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Pitout JDD, Church DL, Gregson DB, Chow BL, McCracken M, Mulvey M, Laupland KB (2007). Molecular epidemiology of CTXM-producing Escherichia coli in the Calgary Health Region: emergence of CTX-M-15-producing isolates. Antimicrob. Agents Chemother. 51: 1281-1286.

Pelczar JR, Harley JP, Klein DA (1993). Microbiology: Concepts and Applications. McGraw-Hill Inc., New York, pp. 591-603.

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Full Length Research Paper

Toxicological and residual effect of Deltamethrin and Chlorpyrifos against the German cockroach, *Blattella germanica* (Linnaeus) (Insecta: Blattodea: Blattellidae)

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The toxicological and residual properties of two insecticidal agents, Deltamethrin and Chlorpyrifos were evaluated against the German cockroach, *Blatella germanica* in laboratory bioassay. The insecticides were diluted in both aqueous and oil-based solvents and tested against the roaches in pre-determined concentrations and untreated control. Experimental cages were either completely sealed after exposure or perforated to simulate fumigation and disinfestation regimes, respectively. Mortality data generated from acute toxicity studies revealed that oil-based Deltamethrin (5%v/v) was more effective (100%) than aqueous solution (53.3%) within similar durations in both chambers. Chlorpyrifos (5%v/v) revealed an acute mortality of 100% for both oil-based and aqueous solutions in both chambers. Residual effect of both Deltamethrin and Chlorpyrifos was dose/time-dependent, with oil-based solution more effective than the aqueous solution. Computed lethal time revealed that LT_{50} showed significant difference ($P<0.05$) between aqueous solution of both insecticidal agents for fumigation treatment. A similar trend was observed for the oil-based solutions of both insecticides in the disinfestations treatment. The implication of this finding in terms of choice of insecticides for acute toxicity and residual efficacy, impact of diluting agents, and sustainable approach to roach control in Nigeria was discussed.

Key words: *Blatella germanica,* disinfestation, fumigation chambers.

INTRODUCTION

The German cockroach (*Blatella germanica*, Linnaeus) is one of the most common species worldwide and prominent household cockroaches in the world, and can be found throughout many human settlements (Jacobs, 2007). It is particularly associated with restaurants, food processing facilities, hotels and nursing homes. It is however less prominent in temperate environments, probably due to its volume/surface area ratio which is a major hindrance to cold tolerance (Rust et al., 1995).

B. germanica is the most commonly encountered of the household pest**s** species in Nigeria. It is also the most persistent and difficult to control (Fasulo, 2002). This is due to its larger egg ratio per capsule than other species that infest households and structures. Secondly, it has the shortest developmental period from hatching to sexual maturity; thus, populations of German cock-

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roaches usually build up faster than other species. Thirdly, German cockroach nymphs have relatively enhanced chance of survival than other species because the female carries the egg capsule during the entire embryonic development of the nymph. These result in the nymphs avoiding many potential environmental hazards as compared to detached and/or isolated eggs. Thus, more nymphs are likely to hatch, with resultant higher reproductive potential. Fourthly, German cockroach nymphs are smaller than most other cockroaches; thus, they are able to conceal themselves in many places which are inaccessible to those of other species. In fact, in a commercial kitchen, there may be potentially thousands of cracks and crevices young cockroaches can hide in and remain protected (Fasulo, 2002). *B. germanica* has aggregation pheromones associated with their droppings, which have the effect of increasing the level of aggregation or clumping of individuals in the population (Engelmann, 1970; Roth, 1970). These biological factors, combined with their highly adaptive feeding habits and other behaviors, give the German cockroach advantages toward increased chances for survival and consistently maintaining high populations.

The control of *B*. *germanica* using conventional insecticidal agents remains a challenge in many parts of the world, due to increased spate of resistance development. *B. germanica* resistance to insecticides was first detected in chlordane use in Corpus Christi, Texas, USA in 1952 (Heal et al., 1953). Thereafter, an increasing number of cases have been documented in the USA (Rust and Reierson, 1991, Zhai and Robinson, 1991), Canada (Batth, 1977), Europe (Chapman *et al*., 1993), and Japan (Umeda et al., 1988). Currently, resistance to all the major groups of insecticides (organochlorines, organophosphates, carbamates and pyrethroids) by *B. germanica* has been reported (Cochran, 1995). Increased tolerance and potential resistance to other novel insecticides, such as sulfluramid (Schal, 1992) and abamectin (Cochran, 1994), along with behavioral changes in response to glucose attractant (glucose-aversion) in cockroach bait (Silverman and Ross, 1994) have been reported recently.

Few studies have been carried out on the control of *B*. *germanica* using different types and/or formulations of insecticides in Nigeria. This study therefore seeks to investigate the comparative insecticidal efficacies of Deltamethrin and Chlorpyrifos against *B. germanica* in laboratory bioassay, identify the impact of different diluents on the effectiveness of the two insecticides. Moreover, it seeks to evaluate the residual activities of the two insecticides, both as fumigation and disinfestation agents, against *B. germanica*

MATERIALS AND METHODS

Site of the experiment

Culture of the German cockroach, *B. germanica* was maintained in the laboratory at the Zoological Gardens, Department of Zoology, University of Lagos, where all bioassays were also carried out.

Insecticides used

Insecticides used, Deltamethrin (2.5 and 5% v/v) and Chlorpyrifos (2.5 and 5% v/v) were purchased from registered agrochemical retail stores around Lagos Island axis of Lagos in Lagos State Nigeria. The choice of diluents was water and diesel, respectively.

Insect culture

Adults and nymphs of the German cockroach were collected from students' cupboards in Fagunwa Hall, a female residential Hostel within the University Campus, as well from the insectary of the Department of Zoology, University of Lagos to set up a mass culture of *B. germanica.* The insects were kept in plastic vials which were smeared with petroleum jelly to prevent the cockroach from moving out of the vials. The vials were also covered with a muslin cloth and striped with rubber band to keep the insects in place.

While the culture lasted, the roaches were fed thrice a week with crumbs of bread and/or biscuits, with water also placed in the container. The containers were regularly cleaned and insect frass and faeces removed. The petroleum jelly at the edge of the vial was also renewed to prevent escape of the roaches upon opening the vial. Cleaning was done using wet foam rubbed sparingly round the containers and the dirt's packed out with a piece of serviette paper.

Experimental procedure

The experiment was carried out using the two aforementioned insecticides, two different concentrations and each treatment was replicated three times. Moreover, two different containers were used- perforated at the top (disinfestation procedure I_o) while the other was fumigation process (I_c)- where the fumigation containers were not perforated. Experimental cages were either completely sealed after exposure or perforated to simulate fumigation and disinfestation regimes, respectively. The procedure was in accordance with that of Shahi et al. (2008) with slight modifications.

Toxicity test

All life stages of *B. germanica* (except the first, second nymphal stages, and gravid females) were used for the toxicity tests. Deltamethrin and Chlorpyrifos insecticide formulation were used in accordance with the instruction on the labels. Four concentrations 2.5 and 5% (v/v) of water; 2.5 and 5% (v/v) of diesel were used. Each formulation was impregnated on filter paper and air-dried. Excess liquid was drained off, and thereafter, ten (10) randomly picked *B. germanica* were confined into each jar.

The upper surface of the jar was lightly greased with petroleum jelly to prevent escape of the insects (redundancy). There were two controls-jars with only water or only diesel sprayed on the filter paper. Each treatment was replicated three times. Mortality of *B. germanica* was observed after 5, 10, 15, 20, 30 min to the 4^{th} h post treatment and the number of dead *B. germanica* was counted and recorded. The jars containing treated and untreated filter papers were kept aside on laboratory bench and used for the residual experiments.

