamectin	Longan	22.50	15	2	1	9.0	6.7
Abamectin	Tangerine	0.77	5	12	1	1.8	
Abamectin	Tangerine	6.79	10	3	1	4.1	
Abamectin	Tangerine	14.63	15	2	1	5.9	
Abamectin	Tangerine	8.12	15	4	1	6.5	
Abamectin	Tangerine	6.75	7	9	1	12	
Abamectin	Tangerine	9.33	7	26	1	48	8.0
Captan	Tangerine	8.01	7	4	1	6.4	
Captan	Tangerine	8.01	15	4	1	6.4	
Captan	Tangerine	97.15	7	26	1	505	19
Carbaryl	Tangerine	26.98	15	4	1	22	6.3
Carbendazim	Longan	312.50	15	2	1	125	107
Carbendazim	Longbean	195.31	5	6	1	234	
Carbendazim	Longbean	195.31	7	9	1	352	205
Carbendazim	Tangerine	173.61	30	2	1	69	
Carbendazim	Tangerine	125.00	7	9	1	225	
Carbendazim	Tangerine	757.27	15	2	1	303	
Carbendazim	Tangerine	757.27	10	3	1	454	
Carbendazim	Tangerine	260.42	7	9	1	469	
Carbendazim	Tangerine	260.42	7	9	1	469	
Carbendazim	Tangerine	1437.77	10	3	1	863	
Carbendazim	Tangerine	773.99	7	9	1	1393	
Carbendazim	Tangerine	1174.78	5	6	1	1410	
Carbendazim	Tangerine	5639.10	7	4	1	4511	3603
Carbendazim	Tangerine	5639.10	15	4	1	4511	
Carbofuran	Coconut	245.45	30	2	0.3	29	20
Carbofuran	Coconut	245.45	30	2	0.3	29	
Cypermethrin	Tangerine	46.40	15	4	1	37	
Cypermethrin	Tangerine	46.40	7	4	1	37	
Cypermethrin	Tangerine	187.50	7	4	1	150	58
Cypermethrin	Tangerine	187.50	15	4	1	150	
Dicrotophos	Tangerine	165.07	30	2	1	66	
Dicrotophos	Tangerine	165.07	7	4	1	132	62
Dimethoate	Longan	1041.67	15	2	1	417	267
Dimethoate	Tangerine	83.33	30	2	1	33	
Dimethoate	Tangerine	83.33	7	9	1	150	
Dimethoate	Tangerine	378.49	15	2	1	151	
Dimethoate	Tangerine	204.08	7	4	1	163	
Dimethoate	Tangerine	367.65	20	3	1	221	
Dimethoate	Tangerine	555.56	30	2	1	222	
Dimethoate	Tangerine	200.00	10	6	1	240	
Dimethoate	Tangerine	204.08	10	6	1	245	
Dimethoate	Tangerine	378.49	7	4	1	303	
Dimethoate	Tangerine	200.00	7	9	1	360	
Dimethoate	Tangerine	555.56	7	4	1	444	
Dimethoate	Tangerine	600.00	7	4	1	480	
Dimethoate	Tangerine	600.00	15	4	1	480	
Dimethoate	Tangerine	1238.39	15	2	1	495	

