Impact of deltamethrin on cockroaches (*Periplaneta americana*) and its residue on environment

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Abstrak

Latar belakang: *Penggunaan insektisida secara intensif tidak hanya memberikan dampak pada spesies target, namun juga pada spesies non-target dan lingkungan. Pada penelitian ini dilakukan penilaian pengaruh residu deltametrin terhadap kecoa (Periplaneta americana), ikan lele (Clarias batrachus), dan nila (Oreochromis niloticus). Selain itu laju infiltrasi residu pada tipe tanah dengan komposisi tanah yang berbeda juga diukur.*

Metode: *Percobaan dilakukan terhadap kecoa yang dikembangbiakan di laboratorium di Institut Pertanian Bogor. Perlakuan dengan tiga ulangan dan lima taraf konsentrasi deltamethrin: 0.8%, 0.4%, 0.2%, 0.1% and 0.05% (v/v) dilakukan untuk mengukur pengaruh residu terhadap kecoa selama 24 dan 48 jam. Penentuan LC_{50} dilakukan dengan analisis Probit. Konsentrasi letal yang didapatkan kemudian diujikan kepada ikan lele dan nila dengan metode semprot. Untuk perbandingan, uji efek organofosfat dengan konsentrasi 1 ppm dan 10 ppm dilakukan melalui metode soaking kepada dua jenis ikan tersebut. Laju infiltrasi residu pada tiga tipe komposisi tanah diukur menggunakan lysimeter.*

Hasil: *Hasil penelitian menunjukkan bahwa LC50 residu deltamethrin terhadap kecoa tercapai pada konsentrasi 0,2% pada 24-jam perlakuan. Lima puluh persen ikan nila mati pada perlakuan deltamethrin 0,2% selama 24 jam. Laju infiltrasi residu lebih tinggi pada jenis tanah berpasir (5 ml/menit) dibandingkan jenis tanah yang didominasi tanah liat.*

Kesimpulan: *Selain memiliki efek mematikan pada kecoa, Deltamethrin 0,2% mencemari tanah dan air, serta membunuh ikan nila (O. niloticus).* ***(Health Science Indones 2014;2:94-9)***

Kata kunci: *deltamethrin, efek residu, P. americana, O. niloticus, tanah*

Abstract

Background: Intensive use of chemical insecticides not only affect the target species, but also non-target species and environment. In this study, we examined residual effect of deltamethrin on cockroaches (*Periplaneta americana*), catfishes (*Clarias batrachus*) and nile-tilapia (*Oreochromis niloticus*). In addition, we aimed to measure the infiltration rate of deltamethrin insecticides in different types of soil.

Methods: An experimental study was conducted on laboratory-reared *P. americana* in *Institut Pertanian Bogor (Agricultural Institute, Bogor)*. Using five different deltamethrin concentrations 0.8%, 0.4%, 0.2%, 0.1% and 0.05% (v/v) in three replications, we assessed deltamethrin residual effect against cockroaches in 24 and 48-hrs. Lethal concentration (LC_{50}) for cockroaches was determined using Probit analysis. The lethal concentration was then tested on *C. batrachus* and *O. niloticus* in spraying and soaking method using organophosphate 1 ppm and 10 ppm. Infiltration rate of insecticide on three soil type was measured with lysimeter.

Results: The toxic effect (LC_{50}) of deltamethrin residue against cockroach reached at concentration of 0.2% in 24-hrs. Fifty per cent of nile-tilapia were killed by deltamethrin 0.2% within 24-hrs. Infiltration capacity of the insecticide were higher on sandy soil (5 ml/mins) than dominantly-composed by clay soil.