At one week after treatment, German roaches were re-introduced into the various vials containing the treated filer papers including the control to check the residual effect of these insecticides on the roaches. The same procedure was used as in the first experiments (for four hours), after which the experiment was stopped and cock-

Table 1. Mean mortality values for both water (positive control) and diesel (negative control) against *B. germanica*.

Time	Water	Diesel	
		I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00
10 min	0.00±0.00	0.00±0.00	0.00±0.00
15 min	0.00±0.00	0.00±0.00	0.00±0.00
20 min	0.00±0.00	0.00±0.00	10.00±0.00
30 min	0.00±0.00	6.70±5.80	10.00±0.00
45 min	0.00±0.00	13.30±5.80	20.00±0.00
1 h	0.00±0.00	13.30±5.80	20.00±0.00
2 h	0.00±0.00	26.70±5.80	26.70±5.80
3 h	0.00±0.00	26.70±5.80	43.30±5.80
34 h	0.00±0.00	36.70±11.60	43.30±5.80

I_O = Disinfestation; I_C = fumigation.

roaches discarded. Same experiment was repeated after two weeks.

Quantal response

Mortality readings were taken for cockroaches when no part of the body or limb movement was observed upon pricking with a *camel hair brush* and waiting for ten minutes for any movement to occur. Responses of cockroaches to the various experimental set up were noted and written down and the parameters used in taking records included the knock down time and rate of mortality per minutes/hours. Four hours was used, because that is the maximum time used for insect bioassay or toxicity test as long as it is in contact with the insect.

Statistical analysis

Statistical analysis of the results was also done after the results have been ascertained and its corresponding mean and standard deviation were recorded against time. This was done using the equations:

Mean, $\bar{x} = \Sigma FX / \Sigma F$

Standard deviation= $\sqrt{\Sigma(x-\bar{x})n/} \quad -1$

The lethal time value (LT_{50}) and the regression slope for each treatment were obtained using probit analysis (SPSS 2000). Mean percentage of insect mortality value was subjected to arcsine transformation. Means were compared using LSD test (SPSS 2000).

RESULTS

Mortality rate in *B. germanica* exposed to diluents and insecticides

Mortality in *B. germanica* exposed to diesel and water

Insects exposed to diesel started dying at 20 and 30 min after treatment in disinfestation (Io) and fumigation (Ic) chambers, respectively. The highest mortality of 43.3% was recorded in fumigation chambers at 4 h after treatment (I_C). No mortality was recorded on insects exposed to water treatment (Table 1).

Acute and residual effect of aqueous and diesel diluted Deltamethrin and Chlorpyrifos exposed to *B. germanica*

In aqueous Deltamethrin, mortality of *B. germanica* was recorded after 30 and 45 min for the and 5% (v/v) treatments, respectively. The highest mortality recorded (53.3%) was in 2.5% (v/v) (I_O-Dis-infestation) (Table 2). On the other hand, 100% mortality was recorded after 45 min in all the replicates and treatments with diesel diluted Deltamethrin.

At one week after treatment, mortality was recorded after 30 min (Table 3) with 5% (I_C-fumigation) and 2.5% (v/v) (I_C-disinfestation) having the highest (30%) and least mortalities (13.3%), respectively. On Diesel diluted Deltamethrin, mortality was recorded at 15 minutes and highest mortality (40%) was recorded at 4 h after introducing the insects in the fumigation and disin-festation chambers.

No mortality was recorded for *B. germanica* on water diluted Deltamethrin at 2 weeks after treatment until after 4 h with 5% (v/v) (I_C-fumigation) having the highest mor-tality (10%). On the other hand, diesel diluted Deltamethrin had less than 20% mortality at 2 h after introducing the insects. 5% (v/v) (I_C-fumigation) had the highest mortality of 16.7%, respectively (Table 4).

Acute and residual effect of aqueous and diesel-diluted *Chlorpyrifos* on *B. germanica*

Mortality of *B. germanica* exposed to Chlorpyrifos was dose-dependent. *Chlorpyrifos* (5% (v/v) mixed with diesel applied to *B. germanica* in the fumigation and disinfes-tation chambers gave 100% mortality at 30 min after treatment while 100% mortality was recorded at 2 h (Ic) and 3 h (Io) at same concentration with aqueous *Chlorpyrifos* (Table 5).

No death was recorded in all replicates at one week after treatment until 30 min of exposure, while 5% (v/v) (I_C-fumigation) had the highest mortality (33.3%) after 4 h (Table 6).

On the other hand, there was no mortality count for *B. germanica* introduced two weeks post-treatment, until after 4 and 3 h exposure to aqueous and oil-based Chlorpyrifos, respectively. Higher concentration of 5% v/v, recorded 23% mortality, after 4 h exposure in the fumigation chambers (Table 7).

A summary of the immediate and residual effect of Deltamethrin and Chlorpyrifos after 4 h exposure is shown in Table 8. In all, percentage mortality was directly dose-dependent and inversely time-dependent. 100%

Table 2. Mean mortality of both aqueous and diesel-diluted Deltamethrin against *B. germanica* (initial).

Time	Control	Water				Diesel			
		2.5% (v/v)		5% (v/v)		2.5% (v/v)		5% (v/v)	
	I_O & I_C	I_0	I_C	I_O	I_C	I_O	I_C	I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
10 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	56.70±23.10	86.70±5.80	73.30±15.30	83.30±5.80
15 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	80.00±10.00	100.00±0.0	83.30±5.80	90.00±10.00
20 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	96.70±5.80	100.00±0.0	93.30±5.80	93.30±5.80
30 min	0.00±0.00	0.00±0.00	0.00±0.00	6.70±11.60	23.30±20.80	100.00±0.00	100.00±0.0	100.00±0.00	100.00±0.00
45 min	0.00±0.00	6.70±5.80	0.00±0.00	6.70±11.60	26.70±15.30	100.00±0.00	100.00±0.0	100.00±0.00	0.00±0.00
1 h	0.00±0.00	6.70±5.80	10.00±0.00	6.70±11.60	30.00±17.30	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00
2 h	0.00±0.00	30.00±17.30	16.70±5.80	13.30±11.60	33.30±11.60	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00
3 h	0.00±0.00	43.30±28.90	16.70±5.80	26.70±23.10	43.30±5.80	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00
34 h	0.00±0.00	53.30±11.60	23.30±15.30	43.30±5.80	40.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00

I_O = Disinfestation; I_C = fumigation.

Table 3. Residual effect (mortality) of both aqueous and diesel-diluted Deltamethrin against *B. germanica* (one week).

Time	Control	Water				Diesel			
		2.5% (v/v)		5% (v/v)		2.5% (v/v)		5% (v/v)	
	I_O & I_C	I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
10 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
15 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	16.70±5.80	30.00±0.0	23.30±5.80	30.00±0.00
20 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	16.70±5.80	30.00±0.0	23.30±5.80	30.00±0.00
30 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.0±0.00	16.70±5.80	30.00±0.0	23.30±5.80	36.70±5.80
45 min	0.00±0.00	6.70±5.80	3.30±5.80	6.70±11.60	0.00±0.00	26.70±5.80	33.30±5.80	23.30±5.80	36.70±5.80
1 h	0.00±0.00	6.70±5.80	3.30±5.80	20.00±0.00	30.00±0.00	30.00±1.000	33.30±5.80	26.70±11.60	36.70±5.80
2 h	0.00±0.00	6.70±5.80	3.30±5.80	20.00±0.00	30.00±0.00	30.00±10.00	33.30±5.80	26.70±11.60	36.70±5.80
3 h	0.00±0.00	16.70±5.80	3.30±5.80	20.00±0.00	30.00±0.00	30.00±0.00	33.30±5.80	26.70±11.60	36.70±5.80
4 h	0.00±0.00	16.70±5.80	13.30±5.80	20.00±0.00	30.00±0.00	30.00±0.00	33.30±5.80	26.70±11.60	40.00±0.00

I_O= Disinfestation; I_C = fumigation.

mortality was recorded in *B. germanica* when newly introduced to both aqueous and oil-based *Chlorpyrifos* as well as *Deltamethrin* in both fumigation and disinfestation chambers. Diesel exposed to *B. germanica* gave 43 and 36% mortality in fumigation and disinfestation chambers, respectively. Residual effect of Deltamethrin and Chlorpyrifos recorded a maximum of 40% after 4 h in one week after treatment in the

Table 4. Residual effect (mortality) of both aqueous and diesel-diluted Deltamethrin against *B. germanica* (two weeks).

