Environment Sustainability: Degradation of Two Pesticides in Cultivated Soils

What is pesticide?

Pesticides which encompass mainly the insecticides, fungicides and herbicides are chemicals used to control insects, fungi, and weeds in agricultural production. In medical field, pesticides are used to control vectors of human diseases. Modern agriculture today is very much dependent on pesticides as the production of crops in an economical scale is impossible without the use of pesticides. Crop losses occurring each year are mostly attributed to pests and diseases despite pesticides being use. However, losses would be even higher and crop yield drastically reduced if no pesticides are used. It is vital that pesticides should be used judiciously to ensure agricultural sustainability, no potential health hazards to consumers or contaminate the environment.

Pesticide use trend

The amount of pesticides used in the world exceeded US 10 billion in 2000 – 2001. Herbicides accounted for the largest portion of total use (36%), followed by insecticides (25%), fungicides (10%) and other pesticides (29%). Of consumption worldwide, 85% of pesticides are used in agriculture. Although the largest volume of pesticides is used in developed countries, the consumption is rapidly growing in developing countries. In addition to increase in total quantity used, farmers may sometimes use higher concentrations, and/or increase application frequencies. In some instances, cocktails of pesticides are used to combat pesticide resistance by pests. These trends are particularly noticeable in Asia and in Africa with tropical climate. While majority of pesticides used in developed countries are herbicides, the bulk of pesticides used in developing countries are insecticides. Excessive use of insecticides may lead to pests developing resistance to these insecticides. They also cause most damage to human health as they are comparatively more toxic than herbicides. Moreover, insecticides used in developing countries are often of older ones which are no longer under patent protection and thus cheaper.

Pesticide usage in the tropic

In the humid tropics, pesticides are applied on crops throughout the growing season and all year round to control pests and diseases. In some instances, pesticides are also applied to soils after a crop has been harvested to control soil-dwelling pests. These practices are common as the humid tropical climate has high humidity, temperature and rainfall which are very conducive for proliferation of pests and diseases. The spread of pests and diseases are unavoidable as most cultivated lands are not fallowed after a crop has been harvested due to limited arable land. In addition, pests and diseases are also introduced to the soils as a result of application of untreated animal manures as fertilizer. Cropping in the humid tropics is possible throughout the year whereas seasonal cropping is practiced in temperate regions. The later could reduce proliferation of pests and diseases. Excessive and repeated use of pesticides may lead to pests developing resistance to pesticides, contaminate soils and water, affect non-target organisms and pose risks to human. Besides, pesticides may be taken up by subsequent crops if they persist in soil.

Pesticide transport and fate

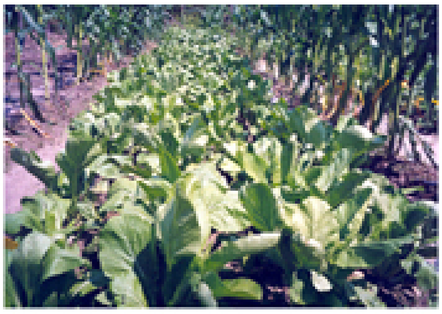
The transport and fate of pesticides are influenced by many interactive processes, such as volatilization, leaching, sorption, chemical and biological degradation. Environmental factors, properties of soils and persistency of pesticides can greatly influence the degradation, leaching and adsorption of pesticides in soil. In the humid tropics, dissipation of pesticides in soils is likely to be rapid due to faster abiotic and microbial degradation caused by higher temperature, favourable soil moisture contents and higher volatilisation. However, intense and high rainfall may cause severe leaching to the subsoils, even for the non-polar pesticides due the presence of macropores, root channels and worm burrows. This may affect surface and groundwater quality, organisms, human health and biodiversity. Data on pesticide fate in humid tropical soils are scarce, as compared to temperate soils. Study on the fate of pesticides in humid tropical soils is needed to ensure food safety and environmental sustainability in these regions. In addition, the information is also needed by the regulatory agencies in formulating legislation on pesticide use in the humid tropics.

Chlorpyrifos and cypermethrin pesticides

Chlorpyrifos and cypermethrin are frequently used to control insects in vegetable production. Both insecticides are hydrophobic with low water solubility of 0.4 and 0.004 mg/L, respectively (at 25^{o}C). Their vapour pressures (25^{o}C) differ widely: chlorpyrifos (2.5mPa), and cypermethrin (8.7x10^{-4}mPa). The metabolite of chlorpyrifos, TCP (3,5,6–trichloropyridinol) has low human toxicity but it is more easily leached in comparison to the parent compound. Cypermethrin is highly toxic to fish and aquatic invertebrates.

