Modeling of pesticide concentrations in downstream waters

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Abstract

Many different models were developed to simulate the downstream toxicity by applying upstream pesticide concentrations. However, model parameters such as landuse on pesticide loading and photo degradation of pesticide under high concentrated suspended sediments are rarely being assessed. Therefore, this study conducted to elucidate the downstream pesticide toxicity using landuse, photo degradation effect, and farmer's attitude with other parameters based on mass balance theory to estimate downstream toxicity using Chlorpyrifos a frequently used pesticide in Sri Lanka. The model simulated Chlorpyrifos concentrations in downstream water were 0.119μg/l, 0.518μg/l, and 0.461μg/l in three different seasons (February to May, June to September and October to January) and photo degradation under suspended sediment in three seasons were 11.4%, 23.1% and 5.5% respectively. These levels exceed the acute and chronic toxic level of Chlorpyrifos on aquatic invertebrates In addition, values derived also exceed chronic toxicity levels on fish in all seasons and acute toxicity levels in October to January.

Keywords: Pesticide, model, downstream toxicity, suspended matter

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Introduction

Various factors were identified as the contributing factors in deteriorating water quality in rivers (Weerasekera *et al.*, 2009; Amarathunga et al, 2013a; Amarathunga *et al.*, 2013b; Azmy *et al.*, 2010) Many researchers developed models to predict the hydrodynamics, water quality, pollution loading, pesticide behaviour etc. Development of a pesticide fate model concept goes back to 1980s and significant progress has been accomplished in the recent past (Pennell *et al*, 1990; Siimes and Kamari, 2003). Many of the models developed to predict pesticide behaviour, mainly consider physical, chemical and biological degradation, such as; leaching, adsorption, volatilization, plant uptake, hydrolysis and microbial degradation. The objective of the current screening model is to predict the toxicity in the downstream while predicting the total pesticide inputs from the farm field and the loading from different tributaries in terms of mass balance.

Concept

Tropical climate conditions like rainfall influence farming practices. It assumed that, cultivation start at the onset of rain and run off predicting after two days from pesticide applications in the farmlands. The model applies the principle of mass balance to simulate downstream pesticide concentrations using different processors such as: pesticide application (loading), volatilization, soil adsorption, plant uptake, leaching, adsorption to suspended sediment, and photo degradation. This model focused on assessing pesticide concentration on downstream and assumes that, pesticide transport from field to downstream within short time period. Therefore, microbial impact is not considered because of very short time period.

Model parameters

Existing data was used to different processors to develop the model except photo degradation in river water (processor) which used original experimental data.

Volatilization

$$P_v = \int_{t=1.5}^{i=1} a \times t \times PAA ----(1)$$

Where, a is volatilization rate (mg/hr/m^2), t is time periods, and PAA is pesticide applied surface area from the total farmlands. Also, volatilization calculated for 9 hours per day.

Adsorption to farm soil and Leaching

$$\mathrm{P_{ad}} = R_{ad} \times F_a \times d \times S_{bd} ----(2)$$

Where, R_{ad} is pesticide amount adsorption to specific weight of farm soil (mg/kg), F_a is pesticide applied farmlands area (ha), d is pesticide contact depth of the soil (cm) and S_{bd} is mean soil bulk density in the farmlands areas (Mapa *et al*, 1999).

$$\mathrm{P_L} = R_L \times F_a \times d \times S_{bd} ----(3)$$

Where, R_L is mean pesticide leaching amount per specific weight (mg/kg), F_a is pesticide applied farmlands area (ha), d is pesticide leach depth of the soil (cm) and S_{bd} is mean soil bulk density in the farmlands areas.

Photo degradation in farm land

$$\mathrm{P_P} = PP_P \times IP_L ----(4)$$

Where, PP_P is percentage of pesticide photodegradation (%), $IP_L$is initial pesticide load after leaching and adsorption (kg).