Time	Control	Water				Diesel			
		2.5% (v/v)		5% (v/v)2.		2. 5% (v/v)		5% (v/v)	
	I_O & I_C	I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
10 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
15 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
20 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
30 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
45 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1 h	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2 h	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3 h	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	6.70±5.80	10.00±0.00	13.30±5.80	16.70±5.80
4 h	0.00±0.00	3.30±5.80	3.30±5.80	3.30±5.80	10.00±0.00	6.70±5.80	10.00±0.00	13.30±5.80	16.70±5.80

I_O = Disinfestation; I_C = fumigation.

Table 5. Mean mortality of both aqueous and diesel-diluted Chlorpyrifos against *B. germanica* (initial).

Time	Control	Water				Diesel			
		2.5% (v/v)		5% (v/v)		2. 5% (v/v)		15/300ML	
	I_O & I_C	I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	33.30±32.20	46.70±15.30	16.70±20.80	43.30±15.30
10 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	26.70±37.90	53.30±15.30	63.30±25.20	43.30±23.10	66.70±23.10
15 min	0.00±0.00	0.00±0.00	0.00±0.00	10.00±17.30	60.00±10.00	56.70±20.80	73.30±15.30	53.30±47.30	86.70±5.80
20 min	0.00±0.00	50.00±17.30	40.00±30.00	10.00±17.30	70.00±10.00	63.30±15.30	80.00±17.30	56.70±49.30	86.70±5.80
30 min	0.00±0.00	76.70±5.80	86.70±11.60	43.30±32.20	76.70±5.80	73.30±5.80	96.70±5.80	100.00±0.00	100.00±0.00
45 min	0.00±0.00	83.30±15.30	93.30±5.30	66.70±28.90	93.30±5.30	86.70±11.60	100.00±0.00	0.00±0.00	0.00±0.00
1 h	0.00±0.00	93.30±5.30	96.70±5.80	76.70±5.80	96.70±5.80	100.00±0.00	100.00±0.00	0.00±0.00	0.00±0.00
2 h	0.00±0.00	100.00±0.00	100.00±0.00	93.30±5.30	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00	0.00±0.00
3 h	0.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00	0.00±0.00
4 h	0.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	100.00±0.00	0.00±0.00	0.00±0.00

I_O= Disinfestation; I_C = fumigation.

fumigation chambers.

In the fumigation chambers, LT_{50} of aqueous Deltamethrin and Chlorpyrifos (5% (v/v)) were 195 and 15 min respectively, while Deltamethrin and Chlorpyrifos mixed with diesel were 9 and 6 min respectively. While under disinfestation chambers,

Table 6. Mean residual effect (mortality) of both aqueous and diesel-diluted Chlorpyrifos against *B. germanica* (one week).

Time	Control	Water				Diesel			
		2.5% (v/v)		5% (v/v)		2.5% (v/v)		5% (v/v)	
		I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
10 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
15 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	16.70±5.80	13.30±5.80	20.00±0.00	16.70±5.80
20 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	16.70±5.80	13.30±5.80	20±.000.00	16.70±5.80
30 min	0.00±0.00	10.00±10.00	16.70±5.80	13.30±5.80	20.00±0.00	16.70±5.80	16.70±5.80	20.00±0.00	20.00±0.00
45 min	0.00±0.00	10.00±10.00	16.70±5.80	13.30±5.80	20.00±0.00	20.00±0.00	20.00±10.00	26.70±5.80	23.30±5.80
1 h	0.00±0.00	20.00±10.00	26.70±5.80	30.00±0.0	33.30±11.60	23.30±5.80	26.70±5.80	30.00±0.00	33.30±5.80
2 h	0.00±0.00	20.00±10.00	26.70±5.80	30.00±0.0	33.30±11.60	26.70±5.80	30.00±0.00	33.30±5.80	40.00±10.00
3 h	0.00±0.00	20.00±10.00	26.70±5.80	30.00±0.0	33.30±11.60	26.70±5.80	30.00±0.00	33.30±5.80	40.00±10.00
4 h	0.00±0.00	20.00±10.00	26.70±5.80	30.00±0.0	33.30±11.60	26.70±5.80	30.00±0.00	33.30±5.80	40.00±10.00

I_O= Disinfestation; I_C = fumigation.

Table 7. Mean residual effect (mortality) of both aqueous and diesel-diluted Chlorpyrifos against *B. germanica* (two weeks).

Time	Control	Water				Diesel			
		2.5% (v/v)		5% (v/v)		2.5% (v/v)		5% (v/v)	
		I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
5 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
10 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
15 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
20 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
30 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
45 min	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
1 h	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
2 h	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00
3 h	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	10.00±0.00	13.30±5.80	20.00±0.00	23.30±5.80
4 h	0.00±0.00	3.30±5.80	3.30±5.80	10.00±0.00	10.00±0.00	10.00±0.00	13.30±5.80	20.00±0.00	23.30±5.80

I_O = Disinfestation; I_C = fumigation.

Table 8. Percentage mortality after four hours of exposure.

Parameter		2.5% (v/v)		5% (v/v)	
		I_O (%)	I_C (%)	I_O (%)	I_C (%)
Diesel	Control	36	43		
Water	Control	0	0		
Deltamethrin/water	Initial	53	23	43	50
	One week	16	13	20	30
	Two weeks	3	3	3	10
Deltamethrin/diesel	Initial	100	100	100	100
	One week	30	33	26	40
	Two weeks	6	10	13	16
Chlorpyrifos/water	Initial	100	100	100	100
	One week	20	26	30	33
	Two weeks	3	3	10	10
Chlorpyrifos/diesel	Initial	100	100	100	100
	One week	26	30	33	40
	Two weeks	10	13	20	23

Table 9. Lethal time values for Deltamethrin (initial).

Lethal time	Aqueous				Diesel			
	2.5% (v/v)		5% (v/v)		2.5% (v/v)		5% (v/v)	
	I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
LT_5 (minutes)	49	67	45	16	6	7	5	5
LT_{50} (minutes)	209	528	358	195	10	9	9	9
LT_{95} (minutes)	880	4000	3000	2000	19	11	18	16

the LT_{50} was 358, 9, 37 and 12 min, respectively (Tables 9 and 10).

DISCUSSION

The study evaluated the effectiveness of two insecticides *Chlorpyrifos* (an organophosphate) and Deltamethrin (a Pyrethroid) on the control of the German cockroach, *B. germanica*. Only aqueous and oil-based Chlorpyrifos and Deltamethrin (oil based) gave 100% mortality of *B. germanica* within the four hours of exposure period. However, the efficacy of both diluents decreased with increase in residual time.

