The residual effect of lambda-cyhalothrin, deltamethrin and dichlorodiphenyltrichloroethane in Zhombe, Kwekwe district, Zimbabwe

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Abstract

Indoor residual house spraying using lambda-cyhalothrin, deltamethrin and dichlorodiphenyltrichloroethane (DDT) was conducted in Zhombe Resettlement area, Zimbabwe. A total of 204/219 (93.1%), 224/260 (86.2%) and 257/325 (79.1%) rooms were sprayed with lambda-cyhalothrin, deltamethrin and DDT wettable powders respectively. Bioassays were conducted on sprayed walls and roofs using 3-5 day old laboratory reared susceptible *Anopheles gambiae sensu lato* mosquitoes placed in World Health Organization cones.

Bioassays conducted on sprayed walls (1 month), showed that efficacy of lambda-cyhalothrin was the same with DDT but different with deltamethrin and this trend continued in the 2nd month. During the 3rd month, lambda-cyhalothrin killed more mosquitoes than deltamethrin ($P=1.931\times10^{-14}$), DDT killed more mosquitoes than deltamethrin (P=0.0001) and lambda-cyhalothrin killed more mosquitoes than DDT (walls). Efficacy of lambda-cyhalothrin and DDT was the same 4 months post spray (P=0.487), notable differences were seen in lambda-cyhalothrin and deltamethrin ($P=2.57\times10^{-6}$), DDT and deltamethrin ($P=2.17\times10^{-8}$). Efficacy of lambda-cyhalothrin and DDT was the same 5 months post spray (P=0.244), major differences were found in lambda-cyhalothrin and deltamethrin (P=0.000), DDT and deltamethrin ($P=5.18\times10^{-5}$) and this trend continued in the 6th month. One month after spraying roofs, mortality of mosquitoes due to lambda-cyhalothrin/deltamethrin ($P=2.56\times10^{-5}$), lambda-cyhalothrin/DDT ($P=1.2\times10^{-7}$) and deltamethrin/DDT (P=0.013) were significantly different and this continued in the 2nd month. However, 3 months after spraying, mortality due to lambda-cyhalothrin/deltamethrin ($P=1.46\times10^{-6}$), lambda-cyhalothrin/DDT (P=0.048), and deltamethrin/DDT (P=0.004) were significantly different and this continued in the 4th month. Five months after spraying roofs, mortality due to lambda-cyhalothrin/deltamethrin (P=0.000) and deltamethrin/DDT ($P=6.6\times10^{-7}$) were significantly different. Six months after spraying, lambda-cyhalothrin/deltamethrin (P=0.34), lambda-cyhalothrin/DDT (P=0.982), and deltamethrin/DDT (P=0.64) were not significantly different. When using exit window traps, no mosquitoes were collected from rooms sprayed with each of the insecticides over a 6-month period. However, 17, 6, 14, 7, 2 and 3 fed *An. gambiae sl* mosquitoes were collected in the 1st, 2nd, 3rd, 4th, 5th and 6th month respectively from unsprayed rooms and none of them died after 24 h.

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Introduction

The use of residual insecticides for indoor residual house spraying (IRS) remains an essential component of malaria control in many parts of the world, including Zimbabwe (Eilsele, *et al.,* 2010). Residual insecticides have life spans of 3-6 months for pyrethroids (Raghavendra *et al.,* 2011) and 8 months to 2 years for organo-chlorines (Taylor *et al.,* 1981). IRS targets mosquitoes that are endophillic (indoor resting) that will eventually pick up a lethal dose before they die. In a study conducted in Kenya, IRS reduced mosquito vector density and disease incidence for a period of 6 months (Zhou *et al.,* 2010). Molineaux & Gramiccia (1980) attributed vector exophily to the failure to interrupt malaria transmission following IRS with the insecticide propoxur in Nigeria. Sharp *et al.* (2007) observed that the number of *Anopheles gambiae sensu stricto* mosquitoes was reduced from 25.5 to 1.9 per trap per 100 nights after spraying with a pyrethroid. World Health Organization (WHO, 2006) set the criteria for knock down as ≥95% and 24 h mortality as ≥80% and a spraying coverage of >80% is required in order to interrupt transmission.