Plant uptake and Photo degradation in river water

$$P_{PU} = R_{PU} \times F_a \times V_{pwb} ----(5)$$

Where, R_{PU} is mean pesticide plant uptake amount per specific weight (mg/kg), $F_a$is pesticide applied farmlands area (ha), and V_{pwb} is mean vegetables plants wet biomass of the total farm lands (kg).

$$P_{PW} = R_{PW} \times T_{WT} \times a \times SE \times ESD --- (6)$$

Where, R_{PW} is mean rate of photodegradation in water with HABSM (mg/l), T_{WT} is total water table in light penetrating depth (m3), a is a constant, SE is shading effect (%), and ESD is Effective sunny days (days). Also T_{WT} is calculated using equation7.

$$T_{WT} = W_{ST} \times TL_S \times LPD_S --- (7)$$

Where,W_{ST} is mean stream width (m), TL_S is total stream length (km) and LPD_S is light penetrating depth of the streams (m) (Fig. 5.3). Also, R_{PW} calculations were based on initial pesticide concentration in water. Therefore, pesticide concentration before photo degradation (P_{CBP})in river calculated using equation 8

$$P_{CBP} = \frac{(P_{RO} + P_{DS})}{(Q * UCF)} --- (8)$$

Where, Q is discharge and UCF is unit conversion factor. Also this value used for equation 9 to calculate photo degradation rate under HABSM (R_{PW})(Amarathunga and Kazama, 2014)

y = 0.6786x + 0.025 ------------------ (9)

Where, y is total chlorpyrifos photo degradation amount (mg/l) and x is initial chlorpyrifos concentration (mg/l), just after runoff water mix with river water.

Adsorption and Desorption by suspended sediment in river water

$$P_{ADS} = R_{ADS} \times SS_L ----(10)$$

Where,R_{ADS} is mean pesticide adsorption amount in sediment (mg/kg), and $SS_L$is mean suspended sediment load (kg).

$$P_{DS} = R_{DS} \times P_{ad} ----(5.11)$$

Where,R_{DS} is mean pesticide desorption rate from soil (%) and $P_{ad}$is pesticide adsorption amount to farm soil (kg). Also, pesticide desorption from river sediment (P_{DRS}, kg) is estimated as equation 12

$$P_{DRS} = R_{DS} \times P_{ADS} --- (12)$$

Where,R_{DS} is mean pesticide desorption rate from river sediment (%) and $P_{ADS}$is pesticide adsorption to river sediment (kg). The pesticide runoff (P_{RO})

$$P_{RO} = \int \{P_{TP} - (P_v + P_{AD} + P_L + P_{PU} + P_P)\} ----(13)$$

Where, P_{TP} is total pesticide load in to farmland and assume that, draining to farm land to stream come to pass within short time period. Also, remaining pesticide load (P_{RL}) before photodegradation in river was calculated using equation 14. After photodegradation in river, downstream pesticide concentration (P_{DSC})was calculated using equation 15.

$$P_{RL} = (P_{RO} + P_{DS}) - P_{ADS} ------(14)$$

$$P_{DSC} = \frac{(P_{RL} + P_{DRS}) - P_{PW}}{(Q * UCF)} ------(5.15)$$

Assume that, desorption from soil occur just after runoff and therefore, just after runoff, chlorpyrifos load in river (P_{TRF})(kg) calculated using equation 16.

$$P_{TRF} = P_{RO} + P_{DS} ----16$$

In addition, remaining pesticide load in downstream (RPL_{DS}) is calculated using equation 17.

$$RPL_{DS} = (P_{TRF} + P_{DRS}) - P_{PW} ----(17)$$

Results and conclusion

The model output is given in figure 1.