The experiment shows that Chlorpyrifos was more effective than Deltameth*rin* at the concentration used. The LT_{50} of (5% (v/v)) aqueous Chlorpyrifos for both dis-infestation (13 min) and fumigation (5 min) trials against *B. germanica* were found to be lower when compared with those exposed to aqueous Deltamethrin (358 and 195 min, respectively), of same concentrations and conditions. Moreover, mortality responses (5% (v/v)) of aqueous Chlorpyrifos for both disinfestations and fumigation trials against *B. germanica* were found to be higher than those of insects exposed to aqueous Deltamethrin. A similar trend was observed in the diesel-diluted insecticidal exposure at both concentrations for fumigation and disinfestation against *B. germanica.*

Diesel-diluted insecticidal treatments recorded significantly higher mortality responses than those of aqueous treatments for all concentrations against *B. germanica.* This result is in conformity with the findings of Limoee et al. (2001), Robison et al. (1999) and Enayati et al. (2007), who revealed that Cypermethrin was more effective than Deltamethrin (Deltamethrin) in the control of *B. germanica.* In a research carried out by Shahi et al. (2008) toxicity of cypermethrin, deltamethrin, diazinon, lambda-cyhalothrin and Negon® (permethrin+propoxur) commercial formulations were investigated against adult German cockroaches collected in different areas of Bandar Abbas City, southern Iran. Maximum mortality rates of 20, 35, 90 and 100% were obtained after one

Table 10. Lethal time values for Chlorpyrifos (initial).

Lethal time	Aqueous				Diesel			
	2.5% (v/v)		5% (v/v)		52.% (v/v)		5% (v/v)	
	I_O	I_C	I_O	I_C	I_O	I_C	I_O	I_C
LT_5 (minutes)	12	13	13	5	1	1	3	2
LT_{50} (minutes)	25	24	37	15	10	7	12	6
LT_{95} (minutes)	54	43	105	47	85	36	46	26

hour contact with label-recommended doses of cypermethrin, deltamethrin, lambad-cyhalothrin, diazinon and permethrin+propoxur insecticides, respectively. This result is not in conformity with other researches done on the *B*. *germanica* using cypermethrin and deltamethrin, as higher mortality was recorded using Deltamethrin than in Cypermethrin. The findings however, of Shahi et al. (2008) on the effects of both insecticides on *B*. *germanica*, as well as those of Spring (2010) and Cakir et al. (2008) on other insect pests revealed that Cypermethrin was more effective than Deltamethrin.

This study also revealed that fumigation treatments were more effective than dis-infestation treatments in the control of *B. germanica*. The results on the residual effect (one and two weeks respectively) of Chlorpyrifos and Deltamethrin were in conformity with the findings of Enayati et al. (2007) and Spring (2010).

Results from this study revealed a higher insecticidal effect of Chlorpyrifos over Deltamethrin (for both fumigation and disinfestation) against *B. germanica. Chlorpyrifos* had a faster knock down effect and higher percentage mortality than Deltamethrin, and this was observed for both concentrations and diluents used for the study. The importance of this finding implies that Chlorpyrifos (organophosphate) insecticides may be adopted for the control of *B. germanica* within Lagos metropolis. The diesel-diluted treatments were more effective than aqueous treatment for both insecticides. The residual properties of both insecticides followed a similar trend observed in initial exposure. The mortality response was however relatively low (<40%) for both insecticides at the maximum time lapse of two weeks. This implies that both insecticidal agents will perhaps become ineffective over a 2-week duration, hence the need to reapply these chemicals when necessary. Ultimately, the sustainable control of *B. germanica* in the long-term will involve various approaches in an integrated manner in order to safeguard the ecosystem for other organisms.

Conflict of Interests

The author(s) have not declared any conflict of interests.

REFERENCES

Batth SS (1977). A survey of Canadian populations of the German cockroach for resistance to insecticides. Canadian Entomol. 109: 49-52.

Cakir G, Yavuz O, Kocak O (2008). Effects of Piperonyl Butoxide and Tetramethrin Combinations on Biological Activities of Selected Synthetic Pyrethroid Insecticides against Different Housefly (*Musca domestica L., Diptera*: *Muscidae*) Populations. Acta Vet. Brno. 77:467-474.

Chapman PA, Learmount J, Pinniger DB (1993). Insecticides resistance in *Blattella* (L.) in the United Kingdom. (Widley KB and Robinson WH, eds.) Proceedings of the First Int Conf. Insect Pests Urban Environ. 19:125-133.

Cochran DG (1994). Abamectin resistance potential in the German cockroach (*Dictyoptera*: *Blattidae*). J. Econ Entomol. 87:899-903.

Cochran DG (1995). Insecticides resistance. In Understanding and Controlling German Cockroach, (Rust MK, Owens JM and Reierson DA, eds.). New York, Oxford University Press. 3:171-192.

Enayati AA, Fazard MH (2007). Biochemistry of pyrethroid resistance in German cockroach (*Dictyoptera*: *Blattelidae*) from hospitals of Sari, Iran. Iran. Biomed. J. 11(4):251-258.

Engelmann F (1970). The Physiology of Insect Reproduction. Pergamon Press. 307p.

Fasulo TR (2002). Stored Product Pests and German cockroach. Bug Tutorials. University of Florida/IFAS. CD-ROM. SW-165.

Heal RE, Nash KB, Williams M (1953). An insecticides resistant strain of the German cockroach, Corpus Christi, Texas. J. Econ. Entomol. 46: 385-386.

Jacobs S (2007). German Cockroaches (On –line). Entomology notes, Pennsylvania State University. http://www.ento.psu.edu/extension/factsheet/german cockroach.htm

Limoee M, Enayati AA, Khassi K, Salami M, Ladoni H (2001). Insecticide reisitance and synergism of three field collected strains of the German cockroach, *Blatella* (L) (*Dictyoptera*: *Blatellidae*) from hospitals in Kermanshah, Iran. Trop. Biomed. 28(1): 111-118.

Roth LM (1970). The stimuli regulating reproduction in cockroaches. Centre National de la Recherche Scientifique 189: 267–286.

Rust MK, Owens JM, Reierson DA (1995). Understanding and Controlling the German Cockroach. Oxford University Press. 448p.

Rust MK, Reierson DA (1991). Chlorpyrifos resistance in German cockroaches (*Dictyoptera: Blattidae*) from resturants. J. Econ. Entomol. 84:736-740.

Schal C (1992). Sulfluramid resistance and vapor toxicity in field collected German cockroaches (*Dictyoptera*: *Blattellidae*). J. Med. Entomol. 29: 207- 215.

Shahi M, Hanafi-Bojd AA, Vatandoost H (2008).Evaluation of Five Local Formulated Insecticides against German Cockroach (*Blattella* L.) in Southern Iran. Iran. J. Arthropod-Borne Dis. 2(1):21-27.

Silverman J, Ross MH (1994). Behavioral resistance of field- collected German cockroaches (*Blattodea*: *Blattellidae*) to baits containing glucose. Environ. Entomol. 23:425- 430.

Spring AB (2010). Susceptibility of *Anopheles species* populations collected from four localities in Juba County to DDT and deltamethrin, Central Equatoria State, Southern Sudan. Resistant Pest Manag Newsletter 19(2): 230-256.

Umeda K, Yano T, Hirano M (1988). Pyrethroid- resistance mechanism in German cockroach, *Blattella* (*Orthoptera*: *Blattidae*). Appl. Entomol. Zool. 23:373- 380.

Zhai J, Robinson WH (1991). Pyrethroid- resistance in a field population of German cockroach, *Blattella* (L.). Jpn. J. Sanitary Zool. 42: 241-244.

