Assessment of Risks to Water Bodies due to Residues of Agricultural Fungicide in Intensive Farming Areas in the Up-country of Sri Lanka using an Indicator Model

Ransilu C. Watawala[1], Janitha A. Liyanage[1] and Ananda Mallawatantri[2]
[1]Department of Chemistry, University of Kelaniya, Kelaniya, Sri Lanka
[2]United Nations Development Programme, Colombo, Sri Lanka

Introduction

Indiscriminate use of agrochemicals poses a major environmental threat to surface and groundwater. Intensive vegetable cultivation on the steep slopes of up-country hills requires extremely high levels of pesticides (insecticides and fungicides) and fertilizers to maintain high yields and profitability. Farmers do not necessarily follow the doses and frequencies recommended in the instructions but apply higher doses more frequently, as they believe that this will increase yields. The implications of these decisions are not considered by farmers due to the lack of information and understanding of the environmental pathways of chemicals after application. In addition, the methods available to account for the variability of soils, climate and other factors influencing the risk of pesticide use are complex.

Potato cultivation in Nuwara Eliya, Bandarawela and Welimada Sri Lanka is a good example of the effects of excessive pesticide use. In these areas precipitation exceeds 1,830mm per annum and crops are affected by a number of diseases and insect attacks, such as late blight caused by Phytopthora infestance. The prevailing misty conditions also promote fungal growth requiring famers to use contact and systemic fungicides for prevention. Lack of understanding of pesticide pathways and the desire to ensure that the disease is under control often lead to overdoses and higher frequency application of pesticides.

An agrochemical applied to a crop may undergo a number of complex processes before the original chemical and its by-products lose their activity or the potential to harm the environment or life forms. The key pathways involved in the fate of agrochemicals are: photo decomposition by sunlight; adsorption by soil organic and clay matter; degradation or decomposition by microbial action; transport through the soil matrix by percolating water (from rain or irrigation); overland runoff or mass transport dissolved in water or attached to sediments (soil erosion); volatilization into the atmosphere and wind transport along with dust (wind erosion). These processes occur simultaneously or certain processes predominate over others depending on agro-climatic conditions, which include: strength of UV radiation in sunlight; extent of rainfall or irrigation; slope steepness; wind and water erosion potential; soil porosity; soil organic carbon; soil pH; extent of macropores in soil due to cracks, roots and structure; soil microbial activity; temperature; and humidity. It is possible to measure some of the individual processes but to understand the net effect of an applied agrochemical in the environment is a difficult task.

As a result of such complexities, determining the potential of pesticide residues to contaminate surface and groundwater is a challenge. Therefore, the users of pesticides, mainly farmers, do not have an efficient way of accessing the information related to pesticide risks or the support necessary for the judicious use of pesticides. Monitoring pesticide residues in ground and surface water is considered a possible mechanism to help in the control of pollution but the analytical techniques available today for pesticide residue analysis in water and soil are costly and sometimes lack the sensitivity to analyze pesticides at the concentration levels present in typical soil-water systems, even immediately after their application.

At the same time, the number of kidney failures and diseases, the causes of which is as yet unclear, are on the rise. Although these illnesses are not directly linked or proven to be related to pesticides, it is known that contamination of water by pesticide residues at very low levels can induce health-related problems. The cost of treatment of kidney failure is high, it puts an enormous strain in national budgets and above all it impacts on the quality of life of the affected people and their relatives.

Therefore, it is necessary to better understand the ultimate fate of pesticides in different agro-climatic environments and adopt certain best management practices to control the movement of pesticide residues to undesirable locations such as water bodies, while keeping agricultural productivity high. These factors require researchers to find alternative systems to analyze the risk for surface and groundwater resources that are capable of taking into account soil and climatic conditions, and pesticide characteristics.

Use of Indicator Models to Study the Risk from Pesticides

Due to the complexity of pathways responsible for pesticide fate in the environment and the rapidly changing and inter-dependent environmental factors, scientists have used computer-based tools to analyze pesticide fate risks. This approach uses a combination of literature data, and laboratory and field measurements on pesticide adsorption, degradation, solubility and climatic data, and provides a broader and more complete picture of chemical fate by including all media (Gerrit and Bernd 1998).

These screening-type risk assessment models (CSIRO 2004; Walker and Barnes 1981) are mostly empirical and are valuable for evaluating and comparing pesticide risk in different environments and for a general risk assessment of the contamination of water resources on a large scale. The conclusions of the risk estimates allow farmers and extension workers to choose pesticides suitable for a given agro-climatic condition, correct application timing and an appropriate land use management system to minimize the environmental risk associated with pesticide applications.

Objective

The objectives of this study are to:

- Understand the patterns and practices of pesticide use in selected high-intensity agriculture areas of the central hills of Sri Lanka.