The epidemiology and history of malaria control in Zimbabwe is well

documented by Taylor & Mutambu (1986). Malaria vector control started in the 1940s and has witnessed the coming and going of such insecticides as dieldrin and benzene hexachloride and the introduction of synthetic pyrethroids such as deltamethrin, alpha-cypermethrin, and lambda-cyhalothrin. IRS remains an essential component of the National Malaria Control Programme (NMCP) in Zimbabwe. Information from previous work indicates that the malaria vectors in Zimbabwe are still susceptible to dichlorodiphenyltrichloroethane (DDT) and pyrethroids (Manokore *et al.*, 2000) although Munhenga *et al.* (2008) documented resistance to permethrin and DDT of mosquitoes collected from one locality in Gwave, Zimbabwe.

The residual effect of DDT, lambda-cyhalothrin and deltamethrin was monitored in Zhombe resettlement area, Zimbabwe.

Material and methods

Study area

Zhombe is one of the malarious areas in Kwekwe district that is not sprayed by the NMCP during its annual spraying cycle. Malaria spraying by the NMCP focuses on the highly burdened districts.

Insecticides

DDT 75WP is a wettable powder containing 75% dichloro-diphenyltrichloro-ethylene, Insectokill 10WP contains 10% lambda-cyhalothrin wettable powder and Deltaguard 5WP contains 5% deltamethrin wettable powder. Deltamethrin (moderately toxic) has an acute toxicity of lethal dose for 50% effect (LD_{50}) oral, rat. >5000 mg/kg and LD_{50} dermal, rat. >2000 mg/kg. Lambda-cyhalothrin (moderately toxic) has an acute toxicity of LD_{50} oral, rat. 144 mg/kg and LD_{50} dermal, rat. 696 mg/kg. DDT (moderately to slightly toxic) has an acute toxicity of LD_{50} oral, rat. 113-800 mg/kg and LD_{50} dermal, rat. 2500-3000 mg/kg

Spraying was conducted using an Xpert 8L Hudson sprayer (H.D. Hudson Manufacturing Company, Chicago, IL, USA), pressurised to 55 psi (pounds per square inch). One hut in Zimbabwe constitutes one room only. A total of 204/219 (93.1%) rooms were sprayed with lambda-cyhalothrin at 30 mg/m^2, 224/260 (86.2%) rooms were sprayed with deltamethrin at 25 mg/m^2, 257/325 (79.1%) rooms were sprayed with DDT at 2 mg/m^2 and 205 rooms served as the control. All insecticides were sprayed in March 2010.

Mosquitoes

Anopheles gambiae sensu lato mosquito larvae were collected from the study sites through larval scooping. The larvae were placed in larval bowls (rearing dishes) in a simulated field insectary and reared to adult stage by the provision of fish food. The resulting female adults were given 10% sugar water. The mosquito colony is susceptible to 4% DDT, 0.05% deltamethrin, 0.05% lambda-cyhalothrin, 0.5% etofenprox, 0.15% cyfluthrin and 0.75% permethrin.

Residual effect

Bioassays were conducted on randomly selected rooms (Table 1) that were sprayed with DDT, lambda-cyhalothrin or deltamethrin in accordance with WHO guidelines (2006). Three WHO cones (8.5 cm in diameter at the base and 5.5 cm high) were fastened on different positions on the wall and other 3 on the roof. Ten to fifteen *An. gambiae sl* mosquitoes were aspirated and placed in each WHO cone and exposed for 30 min. Mosquitoes were retrieved using an aspirator, placed in a holding cup before recording knock down rate. These mosquitoes were provided with 10% sugar solution in a 50 mL bottle that contained a wick and this was done over a period of 6 months. Mortality was scored after 24 h. By adding up all mosquitoes that died in each cone for each surface and dividing by the number of cones, the mean mortality per month for each insecticide was calculated.

Effect of insecticides on mosquito behaviour

This was done monthly using Exit Window Traps (EWT) mounted at 1 window opening at each homestead at 5 p.m. Five rooms for each insecticide were used every month for 6 months and this included 5 unsprayed rooms that served as controls. All the other windows and openings were then closed. Mosquito collection was done using an aspirator and placing mosquitoes in a holding cup by 10 a.m. the following day.

Data analysis

The data analysis was performed with the ANOVA test (analysis of variance) using the 95% confidence limit. Mortality of mosquitoes at each time pont was analyzed for the 3 insectides.