Dimethoate	Tangerine	694.44	15	4	1	556	
Dimethoate	Tangerine	694.44	7	4	1	556	
Dimethoate	Tangerine	312.50	7	9	1	563	
Dimethoate	Tangerine	312.50	7	9	1	563	
Dimethoate	Tangerine	1009.70	10	3	1	606	
Dimethoate	Tangerine	854.70	7	4	1	684	
Dimethoate	Tangerine	1258.97	10	3	1	755	
Dimethoate	Tangerine	1009.70	15	4	1	808	
Dimethoate	Tangerine	1142.86	7	4	1	914	
Dimethoate	Tangerine	367.65	7	13	1	956	
Dimethoate	Tangerine	1653.44	10	3	1	992	
Dimethoate	Tangerine	1666.67	10	3	1	1000	
Dimethoate	Tangerine	1258.97	15	4	1	1007	
Dimethoate	Tangerine	1258.97	7	4	1	1007	
Dimethoate	Tangerine	848.74	15	6	1	1018	
Dimethoate	Tangerine	848.74	5	6	1	1018	
Dimethoate	Tangerine	1428.57	7	4	1	1143	
Dimethoate	Tangerine	1428.57	15	4	1	1143	
Dimethoate	Tangerine	2083.33	10	3	1	1250	
Dimethoate	Tangerine	500.00	7	13	1	1300	
Dimethoate	Tangerine	1653.44	15	4	1	1323	
Dimethoate	Tangerine	1653.44	7	4	1	1323	
Dimethoate	Tangerine	1666.67	7	4	1	1333	
Dimethoate	Tangerine	2401.96	10	3	1	1441	
Dimethoate	Tangerine	1804.51	7	4	1	1444	
Dimethoate	Tangerine	1804.51	15	4	1	1444	
Dimethoate	Tangerine	848.74	7	9	1	1528	
Dimethoate	Tangerine	4000.00	15	2	1	1600	
Dimethoate	Tangerine	2203.70	7	4	1	1763	
Dimethoate	Tangerine	2401.96	15	4	1	1922	
Dimethoate	Tangerine	1666.67	5	6	1	2000	
Dimethoate	Tangerine	1142.86	10	9	1	2057	
Dimethoate	Tangerine	1238.39	7	9	1	2229	
Dimethoate	Tangerine	641.03	10	18	1	2308	
Dimethoate	Tangerine	4000.00	20	3	1	2400	
Dimethoate	Tangerine	2083.33	5	6	1	2500	
Dimethoate	Tangerine	6033.18	10	3	1	3620	
Dimethoate	Tangerine	6033.18	30	3	1	3620	
Dimethoate	Tangerine	2083.33	7	9	1	3750	
Dimethoate	Tangerine	1666.67	15	12	1	4000	
Dimethoate	Tangerine	2203.70	10	12	1	5289	
Dimethoate	Tangerine	1487.32	7	26	1	7734	
Dimethoate	Tangerine	2673.80	7	26	1	13904	
Dimethoate	Tangerine	7407.41	15	12	1	17778	2066
EPN	Longbean	260.42	5	6	1	313	
EPN	Longbean	260.42	7	9	1	469	45
Mancozeb	Tangerine	408.16	7	4	1	327	
Mancozeb	Tangerine	1135.48	15	2	1	454	
Mancozeb	Tangerine	408.16	10	6	1	490	
Mancozeb	Tangerine	600.00	10	6	1	720	
Mancozeb	Tangerine	1135.48	7	4	1	908	
Mancozeb	Tangerine	600.00	7	9	1	1080	
Mancozeb	Tangerine	5600.00	15	2	1	2240	

Mancozeb	Tangerine	5600.00	20	3	1	3360	1705
Methamidophos	For all crop	200.00	7	4	1	160	
Methamidophos	For all crop	200.00	15	4	1	160	
Methamidophos	For all crop	200.00	5	6	1	240	112
Methamidophos	Guava	218.18	30	2	1	87	48
Methamidophos	Guava	218.18	30	2	1	87	
Methamidophos	Tangerine	62.82	10	3	1	38	
Methamidophos	Tangerine	62.82	7	13	1	163	
Methamidophos	Tangerine	454.55	7	4	1	364	
Methamidophos	Tangerine	454.55	15	4	1	364	
Methamidophos	Tangerine	1406.25	10	3	1	844	
Methamidophos	Tangerine	2819.48	15	2	1	1128	
Methamidophos	Tangerine	2819.48	15	2	1	1128	
Methamidophos	Tangerine	3450.66	15	2	1	1380	
Methamidophos	Tangerine	3656.25	15	2	1	1463	
Methamidophos	Tangerine	1406.25	5	6	1	1688	
Methamidophos	Tangerine	2819.48	10	3	1	1692	
Methamidophos	Tangerine	2819.48	10	3	1	1692	
Methamidophos	Tangerine	750.00	7	13	1	1950	
Methamidophos	Tangerine	3450.66	10	3	1	2070	
Methamidophos	Tangerine	621.76	7	17	1	2114	
Methamidophos	Tangerine	3656.25	10	3	1	2194	
Methamidophos	Tangerine	1406.25	7	9	1	2531	
Methamidophos	Tangerine	3656.25	7	4	1	2925	
Methamidophos	Tangerine	2819.48	5	6	1	3383	
Methamidophos	Tangerine	2819.48	5	6	1	3383	
Methamidophos	Tangerine	3450.66	5	6	1	4141	1929
Methomyl	Tangerine	347.22	7	4	1	278	
Methomyl	Tangerine	347.22	10	6	1	417	148
Profenofos	Tangerine	52.35	10	3	1	31	
Profenofos	Tangerine	43.40	15	4	1	35	
Profenofos	Tangerine	43.40	7	4	1	35	
Profenofos	Tangerine	55.84	7	4	1	45	
Profenofos	Tangerine	55.84	5	6	1	67	
Profenofos	Tangerine	206.68	10	3	1	124	
Profenofos	Tangerine	52.35	7	13	1	136	
Profenofos	Tangerine	260.42	10	3	1	156	
Profenofos	Tangerine	206.68	15	4	1	165	
Profenofos	Tangerine	206.68	7	4	1	165	
Profenofos	Tangerine	260.42	7	4	1	208	
Profenofos	Tangerine	260.42	5	6	1	313	
Profenofos	Tangerine	651.04	10	3	1	391	
Profenofos	Tangerine	260.42	15	12	1	625	
Profenofos	Tangerine	390.63	7	9	1	703	
Profenofos	Tangerine	390.63	7	9	1	703	
Profenofos	Tangerine	651.04	5	6	1	781	
Profenofos	Tangerine	651.04	7	9	1	1172	
Profenofos	Tangerine	2467.11	7	4	1	1974	
Profenofos	Tangerine	2467.11	15	6	1	2961	378
Tetradifon	Tangerine	65.28	7	4	1	52	
Tetradifon	Tangerine	65.28	10	6	1	78	