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Full Length Research Paper

Susceptibility test of female anopheles mosquitoes to ten insecticides for indoor residual spraying (IRS) baseline data collection in Northeastern Nigeria

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Malaria is a major public health problem in Nigeria, accounting for about 60% of all outpatient attendances and 30% of all hospital admissions. Indoor residual spraying (IRS) was scaled up in Nigeria to supplement long lasting insecticide treated nets (LLINs) for malaria vector control. The success of IRS partly defends on the susceptibility of local anopheles mosquitoes to insecticides. The WHO standard insecticides-impregnated papers and tubes were used to conduct bioassay tests against local populations of *Anopheles* species in Misau Bauchi State Nigeria with a view of selecting the suitable insecticides for IRS. The tests papers include: Cyfluthrin (0.15%), DDT (4%), Deltamethrin (0.05%), Lambdacyhalothrin (0.05%), Malathion (5%), Permethrin (0.75%), Propoxur (0.01%), Alpha-cypermethrin (0.75%), Bendiocarb (0.1%), Bifenthrin (0.15%) and untreated (control). Twenty (20) two to three day-old, female Anopheles species, glucose fed, none blood fed, were exclusively used in the bioassay per treatments which was replicated three times. The post exposure 1 h knockdown and 24 h mortality was assessed. The results of the knockdown assessment indicate that Alphacypermethrin had the lowest KD_{50} (time taken to knockdown fifty percent of the exposed mosquitoes) value of 4.8 min. Relatively moderate KD_{50} values (minutes) were obtained with Propoxur (11.34), Deltamethrin (13.20), Malathion (15.82), Bendiocarb (17.29), Permethrin (18.43), Cyfluthrin (20.28) and Lambdacyhalothrin (23.11). Relatively higher KD_{50} values were obtained with Bifenthrin (27.29) and DDT (32.12) impregnated papers. The results of mortality assessment indicate that *Anopheles* mosquitoes were susceptible to Alphacypermethrin, Malathion and Propoxur with 100% mortality. The *Anopheles* species were less susceptible to Bifenthrin, Lambdacyhalothrin, Permethrin, Deltamethrin, Bendiocarb, Cyfluthrin and DDT. The Anopheles species used in the tests were morphological identified as *Anopheles gambiae, Anopheles funestus* and *Anopheles nili*. The public health significance of these findings is discussed.

Key words: Nigeria, *Anopheles* mosquitoes, resistance, Misau, Bauchi State, indoor residual spraying (IRS).

INTRODUCTION

WHO current estimates show that malaria mortality rates were reduced by about 42% globally and by 49% in the WHO African Region between 2000 and 2012 and during the same period, malaria incidence rates declined by 25% around the world, and by 31% in the African Region (WHO, 2013a).

In Nigeria, malaria accounts for 60% of outpatient visits to health facilities, 30% of childhood deaths, 25% of death in children under one year and 11% maternal death in addition to about 132 billion naira financial loss in the form of treatment costs, prevention, loss of man-hours, etc in Nigeria (FMoH/ NMCP, 2009). In Nigeria, the economic impact of malaria can be attributed to low gross national income per capital (GNI) of US$260 (FMoH, 2005).

In recent times, IRS is being adopted and scaled up to protect the entire household and community members who possibly have no access to treated bed nets in Africa (Beier et al., 2008).

The Federal Government Policy on Malaria Control in Nigeria focuses on LLINs, IRS, intermittent preventive treatment (IPT) and environmental management (NMCP, 2014). In line with these strategies, the National Malaria Elimination Programme (NMEP) in Nigeria has scaled up indoor residual spraying (IRS) to achieve 85% coverage in 20% of eligible structures in Nigeria in 2014. To achieve these target, IRS activities was progressively expanded in the seven World Bank Supported Malaria Booster States of Bauchi, Gombe, Kano, Jigawa, Rivers, Anambra, Akwa Ibom states, Nigeria from 2009 to 2014 to supplement LLIN and environmental management.

Currently, WHOPES recommends 12 insecticide compounds and formulations, belonging to four chemical classes, for deployment in IRS program (WHO, 2009). The major challenge in use of these insecticides in malarial vector control has been the development of resistance to insecticides among the vector populations. *Anopheles* mosquitoes resistance to insecticides is spreading rapidly across African countries (Awolola et al., 2002, 2005, 2007; Ndams et al., 2006; Oduola et al., 2010; Ranson et al., 2011; Kabula et al., 2012; Natacha et al, 2013; Ibrahim et al., 2014) and could reduce the impact of malaria prevention interventions using IRS and LLINs, particularly in sub-Sahara Africa (NGuessan et al., 2007; Awolola et al., 2008).

The successful implementation of IRS program partly depends on availability of insecticide(s) susceptible Anopheles mosquitoes in the local environment. Therefore, it is imperative to periodically conduct bioassays tests to assess the susceptibility status of local mosquito species to IRS interventional insecticides. The susceptibility of Anopheles mosquitoes against insecticides was fairly evaluated in southern parts of Nigeria (Olayemi et al., 2011; Oduola et al., 2012) but there was dearth of information in the northern Nigeria (Molta and Ali, 1998; Ndams et al., 2006). No documented evidence on the susceptibility status of *Anopheles* mosquitoes to guide procurement of IRS insecticide in Northeast Nigeria is available. Therefore, the presents study was conducted to provide baseline data on insecticides susceptibility status of local *Anopheles* mosquito in Misau, Bauchi State, Nigeria.

MATERIALS AND METHODS

Study area and period

The study was conducted in August 2010 in Misau town, Misau L.G.A located at latitude 11.31897 and longitude 10.47587, human population of 263,487 as at the 2006 census with an area of 1,226km^2. IRS was scaled up in 2009 in the three wards of Misau (Gundari, Kukadi A and Kukadi B) where Lambdacyhalothrin, Deltamethrin and Bifentrin respectively were used. The total coverage for insecticides was 52,000 households.The community has been using LLINs since 2002 till date. The farmers in the suburb cultivate vegetables, rice and wheat on the wetlands where agrochemicals (cypermethrin, lambdacyhalothrin, deltamethrin, dichlovos and primiphos-methyl) are used in pest control. The wetlands also has number of tube bore holes to supplement provision of portable water to Misau community. Pools of standing water from the wetlands and tube bore holes provide active breeding sites for the *Anopheles* mosquitoes.

Mosquito collection and rearing

The *Anopheles* species larvae were collected in naturally infested waterbodies in Misau using entomological ladles. When culicine larvae were collected, they were separated from the Anopheline larvae and discarded on the land. The emerging pupae were sucked out of the larval containers using pipette and kept in plastic cups inside a mosquito cage made from five(5) litres white plastic bucket, fastened with cone shape white mosquito netting with its rear end tied in to a knot to prevent escape of emerging adult mosquitoes. The adult that emerged in 1-3 days were reared according to methods of Umar et al. (2008).

Test kits and insecticide impregnated papers

The WHO susceptibility test kits (WHO tubes and accessories) and insecticide impregnated papers (0.75% Alpha-cypermethrin, 0.1% Bendiocarb, 0.15% Bifenthrin 0.15% Cyfluthrin, 4% DDT, 0.05% Deltamethrin, 0.05% Lambdacyhalothrin, 5% Malathion, 0.75%, Permethrin, 0.01% Propoxur and untreated control) were provided by the National Malaria Elimination Program (NMEP), Federal Ministry of Health, Abuja.

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Bioassay techniques

Insecticide susceptibility tests were carried out using the WHO standard procedures and test kits for adult mosquitoes (WHO, 1998). The bioassay was conducted using 2-3 days old, glucose-fed but non-blood fed female Anopheles mosquitoes.

For each insecticidal paper and the control, a three replicates of 20 adult female *Anopheles* mosquitoes were exposed to tubes and allowed to stand for 1 h and numbers of knocked-down mosquitoes were recorded at intervals of 10 min. After the exposure, mosquitoes were then transferred to a recovery tubes and fed with a pad of cotton wool soaked in 10% glucose solution. The holding tubes were kept for 24 h in a secluded, shaded and sterile place. Adult mortality was assessed after 24 h post-exposure by inability to stand upright and walk when probed with glass rod. The dead and survived mosquitoes at the end of experiment were separately kept in labeled 1.5 mL Eppendorf tubes containing silica gel, for species identification. The susceptibility tests were conducted in laboratory under fluctuating temperature (25-33°C) and relative humidity (90-95%).