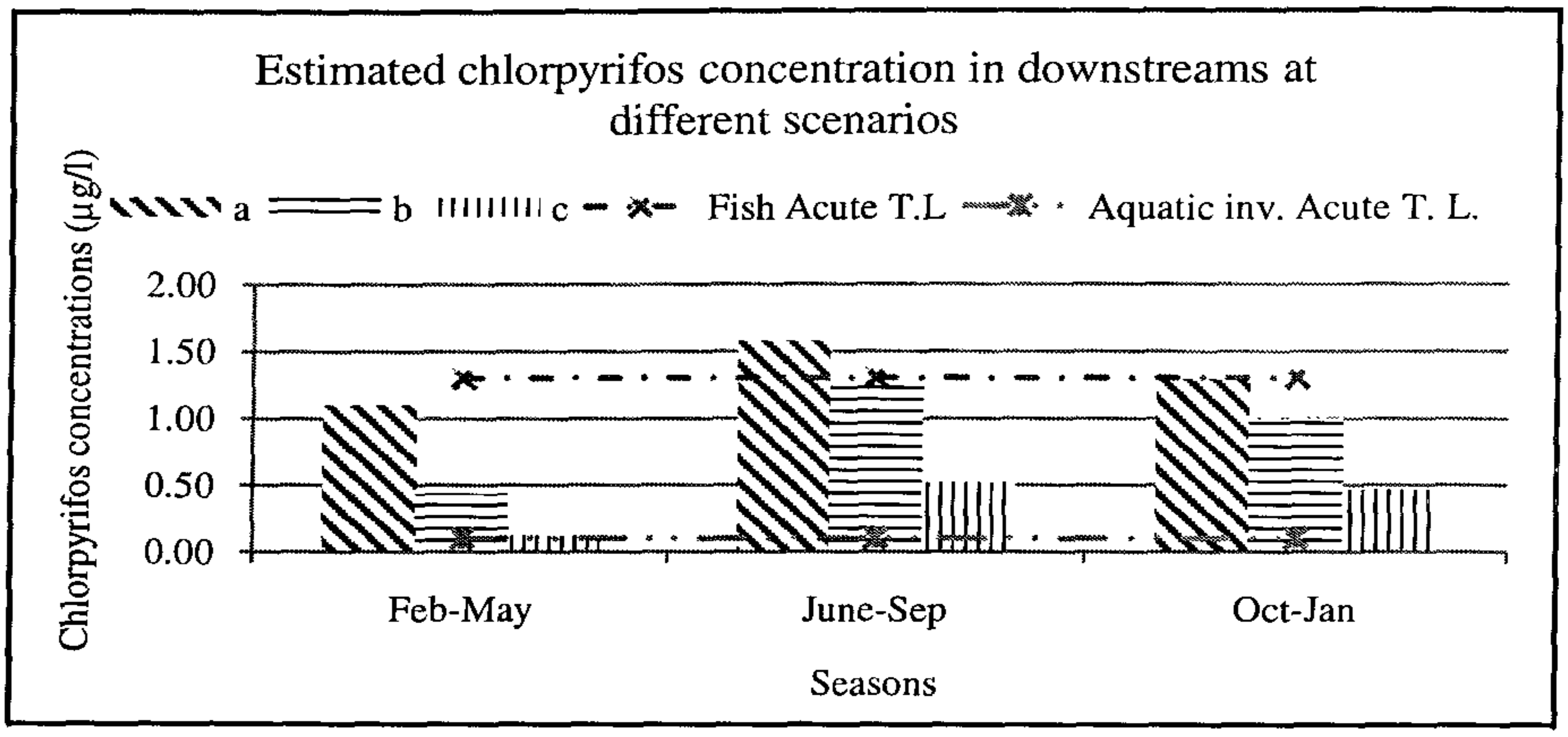

Figure 1: Estimated chlorpyrifos concentrations (µg/l): (a) Just after entering the river (without photo degradation, adsorption or desorption with river sediment) (µg/l), (b) Before photo degradation (µg/l) and (c) after photo degradation (µg/l). Toxicity levels (µg/l) in the river are represented by dash line

Understanding pesticide fate in an association with photo degradation under humic acid bound suspended matter (HABSM) in aquatic environment is very important. Therefore, pesticide fate estimate final concentration of chlorpyrifos in river waters are used following major processes such as: volatilizations, adsorption in soil and adsorption in sediment, plant uptake, leaching and photo degradation under HABSM. The results reveal that, 4% to 12% chlorpyrifos degraded by photo degradation under HABSM systems depend on initial chlorpyrifos concentration, total rainy days and sunny days. Further, estimated chlorpyrifos concentrations in river water are 0.119µg/l, 0.518µg/l, and 0.461µg/l in February to May, June to September and October to January seasons respectively. Theses concentrations exceed the acute and chronic toxicity level for aquatic invertebrate, fish and sediment dwelling organisms.

References

- Amarathunga, A.A.D. and Kazama, F. (2014).Photodegradation of chlorpyrifos an organophosphorus pesticide with humic acid bounded suspended matter, Journal of Hazardous Materials, 280, 671–677

- Amarathunga, A. A. D., Weerasekara, K. A. W. S., Sureshkumar, N., Azmy, S. A. M., Wickramaarchchi, W. D. N., and Kazama, F. (2013). Behavior and Loading of Suspended Sediment and Nutrients from River Basins in the Hilly Catena Under Intensive Agriculture Cropping: A Case Study in Upper Kotmale Basin in Sri Lanka. Journal of Environmental Professionals Sri Lanka, Vol. 2 No. 2, 13-31.