Tetradifon	Tangerine	201.43	7	4	1	161	
Tetradifon	Tangerine	147.45	10	12	1	354	93
Zineb	Tangerine	26.67	7	13	1	69	
Zineb	Tangerine	1135.48	15	2	1	454	
Zineb	Tangerine	833.33	10	3	1	500	
Zineb	Tangerine	833.33	7	4	1	667	
Zineb	Tangerine	833.33	15	4	1	667	
Zineb	Tangerine	1135.48	7	4	1	908	
Zineb	Tangerine	833.33	5	6	1	1000	
Zineb	Tangerine	2742.86	7	4	1	2194	
Zineb	Tangerine	5035.88	10	3	1	3022	
Zineb	Tangerine	3888.89	7	4	1	3111	
Zineb	Tangerine	5035.88	15	4	1	4029	
Zineb	Tangerine	5035.88	7	4	1	4029	
Zineb	Tangerine	2742.86	10	9	1	4937	
Zineb	Tangerine	3888.89	10	18	1	14000	1947

Sri Lanka

Pesticide name	Crop name	Load	Number of applications	Application Interval	Spray drift	1st tier PEC	2nd tier PEC	Dilution factor	2nd tier tank PEC
		g a.i./ha.		days	-	µg/L	µg/L	-	µg/L
Alachlor	Onion	380	1		1	380	379	100	3.79
Alachlor	Rice	380	1		1	380	379	1000	0.38
Captan	Onion	650	1		1	650	649	100	6.49
Captan	Rice	650	1		1	650	649	1000	0.65
Carbaryl	Chilli	850	3	14	1	2550	1038	300	3.46
Carbaryl	Onion	850	2	14	1	1700	1005	100	10.05
Carbofuran	Chilli	120	3	14	1	360	233	300	0.78
Carbofuran	Rice	120	1		1	120	120	1000	0.12
Chlorpyrifos	Chilli	400	2	14	1	800	383	300	1.28
Chlorpyrifos	Onion	400	1		1	400	382	100	3.82
Dimethoate	Chilli	380	3	7	1	1140	722	300	2.41
Dimethoate	Onion	380	2	7	1	760	594	100	5.94
Dimethoate	Rice	380	2	7	1	760	594	1000	0.59
Fenobucarb	Chilli	500	2	21	1	1000	657	300	2.19
Fenobucarb	Onion	500	1		1	500	493	100	4.93
Fenobucarb	Rice	500	1		1	500	493	1000	0.49
Glyposate	Chilli	340	2	21	1	680	376	300	1.25
Glyposate	Onion	340	2	21	1	680	376	100	3.76
Glyposate	Rice	340	2	21	1	680	376	1000	0.38
Mancozeb	Chilli	280	1		1	280	276	300	0.92
Mancozeb	Onion	280	1		1	280	276	100	2.76
Mancozeb	Rice	280	1		1	280	276	1000	0.28
MCPA	Chilli	600	2	21	1	1200	810	300	2.70
MCPA	Onion	600	2	21	1	1200	810	100	8.10
MCPA	Rice	600	2	21	1	1200	810	1000	0.81
Propanil	Chilli	360	1		1	360	359	300	1.20
Propanil	Onion	360	1		1	360	359	100	3.59
Propanil	Rice	360	1		1	360	359	1000	0.36