Identification of *Anopheles* mosquitoes

Morphological keys of Gillies and DeMeillon (1968) and Gillies and Coetzee (1987) were used in morphological identifications of adult *Anopheles* mosquitoes.

Data analysis

The knockdown data was subjected to probit analysis using a statistical software (Statsdirect, 2013) to compute the KDT_{50} and KDT_{90} (time taken to knockdown 50 and 90% of the exposed mosquitoes) and their 95% confidence intervals. The 24 h mortality was manually assessed. The susceptibility of *Anopheles* mosquitoes to insecticides was assessed using the current WHO (2013b) criteria: A mortality in the range 98-100% indicates susceptibility and a mortality of less than 98% is suggestive of the existence of resistance. The adult mortality in control experiments were less than 5% and hence were not corrected for (Abbott, 1925).

RESULTS

The results of knockdown assessment of female *Anopheles* mosquitoes exposed to ten different insecticide impregnated papers is presented in Table 1. The results indicates that Alphacypermethrin has the lowest KDT_{50} and KDT_{90} values of 4.84 and 24.58 min while Bifenthrin had the highest KDT_{50} and KDT_{90} value of 27.29 and 85.95 min among all the pyrethroids tested. Among the cabamates, propoxur was most effective with KDT_{50} and KDT_{90} values of 11.35 and 17.30 min than bendiocarb with KDT_{50} and KDT_{90} values of 17.87 and 30.68 min, respectively. Malathion and DDT had lower KDT_{50} and KDT_{90} values of 15.82 and 29.22 min and higher 32.12 and 65.31 min, respectively.

The results of the 24 h post-exposure mortality presented in Table 2 indicate that the local *Anopheles* mosquito species were susceptible to Alphacypermethrin, Propoxur and Malathion with 100%. The tested *Anopheles* mosquito were resistant to Cyfluthrin (55.00%), DDT (78.33%), deltamethrin (83.33%), Lambdacyhalothrin (93.33%), Bifenthrin, Permethrin and Bendiocarb (96.67% each). The morphological identifications of stored *Anopheles* mosquito revealed *A. gambiae, A. funestus* and A*. nili*. The members of the *Anopheles gambiae* and *Anopheles funestus* were not identified using polymerase chain reactions (PCR) techniques.

DISCUSSION

The present study presents for the first time baseline data on the susceptibility status of *Anopheles* mosquitoes to WHOPES approved IRS insecticides in Misau, Bauchi State, Northeastern Nigeria to guide procurement of IRS insecticides in the state.

The results of knockdown assessment showed that the tested insecticidal papers induced knockdown of adult *Anopheles* mosquitoes suggesting that knockdown mechanism could be operating in the local *Anopheles* mosquito populations. This confirm earlier studies which separately indicates the knockdown effects of impregnated papers against *Anopheles* mosquitoes in Nigeria (Awolola et al., 2005; 2007; Oduola et al., 2010; Olayemi et al., 2011; Oyewole et al., 2011; Ibrahim et al., 2014). The knockdown of *Anopheles* mosquitoes exposed to insecticidal papers indicates the presence of KDR resistance mechanism (Kristan et al., 2003; Awolola et al., 2007; Ibrahim et al., 2014) operating in the populations of *Anopheles* mosquitoes in Misau.

Using the WHO (2013b) criteria for insecticides susceptibility or resistance assessment of mosquitoes, the 24 h post-exposure results indicates that the local *Anopheles* mosquito species were susceptible to alphacypermethrin, propoxur and malathion each with 100% mortality. Other Principal Investigators for IRS working in Northern Nigeria shown that local *Anopheles* mosquito species were particularly susceptibility to alphacypermethrin (Mwansat, 2012; Manu, 2013, Yoriyo, 2013).

The local Anopheles mosquito species were resistant to Cyfluthrin, Deltamethrin, Permethrin, Lambdacyhalothrin, Bifenthrin, Bendiocarb and DDT. Previous reports have documented evidence on resistant of *Anopheles* mosquitoes to Cyfluthrin (Coetzee et al., 2006); Deltamethrin (Betson et al., 2009; Oduola et al., 2012; Awolola et al., 2014); Permethrin (Abdalla et al., 2007; Awolola et al., 2007, 2012, 2014; Ramphul et al., 2009; Kemabonta et al., 2013); Lambdacyhalothrin (Awolola et al., 2014); Bendiocarb (Ibrahimet al., 2013) and DDT (Betson et al., 2009; Oduola et al., 2010, 2012). Sustainable insecticide resistance management strategy is imperative to avoid control failures when the resistant insecticides are used for IRS program in Bauchi State. There is need for periodic monitoring of insecticide resistance in malaria control programmes in Bauchi State, as it affects ITNs and IRS interventions across Africa (Awolola et al., 2008).

Table 1. Knockdown periods of anopheles mosquitoes exposed to ten insecticide impregnated papers in Misau, Bauchi State, Nigeria.

Insecticide group	Insecticidal paper	Concentration (%)	Number exposed	KD_{50} (min)	95% Confidence interval	KD_{90} (min)	95% Confidence interval
Pyrethroids	Bifenthrin	0.15	60	27.29	22.83-32.52	85.95	63.09-126.73
	Lambdacyhalothrin	0.05	60	23.11	19.14-27.34	49.11	40.10-62.43
	Alphacypermethrin	0.75	60	4.84	3.148 - 6.47	24.58	19.78- 32.53
	Permethrin	0.75	60	18.43	16.51-20.34	38.09	34.00-43.79
	Cyfluthrin	0.15	60	20.28	17.63-22.66	40.48	36.17-46.74
	Deltamethrin	0.05	60	13.20	10.12-16.89	36.79	27.45-51.13
Cabamates	Bendiocarb	0.1	60	17.87	14.25-21.78	30.68	25.28-38.24
	Propoxur	0.01	60	11.35	10.34-12.43	17.30	15.46-20.30
Organochlorine	DDT	4.0	60	32.12	29.21-35.01	65.31	57.29-78.54
Organophosphate	Malathion	5.0	60	15.82	14.02-17.53	29.22	26.20-33.45

Table 2. Mortality and susceptibility status of anopheles mosquitoes exposed to ten insecticide impregnated papers in Misau, Bauchi state, Nigeria.

Insecticide group	Insecticidal paper	Concentration (%)	Number Exposed	No Dead	Mortality (%)	Susceptibility status*
Pyrethroids	Bifenthrin	0.15	60	58	96.67	Resistance
	Lambdacyhalothrin	0.05	60	56	93.33	Resistance
	Alphacypermethrin	0.75	60	60	100	Susceptible
	Permethrin	0.75	60	58	96.67	Resistance
	Cyfluthrin	0.15	60	33	55.00	Resistance
	Deltamethrin	0.05	60	50	83.33	Resistance
Cabamates	Bendiocarb	0.1	60	58	96.67	Resistance
	Propoxur	0.01	60	60	100	Susceptible
Organochlorine	DDT	4.0	60	47	78.33	Resistance
Organophosphate	Malathion	5.0	60	60	100	Susceptible

*WHO scoring for resistance (WHO, 2013b).

The multiple insecticide resistances of *Anopheles* mosquitoes to the tested pyrethroids, carbamates and organochlorine insecticides may have grave implications for the malaria control programme. It may compromise the efficacy of interventions and potentially lead to the failure of IRS and ITNs based vector control (Awolola et al., 2008).