Conclusions: Deltamethrin 0.2% had a knockdown effect on *P. americana,* may infiltrate soil and waterbodies, and had a residual toxic effect on nile-tilapia (*Oreochromis niloticus*). ***(Health Science Indones 2014;2:94-9)***

Keywords: deltamethrin, residual effect, *P. americana*, *O. niloticus,* soil

Insects are the most varied and the most dominant creature on earth. Some insects are beneficial for humans by acting as pests at farmlands and plantations, but some are disadvantageous because of its role as disease vectors. One example of pest is cockroach (*Periplaneta americana*). Cockroaches are domestic pests and their presence may affect the community health. In addition to being aesthetically disrupting, cockroaches bite and act as a mechanical vector for various epidemics.[1,2]

One method to control the population of insect pests is to use chemical compounds, i.e. insecticides. Insecticides are widely used due to its practical and economical traits, and the results in reducing the population of such pests are quickly evident. To introduce new active ingredients for insecticides, an efficacy tests and ecological risk assessment of their toxicity level must be ensured.[3]

One of the insecticides compounds, pyrethroid, is generally safe for mammals and birds, but highly toxic for fish and other aquatic organisms. Their low solubility in water and their lipophilic properties are harmful for gills and reduce the effectiveness of enzymes, so they pose a threat for fishes.[4] One of pyrethroids, deltamethrin, has become increasingly popular in the last few years due to its high photo-stability, low toxicity on mammals and their relatively high durability on natural medium.[5] It is important to monitor the residual effects of deltamethrin on the environment. Soil samples can be used to determine the contents of insecticides that infiltrate into the earth, the time they need to fully infiltrate the earth and waterbodies, and their toxicity level on non-target creatures, particularly aquatic organisms.[6] However, studies on residual effect of deltamethrin against *P. americana* and its side-effects on different types of soil and fishes are still limited.

Thus, we conducted this research with objectives: (1) to measure the LC_{50} of deltamethrin insecticide (efficacy) on *Periplaneta americana* with the residual effect method; (2) to measure the infiltration rate of deltamethrin insecticides in different types of soil (organic, sandy and clay soil); and (3) to assess the residual effects of deltamethrin insecticide on catfishes (*Clarias batrachus*) and nile-tilapia (*Oreochromis niloticus*).

METHODS

We conducted an experimental study at the Laboratory of Insect Physiology and Toxicology, Crop Pest and Disease, Faculty of Agriculture, Institut Pertanian Bogor, Indonesia. We conducted two main steps of toxicity tests: first we test the Deltamethrin toxicity on cockroaches to determine the LC_{50}. Second, we did the toxicity test on non-target species and toxin infiltration test on environment (soil).

Deltamethrin toxicity test on cockroaches (*Periplaneta americana*)

The toxicity test with the residual effect method was assigned on laboratory-reared adult cockroaches (*Periplaneta americana*). Samples were obtained from laboratory of Faculty of Veterinary Medicine, Institut Pertanian Bogor. Three replications of five deltamethrin concentrations 0.8%, 0.4%, 0.2%, 0.1% and 0.05% (v/v) and control were prepared. Round filter papers were cut according to the size of the petridishes sand used as top covers. Each concentration of insecticide was dripped on different petridish using pipettes with a spiral pattern. The filter papers were then placed in a closed container together with five cockroaches each (in total 90 cockroaches). We counted the number of knock-downed *P.americana* in 24 and 48-hrs. The results from the toxicity tests were analyzed using probit analysis with POLO PC.[7] The concentrations used were converted by the programme to log dose and the number of dead fishes to mortality Probit values. A plot of these two parameters was made to estimate the 50 percent death rate (LC_{50}) of deltamethrin. The data was analyzed statistically by one-way ANOVA using SPSS 17.0.

Deltamethrin toxicity on non-target species

Toxicity tests were conducted on non-target species: catfish (*C. batrachus*) and nile-tilapia (*O. niloticus*). Toxin was introduced with two separate methods, i.e spraying and soaking. The observations determine the effect of insecticides on the fishes that were exposed with the toxic dose of pesticides for 24 and 48 hours. In the spraying method, 10 catfishes and four nile tilapias were exposed to maximum lethal concentration of deltamethrin. In the soaking method, five catfishes and six nile-tilapias were exposed to organophosphat (Curacron 500EC) at 1 ppm and 10 ppm. Number of killed fishes were counted and reported .[5,7,8]