Appendix 7 Results of NEC calculations for all pesticides evaluated in Thailand and/or Sri Lanka (NED = Not Enough Data)

Active ingredient name	Cass-number	Pesticide type	NEC 1st tier (µg/L)	NEC 2nd tier (µg/L)
Abamectin	71751-41-2	insecticide, acaricide	0.0034	NED
Alachlor	15972-60-8	herbicide	0.46	
Bispyribac-sodium	125401-75-4	herbicide	63	
Captan	133-06-2	fungicide	1.3	
Carbaryl	63-25-2	insecticide, plant growth regulator	0.0042	0.043
Carbendazim	10605-21-7	fungicide	0.56	
Carbofuran	1563-66-2	insecticide, nematocide	0.40	
Carbosulfan	55285-14-8	insecticde	0.015	
Chlorfenapyr	122453-73-0	insecticide, acaricide	0.061	
Chlorfluazuron	71422-67-8	insecticide	0.0091	
Chlorpyrifos	2921-88-2	insecticide	0.0038	0.0067
Cypermethrin	52315-07-8	insecticide	0.0012	0.00088
Diafenthiuron	80060-09-9	insecticide, acaricide	0.0070	
Dicrotophos	141-66-2	insecticide, acaricide	3.4	
Difenoconazole	119446-68-3	fungicide	0.50	
Diflubenzuron	35367-38-5	insecticide	0.33	
Dimethoate	60-51-5	insecticide, acaricide	0.026	0.033
EPN	2104-64-5	insecticide, acaricide	0.0010	0.010
Fenobucarb	3766-81-2	insecticide	1.0	
Fenoxycarb	72490-01-8	insecticide	0.00016	
Fipronil	120068-37-3	insecticide	0.46	
Gibberellic acid	77-06-5	plant growth regulator	1430	
Glyphosate	1071-83-6	herbicide	100	
Glyphosate-isopropylammonium	38641-94-0	herbicide	32	
Glyphosate-trimesium	81591-81-3	herbicide	107	
Malathion	121-75-5	insecticide, acaricide	0.018	0.0066
Mancozeb	8018-01-7	fungicide	0.22	
MCPA	94-74-6	herbicide	4.3	
Metalaxyl	57837-19-1	fungicide	120	
Methamidophos	10265-92-6	insecticide, acaricide	0.33	8.4
Methomyl	16752-77-5	insecticide, acaricide	0.080	
Mevinphos	26718-65-0 and 7786347	insecticide, acaricide	0.0019	0.023
Omethoate	1113-02-6	insecticide, acaricide	0.21	
Oxadiazon	19666-30-9	herbicide	0.56	
Phosalone	2310-17-0	insecticide, acaricide	0.0069	
Profenofos	41198-08-7	insecticide, acaricide	0.011	0.10
Propanil	709-98-8	herbicide	0.50	
Propargite	2312-35-8	acaricide	0.72	
Propineb	12071-83-9	fungicide	19	
Prothiofos	34643-46-4	insecticide	0.14	
Tetradifon	116-29-0	acaricide	9.0	
Zineb	12122-67-7	fungicide	2.0	

Appendix 8 Second tier PEC / NEC risk quotients for crop-pesticide combinations in Thailand and Sri Lanka

Thailand (mixed crop site)

Pesticide name	Crop name	PEC / 1st tier NEC	PEC / 2nd tier NEC
Mevinphos	Drumstick Moringa (Ma rum)	74737	6174
Malathion	Guava	59278	161667
Abamectin	Chinese kale (Ka na)	57353	No value
Dimethoate	Roseapple	37846	29818
Methamidophos	Roseapple	33455	1314
Profenofos	Chinese kale (Ka na)	15091	1660
Prothiofos	Guava	5069	
Chlorfenapyr	Amaranth (Pak Khom)	1616	
Carbosulfan	Roseapple	1600	
Chlorfluazuron	For all crops	1516	
Carbendazim	Guava	1502	
Carbendazim	Chinese kale (Ka na)	1311	
Mancozeb	Roseapple	276	
Mancozeb	Amaranth (Pak Khom)	271	
Dicrotophos	Chinese kale (Ka na)	218	
Difenoconazole	For all crops	159	
Diflubenzuron	Roseapple	72	
Fipronil	Amaranth (Pak Khom)	42	
Propineb	Roseapple	10	
Metalaxyl	For all crops	6.6	
Glyphosate	For all crops	4.3	