Results

Results for bioassays conducted on sprayed walls are shown in Table 2. No mortality occurred in the 2 control rooms that were used per month, with a total of 12 control rooms over the 6-month period. The mortality for mosquitoes exposed to walls sprayed with lambda-cyhalothrin (1 month) was the same with DDT but significantly different with deltamethrin. Two months after spraying, mortality for mosquitoes due to lambda-cyhalothrin was significantly different with deltamethrin (P=0.003) and DDT (P=0.03). During the same period, DDT and deltamethrin were significantly different (P=1.31×10^{-5}). During the 3rd month, lambda-

Table 1. Number of rooms used for bioassays.

Months post spraying	Lambda-cyhalothrin		Deltamethrin		DDT		Control
	Rooms where walls were used	Rooms where roofs were used	Rooms where walls were used	Rooms where roofs were used	Rooms where walls were used	Rooms where roofs were used	Rooms used
1	4	4	6	5	6	5	2
2	7	8	6	4	6	5	2
3	7	7	8	6	4	4	2
4	4	6	4	4	4	4	2
5	5	5	4	4	6	9	2
6	7	9	6	6	4	1	2

DDT, dichlorodiphenyltrichloroethane.

cyhalothrin killed more mosquitoes than deltamethrin ($P=1.931\times10^{-14}$), DDT killed more mosquitoes than deltamethrin (P=0.0001) and lambda-cyhalothrin killed more mosquitoes than DDT (all results were significantly different). Efficacy of lambda-cyhalothrin and DDT was the same 4 months post spray (P=0.487), notable differences were seen in lambda-cyhalothrin and deltamethrin ($P=2.57\times10^{-6}$), DDT and deltamethrin ($P=2.17\times10^{-8}$). Efficacy of lambda-cyhalothrin and DDT was the same 5 months post spray (P=0.244), major differences were found in lambda-cyhalothrin and deltamethrin (P=0.000), DDT and deltamethrin ($P=5.18\times10^{-5}$). Efficacy of lambda-cyhalothrin and DDT was the same 6 months post spray (P=0.427), major differences were found in lambda-cyhalothrin and deltamethrin ($P=3.7\times10^{-7}$), DDT and deltamethrin ($P=1.58\times10^{-9}$). No mortality was observed with the control mosquitoes over the 6-month period.

Results for bioassays conducted on sprayed roofs are shown in Table 3. One month after spraying, the mortality of mosquitoes due to lambda-cyhalothrin/deltamethrin ($P=2.56\times10^{-5}$), lambda-cyhalothrin/DDT ($P=1.2\times10^{-7}$) and deltamethrin/DDT (P=0.013) were significantly different. Results for 2 months after spraying, mortality due to lambda-cyhalothrin/deltamethrin ($P=3.65\times10^{-11}$), lambda-cyhalothrin/DDT ($P=9.18\times10^{-12}$), and deltamethrin/DDT ($P=2.26\times10^{-5}$) were significantly different. Three months after spraying, mortality due to lambda-cyhalothrin/deltamethrin ($P=1.46\times10^{-6}$), lambda-cyhalothrin/DDT (P=0.048), and deltamethrin/DDT (P=0.004) were significantly different. Four months after spraying, mortality due to lambda-cyhalothrin/deltamethrin ($P=1.46\times10^{-6}$), lambda-cyhalothrin/DDT (P=0.048), and deltamethrin/DDT (P=0.004) were significantly different. Five months after spraying, mortality due to lambda-cyhalothrin/deltamethrin (P=0.000) and deltamethrin/DDT ($P=6.6\times10^{-7}$) were significantly different apart from lambda-cyhalothrin/DDT (P=0.811). Six months after spraying, lambda-cyhalothrin/deltamethrin (P=0.34), lambda-cyhalothrin/ DDT (P=0.982), and deltamethrin/DDT (P=0.64) were not significantly different. No mortality was observed with the control mosquitoes over the 6-month period.

Effect of insecticides on mosquito behaviour

After installing one exit window trap per room for a total of 5 rooms per treatment per month, no mosquitoes were collected from rooms sprayed with insecticides over a 6-month period. However, 17, 6, 14, 7, 2 and 3 fed *An. gambiae sl* mosquitoes were collected in the 1st, 2nd, 3rd, 4th, 5th and 6th month respectively from unsprayed rooms and none of them died after 24 h.

Discussion and conclusions

Spraying coverage was above 80% as required by WHO (2006) in lambda-cyhalothrin and deltamethrin sprayed villages although slightly low in DDT sprayed villages. We did not carry out a study on level of product acceptability in the study villages and therefore cannot explain these observed differences.