Deltamethrin infiltration test on soil

The ecotoxicology test was assigned on three types of soil combinations. We mixed sandy, clay and organic soil in different preparats with three different

composition until it reached the weight of 200 grams. Type 1 comprised of 70% sand, 15% organic material, 15% clay; Type 2 consists of 15% sand, 70% organic material, 15% clay; and Type 3 consists of 15% sand, 15% organic material, 70% clay. Soil were then spread evenly and placed into controlled-valve lysimeters until the soil fill up to 3-cm below the mouth of the lysimeter. Two-hundred mililiters of 0.2% deltamethrin were then poured into each of the lysimeter. The remaining volume of pesticide (a result of water administration) was then observed for the speed of the flow of the insecticide inside the soil (the flow of insecticide (cm) per 30 minutes), and the number of drops produced per 30 minute. The flow speed and the flow rate were measured using the following Crosby's formula:[8,9]

Flow speed = [(water height (cm)] / [(time (minute)]
Flow rate = [(flow water volume (ml)] / [time (minute)]

RESULTS

The effect of deltamethrin application on *Periplaneta americana*

In 24-hrs, the highest death rate occurred at the highest concentration (73.3% v/v). The LC_{50} occured at deltamethrin concentration of 0.2% (v/v) ($p < 0.05$). There was no differences on 24-hrs and 48-hrs mortality rate (Table 1).

Table 1. Residual effect (mortality) of five concentration of Deltamethrin against P. americana

Concentration (% v/v)	n	Mortality rate (%)	
		24-hrs	48-hrs
0.80	5	73.3	73.3
0.40	5	66.7	66.7
0.20	5	53.3	53.3
0.10	5	33.3	33.3
0.05	5	0	0
Control	5	0	0

Effects of deltamethrin residue on fish

All of nile-tilapia fishes killed by deltamethrin 0.2% in 24-hrs when applied in spraying method. In the soaking method (using organophospate), all catfishes were killed in both 1 ppm and 10 ppm solution within 24-hours. Meanwhile, only 50 per cent of the nile-tilapias were killed in the 1 ppm and 10 ppm solution in 24-hours (Table 2).

Deltamethrin filtration on three soil characteristics

Pesticide flow rate were varied amongst different types of soil. Deltamethrin residue flown faster across the type 1 soil composition. Water successfully infiltrated the soil, that indicated by numerous drops of water came out of the lysimeter. Fifty-eight (115/200) per cent deltamethrin residue remains in type-1 soil. In contrast, it was only 16 (31/200) % deltamethrin residue successfully washed out from the soil type 3. Flow speed and flow rate on soil type 3 was the lowest (Table 3).

Table 2. Residual effect of Deltamethrin against C. batrachus and O. niloticus based on two different methods

Method	Species	Concentration	N	Mortality rate	
				24-hrs	48-hrs
				%	%
Spraying	*C. batrachus*	0.2%	10	0	0
		Control	10	0	0
	O. niloticus	0.2%	4	100	0
		Control	4	0	0
Soaking[†]	*C. batrachus*	1 ppm	5	100	0
		10 ppm	5	100	0
		Control	5	0	0
	O. niloticus	1 ppm	6	50	50
		10 ppm	6	50	50
		Control	6	0	0

[*]Using organophosphat (Curacron 500 EC)

Table 3. Infiltration rate of deltamethrin residue in different soil compositions

Type	Soil composition	Time (mins)	Depth of water flow (cm)	Volume of pesticide (ml)			Flow speed (cm/mins)	Flow rate (ml/mins)
				V_0	V_1	Δ Vo-V1		
1	70% sand + 15% organic material + 15% clay	17	27	200	85	115	1.6	5.0
2	15% sand + 70% organic material + 15% clay	21	27	200	97	103	1.3	4.9
3	15% sand + 15% organic material + 70% clay	30	10.5	200	169	31	0.3	1.0

Note: The flow speed and the flow rate were measured using the following Crosby's formula[8,9] ; V_0 = initial volume; V_1 = last volume

DISCUSSION

Overall, our study emphasizes that the use of insecticides should be consider carefully for their effect for non-target organisms and environment. In our study, we found that deltamethrin 0.2% had a knockdown effect on more than fifty per cent of target species (*P. americana)* population within 24-hours. Deltamethrin 0.2% also affect non target species. In soaking method, organophospate residue (1 ppm) caused 100% deaths of the catfishes and 50% nile-tilapias within 24-hours. Furthermore, on environmental aspect, the rate of soil and waterbodies pollution by insecticide were varied in different soil compositions.