Thailand (mono-crop site)

Pesticide name	Crop name	PEC / 1st tier NEC	PEC / 2nd tier NEC
Dimethoate	Tangerine	79462	62606
Cypermethrin	Tangerine	48583	66250
EPN	Longbean	44700	4470
Profenofos	Tangerine	34364	3780
Dimethoate	Longan	10269	8091
Mancozeb	Tangerine	7750	
Carbendazim	Tangerine	6434	
Methamidophos	Tangerine	5845	
Abamectin	Tangerine	2344	
Abamectin	Longan	1976	
Methomyl	Tangerine	1850	
Carbaryl	Tangerine	1490	
Zineb	Tangerine	974	
Carbendazim	Longbean	365	
Methamidophos	For all crop	339	
Carbendazim	Longan	190	
Methamidophos	Guava	145	
Carbofuran	Coconut	49	
Dicrotophos	Tangerine	18	
Captan	Tangerine	15	
Tetradifon	Tangerine	10	

Sri Lanka

Pesticide name	Crop name	Channel PEC/1st tier NEC	PEC/2nd tier NEC	Tank PEC/1st tier NEC	PEC/2nd tier NEC
Carbaryl	Chilli	247143	24140	824	80
Carbaryl	Onion	239286	23372	2393	234
Chlorpyrifos	Chilli	100789	57164	336	191
Chlorpyrifos	Onion	100526	57015	1005	570
Dimethoate	Chilli	27769	21879	93	73
Dimethoate	Onion	22846	18000	228	180
Dimethoate	Rice	22846	18000	23	18
Mancozeb	Chilli	1255		4.2	
Mancozeb	Onion	1255		13	
Mancozeb	Rice	1255		1.3	
Alachlor	Onion	824		8.2	
Alachlor	Rice	824		0.82	
Propanil	Chilli	718		2.4	
Propanil	Onion	718		7.2	
Propanil	Rice	718		0.72	
Fenobucarb	Chilli	657		2.2	
Carbofuran	Chilli	583		1.9	
Captan	Onion	499		5.0	
Captan	Rice	499		0.50	
Fenobucarb	Onion	493		4.9	
Fenobucarb	Rice	493		0.49	
Carbofuran	Rice	300		0.30	
MCPA	Chilli	188		0.63	
MCPA	Onion	188		1.9	
MCPA	Rice	188		0.19	
Glyphosate	Chilli	3.8		0.013	
Glyphosate	Onion	3.8		0.038	
Glyphosate	Rice	3.8		0.0038	

Appendix 9 Acceptable daily intake (ADI) and acute reference dose (ARfD) levels calculated for the different pesticides to be used in the human risk assessment.