Field dissipation studies of pesticides in Sarawak

The degradation data of chlorpyrifos and cypermethrin in top soils after foliar application are needed for establishing the proper management practices in ensuring environmental sustainability in vegetable production systems. Three locations with different soil types and climate were used for the experiments: Balai Ringin, Tarat and Semongok. Young seedlings of green mustard were transplanted from nursery into the field at these three locations. Five liters of diluted Agent 505 solutions which contain cypermethrin, 4.59% w/w and chlorpyrifos, 45.9% w/w were sprayed onto the plots of green mustard using a knapsack sprayer with a cone nozzle, immediately after young seedlings had been transplanted into the field. Pesticides were applied again on green mustard three more times, at weekly intervals, on day 7, 14 and 21 after transplanting. For each site, an amount of 0.5kg of the topsoils were sampled between the green mustard plants at weekly intervals, after the last pesticide application using a spade for pesticide analysis. The maximum and minimum air temperatures during the experimental periods were close to 32^{o}C and 23^{o}C, respectively, while the average relative humidity was 84%. The mean air surface temperature ranged from 24.8 to 28.2^{o}C. The amount of sunshine was higher (23.3 – 55.4 h) at the Balai Ringin site as compared to Tarat and Semongok (7.4 – 41.6 h). The rainfall also varied from no rainfall to the highest of 170 mm per week at Tarat.



Left: Soil samples are collected in between the vegetable plants for pesticide analysis

Right: Modern instruments are use to detect trace level of pesticide

Degradation of chlorpyrifos in topsoils

The chlorpyrifos concentrations in soil after the last application on green mustard were 2.47, 5.27 and 2.34 mg/kg, for Balai Ringin, Semongok and Tarat, respectively (Figure 1). Chlorpyrifos at the three sites dissipated to almost similar levels of 0.93 – 1.41 mg/kg at day 7. After one month, the amounts of chlorpyrifos remaining in top soils were less than 10% of the amount immediately after the last pesticide application. The dissipation was slower at Balai Ringin compared to Tarat and Semongok soils. The concentrations of chlorpyrifos dissipated completely at Tarat and Semongok soils in 42 days but dissipated close to instrumental detection limits (0.01 mg/kg) at day 56 for Balai Ringin soil. The half-lives i.e. the amount of time needed for degradation of 50% of the pesticides were 6.8, 3.6, and 9.4 days for Semongok, Tarat and Balai Ringin soils, respectively.

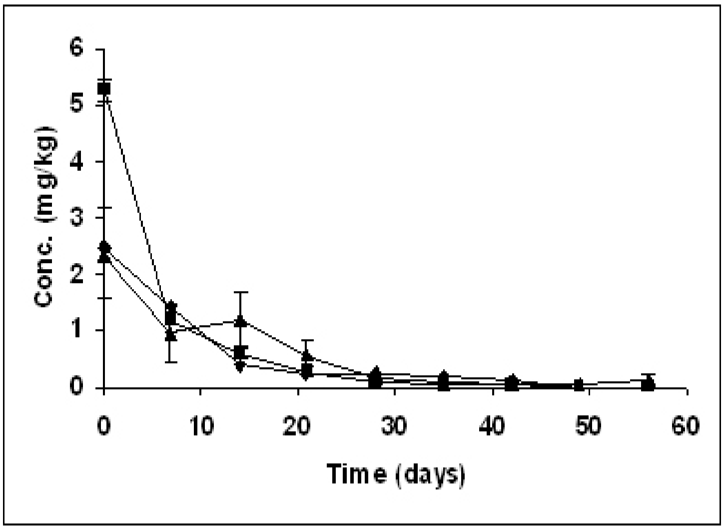


Figure 1. Concentration of chlorpyrifos in Semongok (♦), Tarat (■) and Balai Ringin (▲) topsoils after its last pesticide application on green mustard.

Chlorpyrifos metabolite, TCP was formed in all soils throughout the sampling period. For Semongok, Balai Ringin and Tarat soils, the TCP levels observed immediately after the last pesticide application were 0.53, 0.79 and 1.37mg/kg corresponding to about 21%, 26% and 34% of the parent compound (Figure 2). The TCP levels remaining in the topsoils after about a month since last application ranged from 0.14 to 0.23mg/kg. The highest TCP concentrations were detected in Tarat soil corresponding with the higher chlorpyrifos concentrations in this soil. TCP degraded completely at day 49 for Tarat and Semongok soils but lower amount closed to the detection limit was still detected at Balai Ringin soil at day 56.

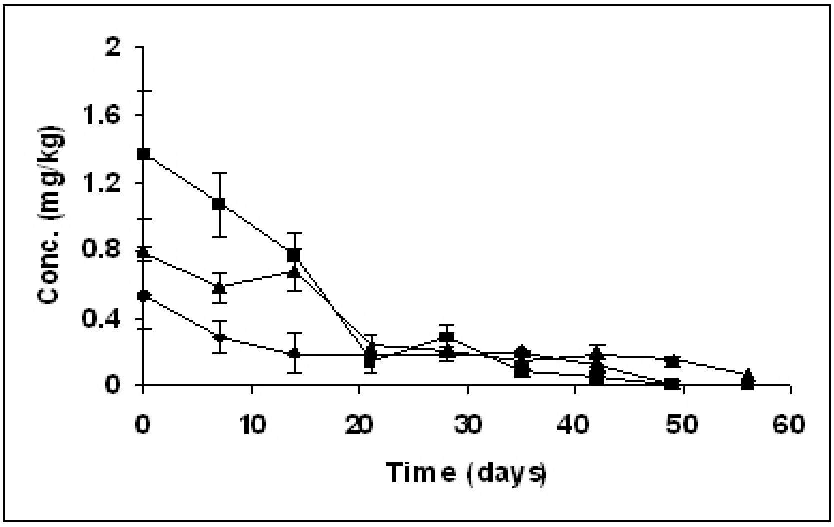


Figure 2. Concentration of TCP in Semongok (♦), Tarat (■) and Balai Ringin (▲) topsoils after the last chlorpyrifos application on green mustard.