In our observation, cockroaches experienced seizures (before dying) after contacted with insecticide. Effect of deltamethrin against cockroaches has been examined in another studies where deltamethrin 2.5% (v/v) was shown to be lethal for bigger type of cockroaches: German cockroach (*Blattella germanica*).[10] It shows that every cockroach species may differ on their sensitivity to deltamethrin exposure. Physiological properties and resistance level might affect the cockroaches vulnerability to chemical exposure. Insecticide may accumulated and affected the group of insects and causes disrupted development, changed eating behavior, growth and finally death.[11] Yet, our study cannot conclude if *P.americana* more sensitive to deltamethrin than *B. germanica*.

We showed that nile-tilapias are more susceptible to deltamethrin-contaminated water than catfishes (*C. batrachus*). Another study showed that deltamethrin is highly toxic to the species at LC_{50} of 15.47 mg/l.[12] Deltamethrin is a type-II pyrethroid compound that is more potentially toxic to fish and least toxic to mammals contaminating aquatic ecosystems as potential toxic pollutants, causes severe morphological alterations in the gill and liver of fingerlings of nile-tilapias.[13] Catfish is known to survive in polluted water, including media contains gutters and trenches. Small fishes, like catfishes, are more vulnerable to pesticide and thus easily died.[7] Our study shows that compare to deltamethrin, organophospate have a deadliest impact on catfishes. We show that dissolved insecticide residue in water can affect the life of aquatic organisms. Insecticide can accumulate in organs and affects enzymes activity. In addition, it may cause genetic, morphological and physiological changes, and even death. The differences in size and age of the fish may affect their vulnerability. A study revealed that deltamethrin slowed down lipase enzyme in *Poecilia reticulata* and negatively affecting the nutrition in its body and physiology.[13] Another effect of deltamethrin on fishes have also been explained in several laboratory studies.[14,15] Deltamethrin causes morphologic disruptions to the gills, liver, and haemobiotic organs.[16,17]

This study also provides evidence that sandy soil was more likely to absorb and release a high amount of insecticide residue faster than on dominantly-composed clay soil. This proves that infiltration rate of insecticide residue on sandy soil area is greater than other types of soil. Thus, the waterbodies will be rapidly contaminated. It is also indicate that clay soil has higher holding capacity than sandy soil. As a result, higher proportion of clay on soil would be able to hold pesticide residue longer.

Pesticide may infiltrates the soil and flow into the water bodies together with runoff water. This phase initiates the sequence of bioconcentration, bioaccumulation, and biomagnification of pesticides

in the soil and water. Bioconcentration occurs when the dissolved chemicals in the water are absorbed by gills and epithelium tissue of organisms. Next, bioaccumulation of the chemical ingredients happens when aquatic organisms consumes. In the last phase, biomagnification, the chemical compounds of the insecticide compounds accumulated in many organisms and concentrated in two or more trophic level food web, including plant and human.[18] Even deltamethrin has strong adsorption on particles and low solubility in water, it still potentially affect ecosystem. Deltamethrin may reduces insect population and indirectly cause the proliferation of algal blooms, which in turn consequently decreasing dissolved oxygen in water.[19]

Chemical insecticides, like deltamethrin, are a popular alternative to control the population of pests in both the agriculture and the health sector. Deltamethrin is commonly used as disease vector controls.[10] In daily life, deltamethrin is used as pesticide with concentration of 0.6%; higher than our observed lethal concontration. Intensive and long-term use of insecticides may have impacts on the vectors resistance. Few studies revealed that rapid insecticide use had increased target insects resistance.[20] The increasing resistance trend among target species is something that deserves serious attention.

In conclusion, at concentration of 0.2%, Deltamethrin not only had a knockdown effect on *P. americana,* but had also infiltrated soil and killed nile-tilapias. Monitoring on continous use of insecticide is important to minimize its impacts on non-target species and the surrounding enviroment. The precautionary principle of applying a low-dose insecticide (based on standard regulation) and re-evaluation on pesticide residual regulation (especially on consumable organisms) must be strengthen and highly promoted.

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