Active ingredient	Cas number	Pesticide type	ADI (mg/kg/day)	Acute RfD (mg/kg)
Abamectin	71751-41-2	insecticide, acaricide	0.002	0.094 *****
Alachlor	15972-60-8	herbicide	0.0005 *	0.024 *****
Captan	133-06-2	fungicide	0.1	4.7 *****
Carbaryl	63-25-2	insecticide, plant growth regulator	0.008	0.2
Carbendazim	10605-21-7	fungicide	0.03	1.4 *****
Carbofuran	1563-66-2	insecticide, nematocide	0.002	0.009
Carbosulfan	55285-14-8	insecticide	0.01	0.47 *****
Chlorfenapyr	122453-73-0	insecticide, acaricide	0.02 *	0.94 *****
Chlorfluazuron	71422-67-8	insecticide	0.005 *	0.24 *****
Chlorpyrifos	2921-88-2	insecticide	0.01	0.1
Cypermethrin	52315-07-8	insecticide	0.05 *	2.4 *****
Dicrotophos	141-66-2	insecticide, acaricide	0.000002 ***	0.000094 *****
Difenoconazole	119446-68-3	fungicide	0.01 *	0.47 *****
Diflubenzuron	35367-38-5	insecticide	0.02	0.94 *****
Dimethoate	60-51-5	insecticide, acaricide	0.02	0.94 *****
EPN	2104-64-5	insecticide, acaricide	0.00001	0.00048 *****
Fenobucarb	3766-81-2	insecticide	0.00010 ****	0.0047 *****
Fipronil	120068-37-3	insecticide	0.0002	0.003
Gibberellic adic	77-06-5	plant growth regulator	5 *	235 *****
Glyphosate	1071-83-6	herbicide	0.3	14 *****
Glyphosate-isopropylammonium	38641-94-0	herbicide	0.3	14 *****
Malathion	121-75-5	insecticide, acaricide	0.3	14 *****
Mancozeb	8018-01-7	fungicide	0.03	1.4 *****
MCPA	94-74-6	herbicide	0.01 *	0.47 *****
Metalaxyl	57837-19-1	fungicide	0.08	3.8 *****
Methamidophos	10265-92-6	insecticide, acaricide	0.004	0.19 *****
Methomyl	16752-77-5	insecticide, acaricide	0.02	0.02
Mevinphos	26718-65-0 and 7786347	insecticide, acaricide	0.0008	0.003
Profenofos	41198-08-7	insecticide, acaricide	0.01	0.47 *****
Propanil	709-98-8	herbicide	0.2 *	9.4 *****
Propineb	12071-83-9	fungicide	0.007	0.33 *****
Prothiofos	34643-46-4	insecticide	0.0001 *	0.0047 *****
Zineb	12122-67-7	fungicide	0.005 *	0.24 *****

* = http://www.health.gov.au/tga/docs/pdf/adi.pdf

** = Pesticide manual 12th edition

*** = cRfD from http://www.ecologic-ipm.com/Table1.pdf

**** 5% level of all other observations (log-normal distribution)

***** based on extrapolation factor being the 95% of existing ARfD/ADI (47)

Appendix 10 Results of dietary risk assessment for Thailand and Sri Lanka. For the individual diet items the NEDI (mg/kg BW/day) are given, the total NEDI is compared to the ADI and ARfD

Thailand (mixed crop site)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
Prothiofos	Guava	1.27E+01	7.87E-01	5.91E-02	14	135694	2887
Chlorfenapyr	Amaranth	3.42E-01	6.89E+02	8.22E-03	690	34479	734
Dicrotophos	Chinese kale	7.56E-05	4.11E-06	6.17E-02	0.062	30873	657
Abamectin	Chinese kale	2.91E-01	8.52E-01	1.63E-02	1.16	580	12
Methamidophos	Roseapple	6.27E-04	8.75E-06	9.20E-01	0.92	230	4.9
Fipronil	Amaranth	1.33E-02	2.53E-03	1.63E-03	0.017	87	5.8
Chlorfluazuron	For all crops	3.19E-01	9.55E-04	1.15E-03	0.32	64	1.4
Carbosulfan	Roseapple	3.54E-01	1.03E-02	2.00E-03	0.37	37	0.78
Profenofos	Chinese kale	2.68E-01	3.75E-03	1.38E-02	0.29	29	0.61
Mevinphos	Drumstick Moringa	4.95E-05	7.88E-07	1.18E-02	0.012	15	4.0
Difenoconazole	For all crops	8.05E-02	2.70E-03	6.64E-03	0.090	9.0	0.19
Dimethoate	Roseapple	1.06E-03	2.77E-04	8.20E-02	0.083	4.2	0.089
Carbendazim	Guava	4.39E-03	4.29E-02	7.01E-02	0.12	3.9	0.083
Carbendazim	Chinese kale	3.83E-03	3.74E-02	6.12E-02	0.10	3.4	0.073
Propineb	Roseapple	3.00E-05	8.11E-03	1.53E-02	0.023	3.4	0.071
Diflubenzuron	Roseapple	1.31E-02	2.42E-02	1.98E-03	0.039	2.0	0.042
Metalaxyl	For all crops	6.58E-03	4.37E-04	6.57E-02	0.073	0.91	0.019
Malathion	Guava	6.31E-02	8.27E-03	8.89E-02	0.16	0.53	0.011
Mancozeb	Roseapple	2.23E-04	3.65E-03	5.06E-03	0.0089	0.30	0.0063
Mancozeb	Amaranth	2.19E-04	3.59E-03	4.97E-03	0.0088	0.29	0.0062
Glyphosate	For all crops	5.08E-06	1.92E-04	3.57E-02	0.036	0.12	0.0025