- Evaluate the possibility of using a simple computer-based risk assessment tool to better understand the potential risk of water pollution by pesticides, as an alternative to expensive and difficult pesticide monitoring and analysis in water bodies.

Materials and Methods

Description of the Study Areas

Three areas in the central hills of Sri Lanka, that are under intensive cultivation were selected for this study, namely, Nuwara Eliya, Welimada and Bandarawela, where potato is the dominant crop. The Nuwara Eliya site is located within the catchment of Gregory Lake; the site in Welimada is in the valley of Uma Oya in the Paranagama area, where the water pumping house for the Welimada Town is also located; and the Bandarawela site is near Poona Wewa (tank) between Welimada and Bandararawela near Boralanda, where the tank water is being used for domestic consumption. In addition, the potato fields were next to the water bodies, thus, leaving no buffer area between the agricultural land and the surface water body. The conditions in these areas are given in Table 1.

Table 1. Soil and environmental characteristics of the study sites.

	Nuwara Eliya (Gregory Lake)	Welimada (Uma Oya)	Bandarawela (Poona Oya)
Mean temperature ºC	15.0	19.5	19.5
Rainfall (mm/annum)	2,017	2,000	1,875
Recharging rate			
mm per year	121	121	121
Soil texture	Sandy Clay Loam	Sandy Loam	Sandy Clay
Organic matter (%)	4.0	3.0	3.4
Soil loss (k/ha)	19.6	19.6	19.5

Source: De Silva 2000; Thenabadu 1988

Farmer Survey of Pesticide Use

Information on pesticide use practices was collected through a questionnaire circulated among 69 farmers in the three study sites. Key questions asked included the type of pesticides used (commercial and chemical names), dosage, frequency of application, perceptions of dose effectiveness, and the extent of knowledge of the pollution potential and personal risk. Based on the given field information, two commonly used pesticides, Moncozeb and Propineb were selected for a study of the risks to water bodies using the Pesticides Impact Rating Index (PIRI).

Pesticide Impact Rating Model

The PIRI is a simple modeling tool that integrates the information related to the risk to surface and groundwater due to a selected chemical for selected crops in a given environment. To compute the risks, PIRI uses an extensive data set that includes climatic, soil and chemical data, as well as land use and landscape characteristics, and information related to pesticide fate in soil, water and air. Data requirements include minimum and maximum air temperature, rainfall and irrigated water, soil texture, soil organic matter content, pesticide chemical data such as adsorption partition coefficient and half-life, and pesticide application data such as frequency and dose, land use, cropping season, field cover, recharge rate, depth of water, diameter of nearest water body, distance from edge of the water body to the field or the width of the buffer zone, slope of land towards the water body, estimated average soil loss and minimum number of days from application of pesticides to first rainfall. PIRI outputs on risk are divided into six categories of risks due to mobility and toxicity, these are: very low (VL), low (L), medium high (MH), high (H), very high (VH) and extremely high (EH).

While most of the site-related PIRI data requirements are available through field measurements and literature, pesticide properties for the PIRI risk estimation for selected chemicals can be obtained-from the Farm Chemical Handbook by Meister Publishing Company (2001).

Results and Discussion

Extent of Pesticide Use

The patterns of pesticide use in Nuwara Eliya, Welimada and Bandarawela, as reported by the 69 farmers surveyed, indicated that potato farmers use fungicides extensively (Table 2).

Table 2. Pesticide use patterns in the three study areas.

Pesticide	Farmers (%)			
	Nuwara Eliya	Welimada	Bandarawela	Average
Propineb	83.4	75.0	72.0	76.8
Mancozeb	62.5	61.0	64.5	62.6
Chlorothalonil	54.0	65.2	48.0	55.7
Captan	52.4	56.5	53.0	53.9
Sulfur	50.0	45.5	56.4	50.6
Metalaxyl	48.2	50.1	53.6	50.6

More than 60 % of the farmers reported using the fungicides Mancozeb (Manganese ethyl bis dithiocarbamte polymerace complex with zinc salt) and Propineb (polymeric zinc propylene bis dithiocarbamate). On average more than 50 % of farmers use some type of chemical indicating a potential pollution problem unless good management practices are being implemented.

Pesticide Application Practices

Questions related to farmer practices of using pesticides indicated that farmers prefer to overdose and adopt higher frequencies than the recommended amounts. Forty-five percent of farmers indicated that they prefer to use more pesticides than the recommended dose of pesticides to ensure better results in crop productivity. They further indicated that they had limited knowledge about occupational exposure or the adverse effects of the pesticides that they used. Fifty-seven percent did not know the exact action of the pesticides nor were they aware that they had to use exactly the right amount of pesticides. For example, during the rainy period daily applications of fungicides were made. According to the survey some farmers highlighted the need for government support to be regular, informative and to include innovation while addressing their needs.