The resistance of *Anopheles* mosquitoes to bifenthrin, lamdacyhalothrin and deltamenthrin may be linked to use of these insecticides in 2009 IRS intervention in the communities. It is established that prior exposure of mosquitoes to insecticides may induced selection pressure (Kerah-Hinzoumbé et al., 2008). Pyrethroids based aerosols and coils are used for control of mosquitoes and domestic pests and it might contribute to the development of resistance as reported elsewhere (Kristan et al., 2003). The farmers in the community also use cypermethrin, lambdacyhalothrin, deltamethrin, dichlovos and primiphos-methyl for agricultural crop protection. Previous researchers have reported that exposure of malarial vectors to crop protection insecticides could result in development of insecticide resistance (Etang et al., 2003; Awolola et al., 2007; Müller et al., 2008; Chouaibou et al., 2008; Bigoga et al., 2012; Philbert et al., 2014). LLIN was used in Misau for protection against mosquitoes since 2002 to date and it may induce selections to pyrethroids insecticides. Previous studies revealed that use of LLIN could result in development of insecticide resistance in Anopheles mosquitoes (Kabula et al., 2011).

The morphological analysis of preserved mosquito samples showed populations of *A. gambiae, A. funestus a*nd *A. nilin* were used in the bioassays. *A. gambiae* is the principal vector of malaria in sub-Saharan Africa (Gillies and Coetzee, 1987; Samdi et al., 2006; Sinka et al., 2010). The fauna of *A. gambiae, A funestus and A nili* was earlier documented in northern Nigeria (Molineaux and Gramiccia, 1980; Gadzama, 1983; Molta et al., 1999; Samdi et al., 2006; Ahmed, 2013). The *A gambiae* and *A. funestus* are major malarial vector in Nigeria (Molineaux and Gramiccia, 1980) and have great implication in malaria transmission in Bauchi State. Therefore, periodic monitoring of insecticides resistance in this mosquito species is imperative to avoid vector control failures.

Conclusion

It is concluded that procurement of IRS insecticide(s) in the state should be guided by the results of the present study until new susceptibility status is established and resistance management strategies should be considered when using the less susceptible insecticides. It is recommended that future studies should focus on investigation on the *A. gambiae* and *A. funestus* complexes and elucidations of resistance mechanisms in these mosquito species.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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REFERENCES

Abdalla H, Matambo TS, Koekemoer LL, Mnzava AP, Hunt RH, Coetzee M (2007). Insecticide susceptibility and vector status of natural populations of *Anopheles arabiensis* from Sudan. Trans. R. Soc. Trop. Med. Hyg. 102 (3): 263-71.

Abbott WS (1925). A method of computing the effectiveness of an insecticide. J. Econ. Entomol.18: 265-267.

Ahmed UA (2013). Morphological identification of malaria vectors within Anopheles species at Hadeja and Jahun. Bayero J. Pure Appl. Sci. 6(1):92-94.

Awolola TS, Brooke BD, Hunt RH, Coetzee M (2002). Resistance of the malaria vector*Anopheles gambiae* s.sto pyrethroid insecticide in Southwestern Nigeria. Ann. Trop. Med. Parasitol. 96:849-852.

Awolola TS, Oyewole IO, Amajoh CN, Idowu ET, Ajayi MB, Oduola A, Manafa OU, Ibrahim K, Koekemoer LL, Coetzee M (2005).Distribution of the molecular forms of *Anopheles gambiae*and pyrethroid knock down resistance gene in Nigeria. Acta Trop. 95:204-209.

Awolola TS, Oduola AO, Oyewole IO, Obansa JB, Amajoh CN, Koekemoerd LL, Coetzeed M (2007). Dynamics of knockdown pyrethroid insecticide resistance alleles in a field population of *Anopheles gambiae s.s***.** in southwestern Nigeria. J. Vect. Borne Dis. 44:181-188.

Awolola TS, Oduola OA, Strode C, Koekemoer LL (2008). Evidence of multiple pyrethroid resistance mechanisms in the malaria vector *Anopheles gambiae* sensu stricto from Nigeria. Trans. R. Soc. Trop. Med. Hyg. 103(11):1139-1145.

Awolola ST, Adeogun AO, Olojede JB, Oduola AO, Oyewole IO, Amajoh CN (2014). Impact of PermaNet 3.0 on entomological indices in an area of pyrethroid resistant *Anopheles gambiae* in south-western Nigeria. Parasitol. Vectors 7:236.

Beier JC, Keating J, Githure JI, Macdonald MB, Impoinvil DE, Novak RJ (2008). Integrated vector management for malaria control. Malar J. 7(sup 1).

Betson M, Jawara M, Awolola TS (2009). Status of insecticide susceptibility in *Anopheles gambiae* s.l. from malaria surveillance sites in The Gambia. Malar J.

Bigoga JD, Ndangoh DN, Awono-Ambene PH, Patchoke S, Fondjo E, Leke RG (2012).Pyrethroid resistance in *Anopheles gambiae* from the rubber cultivated area of Niete, South Region of Cameroon. Acta Trop. 124:210-214.

Chouaibou M, Etang J, Brevault T, Nwane P, Hinzoumbe CK, Mimpfoundi R, Simard F (2008).Dynamics of insecticide resistance in the malaria vector *Anopheles gambiae*s.l. from an area of extensive cotton cultivation in Northern Cameroon.Trop. Med. Int. Health. 13:476-486.

Coetzee M, van Wyk P, Booman M, Koekemoer LL, Hunt RH (2006). Insecticide resistance in malaria vector mosquitoes in a gold mining town in Ghana and implications for malaria control. Bull. Soc. Pathol. Exot. 99(5):400-403.

Etang J, Manga L, Chandre F, Guillet P, Fondjo E, Mimpfoundi R, Toto JC, Fontenille D (2003). Insecticide susceptibility status of *Anopheles gambiae s.l***.** (Diptera:Culicidae) in the Republic of Cameroon.J. Med. Entomol. 40:491-497.

Federal Ministry of Health (FoMH) (2005). Training manual for management of malaria in Nigeria. National malaria and vector control division, Abuja Nigeria. pp. 1-86.

FMOH/NMCP (2009). Federal Republic of Nigeria training manual for management of malaria in Nigeria Participants' Manual Federal Ministry of Health National Malaria and Vector Control Division, Abuja- Nigeria.

Gadzama NM (1983). Mosquito Vectors of the Sahel savanna and environmental development. Annals Borno 1: 99-104.

Gillies MT, de Meillon B (1968). Anophelinae of Africa South of Sahara (Ethiopian Zoogeographical area). Publ. S. Afri. Ins. Med. Res. No 54.

Gillies MT, Coetzee M (1987). A supplement to the anophelinae of Africa south of the sahara. Pub. South African Inst. Med. Res. 55: 1-143.

Ibrahim KT, Popoola KO, AdewuyiOR (2013). Susceptibility of Anopheles gambiae sensu lato (Diptera:Culicidae) to permethrin, deltamethrin and bendiocarb in Ibadan city, Southwest Nigeria. Curr. Res. J. Biol. Sci. 5(2):42-48.