Degradation of cypermethrin in topsoils

The dissipation characteristics of cypermethrin were similar to that of chlorpyrifos but relatively faster (Figure 3). The initial concentrations of cypermethrin immediately after the last pesticide application were 0.21, 0.28, 0.15mg/kg for Semongok, Tarat and Balai Ringin, respectively. The lower initial concentration of cypermethrin detected corresponding with its lower content of active ingredient in its formulation (4.59% by mass). Despite its low concentration, cypermethrin persisted at low concentration for 21 days in the three soils and only dissipated completely in 28 days. The half-lives for Semongok, Tarat and Balai Ringin soils 7.5, 7.6, and 5.6 days respectively.

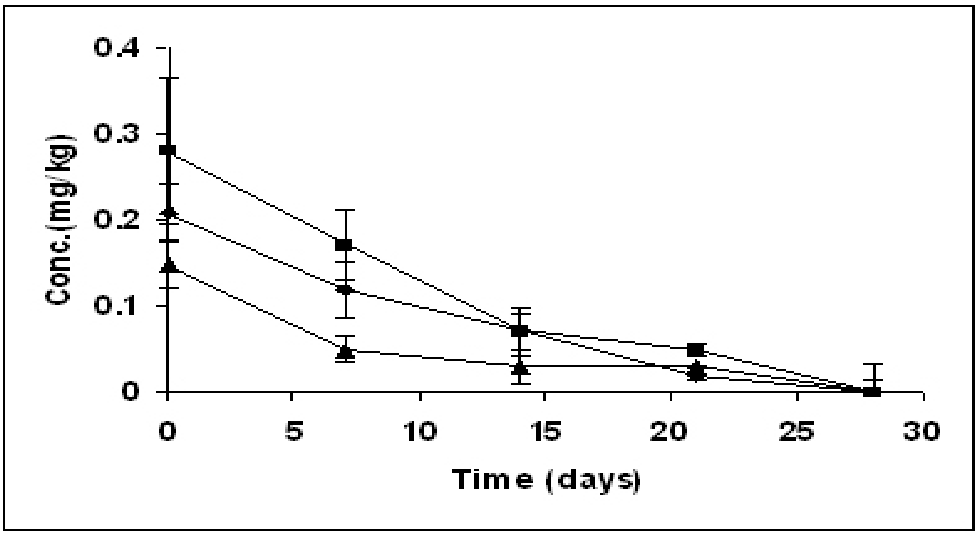


Figure 3. Concentration of cypermethrin in Semongok (♦), Tarat (■) and Balai Ringin (▲) topsoils after its last application on green mustard.

Behavior of two pesticides in soils

Chlorpyrifos and cypermethrin are strongly sorbed to soil particles which may retard their degradation. The half-lives for chlorpyrifos from this study were between 3.6 and 9.4 days. The slower chlorpyrifos degradation under green mustard reported in our study may possibly be attributed to higher clay in our soils which cause higher adsorption of chlorpyrifos. The shading of the topsoil by green mustard with larger leaves may also resulting in less photo-degradation and volatilization and thus prolongs the half-lives of chlorpyrifos. The half-lives for cypermethrin from this study were 5.6 – 7.6 days. As discussed earlier, the data indicate that the longer half-lives under green mustard may be possibly attributed to the shading effect of the vegetable. It is found that the dissipation half-lives in topsoil for the three sites are linearly correlated rain, sunshine and vapour pressure for chlorpyrifos, but not for cypermethrin. This indicates that climatic conditions are the main variables affecting dissipation of chlorpyrifos, while for cypermethrin soil properties such as sorption and microbial activity may have a stronger influence on degradation rates in soil.

Conclusions

The persistence and dissipation of the pesticides in soil varied among sites and may have been affected by plant size, soil type, rain and solar radiation. The half-lives for chlorpyrifos and cypermethrin in topsoils were somewhat longer (3.4 – 9.4 days) than seen in other similar studies with and without plant cover. Vegetable shading appeared to retard pesticide degradation in soil. However, these half-lives were shorter when compared to temperate soils. The metabolites TCP were observed at low levels of below 1.37mg/kg in topsoil and dissipated almost completely in 56 days. The results from this study show that the vegetation affects pesticide degradation in top soils and those metabolites need to be taken into account when making recommendations for their use.

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