Thailand (mono-crop site)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
EPN	Longbean	2.25E-01	9.30E-03	3.73E-03	0.24	23761	495
Dicrotophos	Tangerine	6.36E-06	3.46E-07	5.19E-03	0.0052	2599	55
Cypermethrin	Tangerine	6.45E+00	4.16E-01	4.86E-03	6.9	137	2.9
Profenofos	Tangerine	6.10E-01	8.54E-03	3.15E-02	0.65	65	1.4
Zineb	Tangerine	6.74E-03	8.59E-02	1.62E-01	0.25	51	1.1
Methamidophos	Tangerine	1.09E-04	1.53E-06	1.61E-01	0.16	40	0.86
Abamectin	Tangerine	1.19E-02	3.48E-02	6.64E-04	0.047	24	0.50
Abamectin	Longan	1.00E-02	2.94E-02	5.60E-04	0.040	20	0.43
Carbendazim	Tangerine	1.88E-02	1.84E-01	3.00E-01	0.50	17	0.36
Tetradifon	Tangerine	2.09E-01	9.61E-02	7.74E-03	0.31	16	0.33
Dimethoate	Tangerine	2.23E-03	5.82E-04	1.72E-01	0.17	8.7	0.19
Mancozeb	Tangerine	6.26E-03	1.03E-01	1.42E-01	0.25	8.4	0.18
Methamidophos	For all crop	6.35E-06	8.86E-08	9.32E-03	0.0093	2.3	0.050
Dimethoate	Longan	2.88E-04	7.52E-05	2.23E-02	0.023	1.1	0.024
Methamidophos	Guava	2.72E-06	3.80E-08	4.00E-03	0.0040	1.0	0.021

Carbendazim	Longbean	1.07E-03	1.04E-02	1.71E-02	0.029	1.0	0.020
Carbofuran	Coconut	1.04E-04	9.04E-05	1.63E-03	0.0018	0.91	0.20
Methomyl	Tangerine	4.82E-05	2.34E-05	1.23E-02	0.012	0.62	0.62
Carbendazim	Longan	5.56E-04	5.43E-03	8.88E-03	0.015	0.50	0.011
Carbaryl	Tangerine	3.82E-05	5.49E-05	5.22E-04	0.00061	0.077	0.0031
Captan	Tangerine	1.26E-03	1.76E-03	1.62E-03	0.0046	0.046	0.0010

Sri Lanka (farm channel)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
Fenobucarb	Chilli	4.20E-02	2.55E-03	5.48E-02	0.10	985	21
Fenobucarb	Onion	3.15E-02	1.92E-03	4.11E-02	0.075	739	16
Fenobucarb	Rice	3.15E-02	1.92E-03	4.11E-02	0.075	739	16
Alachlor	Onion	4.36E-02	2.65E-03	3.16E-02	0.078	156	3.3
Alachlor	Rice	4.36E-02	2.65E-03	3.16E-02	0.078	156	3.3
Chlorpyrifos	Chilli	1.03E+00	6.06E-02	3.19E-02	1.1	112	11
Chlorpyrifos	Onion	1.03E+00	6.05E-02	3.18E-02	1.1	112	11
Carbaryl	Chilli	6.34E-03	9.10E-03	8.65E-02	0.10	13	0.51
Carbaryl	Onion	6.13E-03	8.81E-03	8.38E-02	0.10	12	0.49
MCPA	Chilli	4.79E-02	4.15E-03	6.75E-02	0.12	12	0.25
MCPA	Onion	4.79E-02	4.15E-03	6.75E-02	0.12	12	0.25
MCPA	Rice	4.79E-02	4.15E-03	6.75E-02	0.12	12	0.25
Carbofuran	Chilli	1.24E-03	1.08E-03	1.94E-02	0.022	11	2.4
Carbofuran	Rice	6.39E-04	5.56E-04	1.00E-02	0.011	5.6	1.2
Dimethoate	Chilli	7.78E-04	2.03E-04	6.02E-02	0.061	3.1	0.065
Dimethoate	Onion	6.40E-04	1.67E-04	4.95E-02	0.050	2.5	0.054
Dimethoate	Rice	6.40E-04	1.67E-04	4.95E-02	0.050	2.5	0.054
Captan	Onion	4.23E-02	5.88E-02	5.41E-02	0.16	1.6	0.033
Captan	Rice	4.23E-02	5.88E-02	5.41E-02	0.16	1.6	0.033
Mancozeb	Chilli	1.01E-03	1.66E-02	2.30E-02	0.041	1.35	0.029
Mancozeb	Onion	1.01E-03	1.66E-02	2.30E-02	0.041	1.35	0.029
Mancozeb	Rice	1.01E-03	1.66E-02	2.30E-02	0.041	1.35	0.029
Propanil	Chilli	6.23E-02	2.99E-03	2.99E-02	0.10	0.48	0.010
Propanil	Onion	6.23E-02	2.99E-03	2.99E-02	0.10	0.48	0.010
Propanil	Rice	6.23E-02	2.99E-03	2.99E-02	0.10	0.48	0.010
Glyphosate	Chilli	4.46E-06	1.69E-04	3.13E-02	0.032	0.11	0.0022
Glyphosate	Onion	4.46E-06	1.69E-04	3.13E-02	0.032	0.11	0.0022
Glyphosate	Rice	4.46E-06	1.69E-04	3.13E-02	0.032	0.11	0.0022