Ibrahim SS, Manu YA, Tukur Z, Irving H, Wondji CS (2014). High frequency of kdr L1014F is associated with pyrethroid resistance in Anopheles coluzzii I Sudan savannah of Northern Nigeria. MBC Infect. Dis. 14(1):441. www.ncbi.nlm.nih.gov/pubmed/25127882?dopt=abstract. Accessed on 10th August, 2014

Kabula B, Tungu P, Matowo J, Kitau J, Mweya C, Emidi B, Masue D, Sindato C, Malima R, Minja J, Msangi S, Njau R, Mosha F, Magesa S, Kisinza W (2012). Susceptibility status of malaria vectors to

insecticides commonly used for malaria control in Tanzania. Trop. Med. Int. Health.17:742-750.
Kabula B, Derua Y.A, Tungu P, Massue DJ, Sambu E, Stanley G, MoshaFW, Kisinza WN (2011). Malaria entomological profile in Tanzania from 1950 to 2010: A review of mosquito distribution, vectorial capacity and insecticide resistance. Tanz. J. Health Res. 13(1).
Kemabonta KA, Anikwe JC, Adaezeobiora IB (2013). Bioefficacy of Skaeter Abate and Spintor on Anopheles gambiae and *Aedes aegypti* mosquitoes from insecticides resistance areas of Lagos and Oyo State, Nigeria. J. Agric. Healthcare 3(3) www.iise.org/journal/. Accessed on 20th August, 2014.
Kerah-Hinzoumbé C, Péka M, Nwane P, Donan-Gouni I, Etang J, Samè-Ekobo A, Simard F (2008). Insecticide resistance in *Anopheles gambiae* from south-western Chad, Central Africa. Malar. J. 7: 192.
Kristan M, Fleischmann H, della Torrey A, Stich A, Curtis CF (2003). Pyrethroid resistance/susceptibility and differential urban/rural distribution of *Anopheles arabiensis* and *An. gambiae*s.s. malaria vectors in Nigeria and Ghana. Med. Vet. Entomol. 17:326-332.
Manu YA (2012). Personal communications; Susceptibility Status of Anopheles mosquitoes to insecticides in Jigawa State, Nigera.
Molineux L, Gramiccia G (1980). The Garki Project Research on the Epidemiological and control of malaria in the Sudan savanna of West Africa. World Health Organization. 311 p.
Molta NB, Ali A (1998). Susceptibility of Anopheles species of northeastern Nigeria to Permethrin. Entomological Society of Nigeria Occasional Publication. 31: 101-107.
Molta NB, Bdliya HH, Akinsola OA, Buahin GKA (1999). Insects of medical and veterinary importance at the Hadejia Nguru wetlands of Nigeria. Nig. J. Entomol. 16:1-13.
Müller P, Chouaïbou M, Pignatelli P, Etang J, Walker ED, Donnelly JM, Simard F, Ranson H (2008). Tolerance to pyrethroids in*Anopheles arabiensisis* associated with elevated levels of antioxidant genes and correlates with agricultural use of insecticides. Mol. Ecol. 17:1145-1155.
Mwansat GS (2012). Personal communications; Susceptibility Status of Anopheles mosquitoes to insecticides in Nasarawa State, Nigera.
Natacha P, Johnson M, Robert M**,** Reginald K, Robert K, Alexandra W, Philippa AW, Immo K, William K, Franklin WM, Mark R (2013). High level of resistance in the mosquito *Anopheles gambiae* to pyrethroid insecticides and reduced susceptibility to bendiocarb in north-western Tanzania. Malar J. 12:149. http:/www.mlariajournal.com/content/12/1/149. Access on 23rd April, 2014.
Ndams IS, Laila KM, Tukur *Z (*2006). Susceptibility of some species of mosquitoes to permethrin pyrethroid in Zaria, Nigeria. Sci. World J. 1(1):15-19.
N'Guessan R, Corbel V, Akogbeto M, Rowland M (2007). Reduced efficacy of insecticide treated nets and indoor residual spraying for malaria control in pyrethroid resistance area, Benin. Emerg. Infect. Dis. 13:199-206.
MNCP(National Malaria Control Program) (2014). Official website. www.nmcp.gov.ng. Accessed on 8th August, 2014
Oduola AO, Obansa JB Ashiegbu CO, Adeogun A, Otubanjo OA, Awolola TS (2010). High level of DDT resistance in the malaria mosquito: *Anopheles gambiae* s.l. from rural, semi urban and urban communities in Nigeria. J. Rural Trop. Pub. Health 9:114-120.
Oduola AO, Idowu ET, Oyebola MK, Adeogun AO, Olojede JB, Otubanjo OA, Awolola TS (2012).Evidence of carbamate resistance in urban populations of *Anopheles gambiae*s.s. mosquitoes resistance to DDT and deltamethrin insecticides in Lagos, South-Western Nigeria. *Parasit Vectors.*5:116.doi:10.1186/1756-3305-5-116. Access June 4th, 2013
Olayemi IK, Ande AT, Chita S, Ibemesi G, Ayanwale VA, Odeyemi OM (2011). Insecticide susceptibility profile of the principal malaria vector, *Anopheles gambiae* s.l. (Diptera: Culicidae), in north-central Nigeria. J. Vector Borne Dis. 48(2):109-112.
Oyewole IO, Ogunnowo1 AA, Ibidapo CA, Okoh HI, Awolola TS, Adedayo MA (2011). Epidemiology of malaria and insecticide resistance burden in Nigeria. J. Pub.Health Epid. 3(1):6-12. http://www.academicjournals.org/jphe. Accessed on 3rd August, 2014.
Philbert A, Lyantagaye SL, Nkwengulila G (2014). A Review of Agricultural Pesticides Use and the Selection for Resistance to Insecticides in Malaria Vectors. Adv. Entomol. 2:120-128. http://www.scirp.org/journal/ae. doi.org/10.4236/ae.2014.23019
Ramphul U, Boase T, Bass C, Okedi LM, Donnelly MJ, Muller P (2009). Insecticide resistance and its association with target-site mutations in natural population of *Anopheles gambiae* from eastern Uganda. Trans. R. Soc. Trop. Med. Hyg.103(11):1121-1126.
Ranson H*,* N'Guessan R*,* Lines J*,* Moiroux N*,* Nkuni Z*,*Corbel V (2011). Pyrethroid resistance in African Anopheles mosquitoes: what are the implications for malaria control?Trends Parasitol*.* 27:91-98.
Samdi LM, Anyanwu GI, Molta NB, Awolola TS, Oduola DO, Obansa J, Watila IM, Oguche S (2006). Determination of malaria vectorial status of Anopheles mosquitoes of the Sahel, Northeastern Nigeria. J. Life Envi. Sci. 8(1 and 2):442-448.
Sinka ME, Bangs MJ, Manguin S, Coetzee M, Mbogo CM, Heminway J, Patii AP, Temperley WH, Gething PW, Kabaria CW, Okara RM, Boeckel TV, Godfray HCI, Harbach RE, Hay SI (2010). The dominant Anopheles vectors of human malaria in Africa, Europe and the Middle East: occurrence data, distribution maps and bionomic précis. Parasites Vectors 3:117.
Statsdirect (2013).StatsDirect Statistical Software, StatsDirectLtd Uk Version 2.8.0(10/27/2013). No.11 Gresham Way Cheshire, M33 3UY U K.
Umar A, Kela SL, Ogidi JA (2008). Enhancement of WHOTechnique for Glucose Feeding of Adult Mosquitoes in laboratory Under Dry Arid Environment. J. Entomol. 5(3):164-166.
WHO (1998).Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces.In *vol.* WHO/CDS/MAL/98.12*.* Geneva: World Health Organization. pp. 15-20.
WHO (2009). Recommended insecticides for indoor residual spraying against malaria vectors. Geneva, World Health Organization (WHO), (http://www.who.int/whopes/
Insecticides_IRS_Malaria_09.pdf, accessed 15 October 2013)
WHO (2013a). World malaria reports. www.who.int/mediacenter/news/releases/20131211/en/(Accessed on 10th August, 2014).
WHO (2013b). Test procedures for insecticide resistance monitoring in malaria vector mosquitoes. www.who.int/malaria (Accessed on 20thApril, 2014).
Yoriyo YP (2013). Personal communications; Susceptibility Status of Anopheles mosquitoes to insecticides in Gombe State, Nigera.

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