In addition to the survey, field observations during the study indicated that the farmers do not use appropriate mechanisms to measure the pesticide volumes that they add to the mixing tanks prior to application. For example, one common practice is to pour a fraction of the content of the bottle into the tank and judge the quantity by eye rather than measurement. Not using calibrated measuring equipment and inaccurate judgments by farmers may severely contribute to the inefficiency in pesticide use as well as contamination of water bodies.

Lack of literacy has been reported as the major reason for the misuse of pesticides and overdosing in Central Africa, which in turn results in phytotoxicity, and yield and financial losses (Youdeowei 1989). However, in Sri Lanka, the standard recommended approach of increasing awareness to improve management of pesticide use may need additional interventions to be effective because the high literacy rates prevailing in the study areas suggest that awareness is not the main issue.

It is noteworthy that Chandrasekara et al. (1985) reported similar observations on farmer perceptions and practices through a survey of pesticide use in vegetable cultivation in the central hill-country covering Nuwara Eliya, Badulla, Kandy and Matale districts. According to Chandrasekara et al. (1985), 59 % of farmers used more than the recommended quantity of pesticides in each of the districts they studied. It can be seen therefore, that even after more than 20 years, 45 % of farmers still share the same perception as regards the need and usefulness of higher doses of pesticide application, and the fact that such perceptions have endured and such practices have been followed for such a long period of time, is worth further investigation. This observation also probably calls for tighter controls over pesticide use.

Estimation of Risks

Integrated risk assessment using the PIRI model with site-specific data inputs on environmental and soil conditions for Nuwara Eliya, Welimada and Bandarawela indicates different risks for the two pesticides studied (Table 3).

Table 3. Relative risk levels and toxicity.

Pesticide	Location	Risk		Toxicity	
		Ground-water	Surface water	Ground-water	Surface water
Mancozeb	Nuwara Eliya	EH	EH	H	H
	Welimada	H	EH	M	H
	Bandarawela	H	EH	H	H
Propeneb	Nuwara Eliya	EH	EH	M	H
	Welimada	M	H	M	M
	Bandarawela	M	H	M	M

Note: EH – Extremely high; H – High; M – Medium; L- Low

According to the risk assessment, both Mancozeb and Propineb fungicides exhibited extremely high risk for groundwater and surface water contamination in Nuwara Eliya. For the Welimada and Bandarawela sites there was a high risk of groundwater pollution by Mancozeb and a medium risk by Propineb, while the surface water contamination potential was extremely high for Mancozeb and was a high risk for Propineb.

Toxicity levels of pesticides in water are derived by comparisons with their lethal dose that will kill 50 % of algae aquatic species (LC50). For surface water, Mancozeb has high toxicity levels in each area except in Welimada, where the toxicity level is medium. Propineb toxicity level is high in Nuwara Eliya surface water and medium in ground and surface waters in all other locations.

This analysis indicates the possibility of obtaining different and relative risk levels for ground and surface water for different pesticides in different soil-climatic conditions. Therefore, the method adopted in this study allows us to compare the risks to water bodies by different pesticides using limited data obtained from literature and field measurements. This work did not involve field level pesticide concentration measurements, which are very costly and require low detection limits, which often cannot be reached, as discussed in the introduction. These risk estimates can be used to explain to farmers how different soil and climatic conditions can influence the fate of the pesticides that they use and the consequent potential risk to their water supply systems. The approach also allows for the simulation of scenarios to evaluate different management methods. For example, the buffer area (area between the cropping area and surface water body) or extent of irrigation, and the management practices can be changed in the simulation. Use of PIRI as an extension tool may help to improve governance and promote best management practices for farmers.

Conclusions

Use of fungicides is very common in potato cultivation in the hill country of Sri Lanka. Propineb and Mancozeb were found to be the most common fungicides used, based on a famer survey conducted in Nuwara Eliya, Welimada and Bandarawela. The survey revealed that most farmers prefer higher doses of pesticides than recommended, and they do not use recommended mechanisms to measure pesticide volumes during the preparation of pesticide mixes. These perceptions and practices have not changed much over the years despite investments to raise awareness. This shows the necessity for additional interventions (legal and penalties) and incentives to minimize malpractice and risks to water bodies.

The common approach of water quality monitoring, to evaluate the concentrations of chemicals in water bodies, may not work for pesticides used in agriculture due to costs and lack of analytical sensitivity to identify pesticide residues. However, minute amounts of pesticides in water bodies, even below detection limits, can pose a threat to humans and biological organisms. In the absence of a proper analytical tool, the PIRI approach can be used to evaluate potential pesticide contamination of water bodies. It uses a wide range of environmental and chemical data to represent most of the environmental processes, and the results of this study demonstrated distinct variations of levels of risk and toxicity for the areas studied. Further refinement of this method could lead to a 'risk atlas' of pesticides for different soil-agro-ecological environments in Sri Lanka.

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