Sri Lanka (tank)

Pesticide	Crop	NEDI Fish	NEDI Macr.	NEDI Water	NEDI Total	NEDI/ ADI	NEDI /ARfD
Fenobucarb	Onion	3.15E-04	1.92E-05	4.11E-04	0.00	7.4	0.16
Fenobucarb	Chilli	1.40E-04	8.51E-06	1.83E-04	0.00	3.3	0.070
Alachlor	Onion	4.36E-04	2.65E-05	3.16E-04	0.00	1.6	0.033
Chlorpyrifos	Onion	1.03E-02	6.05E-04	3.18E-04	0.01	1.1	0.11
Fenobucarb	Rice	3.13E-05	1.90E-06	4.08E-05	0.00	0.73	0.016
Chlorpyrifos	Chilli	3.44E-03	2.03E-04	1.07E-04	0.00	0.37	0.037
Alachlor	Rice	4.37E-05	2.65E-06	3.17E-05	0.00	0.16	0.0033
Carbaryl	Onion	6.13E-05	8.81E-05	8.38E-04	0.00	0.12	0.0049
MCPA	Onion	4.79E-04	4.15E-05	6.75E-04	0.00	0.12	0.0025
Carbaryl	Chilli	2.11E-05	3.03E-05	2.88E-04	0.00	0.042	0.0017
MCPA	Chilli	1.60E-04	1.38E-05	2.25E-04	0.00	0.040	0.00085
Carbofuran	Chilli	4.15E-06	3.62E-06	6.50E-05	0.00	0.036	0.0081
Dimethoate	Onion	6.40E-06	1.67E-06	4.95E-04	0.00	0.025	0.00054
Captan	Onion	4.23E-04	5.88E-04	5.41E-04	0.00	0.016	0.00033
Mancozeb	Onion	1.01E-05	1.66E-04	2.30E-04	0.00	0.014	0.00029
MCPA	Rice	4.79E-05	4.15E-06	6.75E-05	0.00	0.012	0.00025
Dimethoate	Chilli	2.60E-06	6.79E-07	2.01E-04	0.00	0.010	0.00022
Carbofuran	Rice	6.39E-07	5.56E-07	1.00E-05	0.00	0.0056	0.0012
Propanil	Onion	6.23E-04	2.99E-05	2.99E-04	0.00	0.0048	0.00010
Mancozeb	Chilli	3.38E-06	5.54E-05	7.67E-05	0.00	0.0045	0.000096
Dimethoate	Rice	6.36E-07	1.66E-07	4.92E-05	0.00	0.0025	0.000053
Propanil	Chilli	2.08E-04	9.99E-06	1.00E-04	0.00	0.0016	0.000034
Captan	Rice	4.24E-05	5.89E-05	5.42E-05	0.00	0.0016	0.000033
Mancozeb	Rice	1.03E-06	1.68E-05	2.33E-05	0.00	0.0014	0.000029
Glyphosate	Onion	4.46E-08	1.69E-06	3.13E-04	0.00	0.0011	0.000022
Propanil	Rice	6.24E-05	3.00E-06	3.00E-05	0.00	0.00048	0.000010
Glyphosate	Chilli	1.48E-08	5.62E-07	1.04E-04	0.00	0.00035	0.0000074
Glyphosate	Rice	4.51E-09	1.71E-07	3.17E-05	0.00	0.00011	0.0000023