The number of rooms used for bioassays sometimes differed in some months due to either availability of mosquitoes or presence of the head of a household to give consent. During the first month on sprayed walls, deltamethrin was not as effective as either lambda-cyhalothrin of DDT but this trend was totally different on sprayed roofs over the same period. In the second and third month, the efficacy of these 3 insecticides was totally different on the walls and roofs. During the 4th month, efficacy of lambda-cyhalothrin and DDT on walls was the same but different with deltamethrin but all roofs were totally different over the same period. In the 5th month, efficacy of lambda-cyhalothrin was the same both on the walls and roofs but different with deltamethrin and this trend in the sixth month on walls, however, mortality on the roof was the same. These results were obtained when a susceptible colony of *An. gambiae sl* mosquitoes was used. Our observations on DDT did not go beyond 6 months and therefore cannot be compared with observations by Taylor *et al.* (1981). Insecticide manufacturers claim longer residual periods on their products, making it necessary for control programmes to verify such claims. The residual effect of each insecticide formulation largely depends on the quality of the product (for the manufacturer) and the quality of spraying (for control programmes).

Studies on mosquito behaviour have shown that no mosquitoes were collected in huts sprayed with any of the insecticides. These results imply that mosquitoes died after getting in contact with sprayed surfaces and therefore could not exit sprayed houses. Even if the mosquito population in the study villages had exophilic tendencies, they died before leaving the sprayed houses.

In comparison with mosquitoes that were continuously caught from

Table 2. Bioassays conducted on walls.

Months post spraying	Lambda-cyhalothrin	Deltamethrin	DDT
1	107/107 (100%)[a] Range (100%)	151/161 (93.8%)[b] Range (88-100%)	161/161 (100%)[a] Range (100%)
2	214/218 (98.2%)[c] Range (90-100%)	161/172 (93.6%)[d] Range (87-100%)	171/171 (100%)[e] Range (100%)
3	199/200 (99.5%)[f] Range (90-100%)	203/225 (90.2%)[g] Range (87-100%)	120/126 (95.2%)[h] Range (93-100%)
4	117/120 (97.5%)[i] Range (90-100%)	105/117 (89.7%)[k] Range (86-97%)	118/120 (98.3%)[i] Range (93-100%)
5	148/153 (96.7%)[m] Range (87-100%)	97/107 (90.7%)[n] Range (88-97%)	166/174 (95.4%)[m] Range (92-97%)
6	186/211 (88.2%)[p] Range (81-95%)	125/163 (76.7%)[q] Range (72-88%)	96/107 (89.7 %)[p] Range (80-94%)

DDT, dichlorodiphenyltrichloroethane. Same letter in the same row denotes no significant difference and different letter in the same row denotes significance difference.

Table 3. Bioassays conducted on roofs.

Months post spraying	Lambda-cyhalothrin	Deltamethrin	DDT
1	99/99 (100%)[a] Range (100%)	130/138 (94.2%)[b] Range (90-100%)	132/136 (97%)[c] Range (96-100%)
2	223/223 (100%)[d] Range (100%)	106/112 (94.6%)[e] Range (92-100%)	1291/131 (98.5%)[f] Range (98-100%)
3	200/203 (98.5%)[g] Range (90-100%)	166/179 (92.7%)[h] Range (88-100%)	110/114 (96.5%)[i] Range (90-100%)
4	170/178 (95.5%)[j] Range (90-100%)	112/124 (90.3%)[k] Range (88-100%)	103/111 (92.8%)[l] Range (90-100%)
5	140/151 (92.7%)[m] Range (88-100%)	112/128 (87.5%)[n] Range (85-90%)	238/256 (92.9%)[m] Range (90-100%)
6	224/256 (87.5%)[p] Range (81-94%)	138/160 (86.3%)[p] Range (74-90%)	24/28 (85.7 %)[p] Range (84-90%)

DDT, dichlorodiphenyltrichloroethane. Same letter in the same row denotes no significant difference and different letter in the same row denotes significance difference.

EWT installed in unsprayed houses, there are indications that these mosquitoes did not die after being in contact with unsprayed houses and there had to leave these houses under natural conditions. It can be assumed that mosquitoes that were in contact with sprayed structures died and therefore could not be collected from EWT and these results are in agreement with observations of Bruce-Chawett (1964). Mosquitoes collected from unsprayed houses were blood fed and did not die, as observed by Sharp *et al.* (2007).

In conclusion, DDT and lambda-cyhalothrin had residual effects of 6 months as compared with deltamethrin that had a residual effect of 5 months.

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