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Impacts of insecticide-treated plastic sheeting (ITPS) on malaria transmission in the commune of Aguégués in Benin

F. Modeste Gouissi[1,4*], Sahidou Salifou[2], A. Patrick Edorh[1,3], W. Anges Yadouleton[4], R. Ablawa Sedjame[1], Renaud Govoetchan[4], Victorien Dougnon[1], Martin Akogbeto[4]

[1]*Laboratory of Toxicology and Environmental Health, CIFRED, University of Abomey-Calavi (UAC), 03 BP 1463 Jericho, Cotonou, Benin*

[2]*Polytechnic School of Abomey-Calavi (EPAC), Department of Animal Production, University of Abomey-Calavi (UAC), 01 BP 2009 Cotonou, Benin*

[3]*Department of Biochemistry and Cell Biology, Faculty of Science and Technology (FAST), University of Abomey-Calavi (UAC), 01 BP 526, Cotonou, Benin*

[4]*Entomological Research Center of Cotonou (CREC), 06 BP 2604 Cotonou, Benin*

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Abstract

Malaria is one of the most common parasitic diseases in the world and probably one of the deadliest of all human affections. The fact that people sleep after 10 pm and that mosquitoes swarm already at about 6 pm leads us to other options such as the use of insecticide-treated plastic sheeting in reducing malaria transmission in the commune of Aguégués. The insecticide-treated plastic sheeting were employed on the inside walls of 291 dwellings in the treated zone, where the mosquitoes land after biting. Entomological and parasitological parameters were studied. Human aggressive density (m.a) of anophelines has been a crude reduction to 87.26%. Corrected reduction was 85.78%. The crude reduction of the parous rate of *Anopheles gambiae S.I.* was 38.3%. Corrected reduction was 45%. The crude reduction of sporozoite index is 25% and the corrected reduction was 40%. The crude reduction for the number of infective bites per man is 90% and the corrected reduction was 88.88%. In residual fauna, the crude reduction of indoor residual density (IRD) was 86.5%. The corrected reduction was 90.3%. The introduction of insecticide treated plastic sheeting has significantly reduced the incidence of positive slides which is 2.69%. The crude reduction was 92.8% and the corrected reduction was 92.76%. The installation of insecticide-treated plastic sheeting in Akpadon in 2011 has significantly corrected hemoglobin levels. The insecticide-treated plastic sheeting provide a shelter "zero fly" which play an important role in reducing malaria transmission in the commune of Aguégués in Bénin.

***Corresponding Author:** F. Modeste Gouissi ✉ gouissi@yahoo.fr

Introduction

Malaria remains one of most frequently parasitic diseases in the world and probably one of the deadliest of all human affections. The record is not optimistic as 3.2 billion people are exposed to the mischief of this disease, more than 41% of world population (OMS, 2008). Each year, 300 to 500 million people are infected with malaria, often in its severe form, with one million deaths (Greenwood and Mutabingwa, 2002; Bray *et al.*, 2006, OMS, 2008). Unfortunately, it is mainly children less than 5 years (OMS, 2008) and pregnant women (primigravidae) (Steketee *et al.*, 1996, Rogerson *et al.*, 2007; Tan *et al.*, 2008) who pay the heaviest price for this sad record for most mortality in Sub-Saharan Africa. ITNs are an essential tool for the fight against malaria in Africa south of Sahara (Darriet, 1998; Lengeler *et al.*, 1996). The emergence and spread of resistance to *Plasmodium falciparum* to chloroquine antipaludiques usual which have revived interest in vector control. This was commonly done by indoor spraying of residual insecticides. If this control method is still effective, its implementation faces many technical and economic constraints. Significant efforts have been made in research tools and control methods according to epidemiological conditions and accepted by communities. The use of bed nets is an effective personal protection against mosquito bites, and in Africa, their use is widespread in some communities, even if they are not always well maintained or used improperly. Many tests were conducted to evaluate the effectiveness of using insecticide-treated nets for malaria control in Africa. They show that the pervasive use of ITNs reduces the vector populations and transmission (Carnevale *et al.*, 1988; Akogbeto and Nahum, 1996) of morbidity and mortality caused by malaria (Bradley *et al.*, 1986; Alonso *et al.*, 1991). But the variability of endemic malaria in terms of infection, morbidity and mortality by ecological situations, the fact that people sleep after 10 pm and mosquitoes abound already at about 6 pm make it difficult to extrapolate the results obtained in the study areas to other malaria-endemic areas and lead us to other options such as use of insecticide-treated plastic sheets in reducing malaria transmission in the commune of Aguégués.

Materials and methods

Study area

The study was conducted at 6 km from Porto-Novo and 15 km from Cotonou in the lowest part of the valley of Ouémé, the lacustrine commune of Aguégués. The lacustrine commune of Aguégués presents a humid tropical climate characterized by two (02) rainy seasons and two (02) dry seasons of equal importance. The intervention was conducted from May to October 2011 in the borough of Avagbodji. The village Akpadon is chosen for the study and the village Djèkpé, the control village. The villages Akpadon and Djèkpé are implanted on either side of the river Ouémé.

Basic data

In the commune of Aguégués, malaria transmission is seasonal and related to floods. Anopheline population dynamics is dependent on rainfall and the proximity of rivers. Studies in this country in 2010 (Gouissi *et al.,* 2012) showed that *Anopheles melas* is the main vector but minor in malaria transmission. *Anopheles gambiae*, another malaria vector, is present only during floods and contributes enormously to the transmission of malaria (Gouissi *et al.,* 2012). The proportions of these two species showed significant seasonal fluctuations: *Anopheles gambiae S.S.* represents 92.98% of 4066 females of *Anopheles gambiae S.I.* collected in flood and *Anopheles melas*, 90.46% of 6734 females collected in period of recession. All throughout the study, the aggressive density is higher for external capture than internal capture. The lowest densities are recorded on both sides in December (one mosquito captured internally and three mosquitoes collected externally). They present a first peak in June (12 internally mosquitoes and 26 externally mosquitoes). They present a second peak in October (10 internally and 19 externally). Of 910 thorax dissected during the period from January to May, 4 are carriers of

sporozoites, a sporozoitic index of 2.06%. Although *An. melas* is dominant during this period in the commune, the sporozoitic index recorded with *An. gambiae* is the highest 1.81% (2 positive chest for 110 dissected). The sporozoitic index with *An melas* is low 0.25% (2 positive thorax for 800 dissected). X^2 = 2.38, P = 0.12. During the rainy season from June to October, the sporozoitic index was 0% with *An. melas* and 8.11% with *An. gambiae*. It is 0.31% with *An. melas* (1 positive thorax for 315 dissected) and 1.5% for *An. gambiae*. Globally the sporozoitic index is high with *An. gambiae* during the flood and is low during the recession. It is low with *An. melas* during the recession and is canceled during the flood. Transmission by *An. melas* is very low during the period from January to May and November to December 0.015 and 0.032 respectively. It is zero during the rainy season (June-October). However, the EIR during the rainy season (June-October) was 9.22 with *An. gambiae*. During the rainy season we therefore recorded more than 9 infective bites in the commune of Aguégués. It is 1.27 in the dry season for *An. gambiae*. During this period we recorded more than one infective bite.

Demographic survey

A demographic survey was conducted in March 2011. In Akpadon 291 rooms, 594 children under 5 years were counted. In Djèkpé 192 rooms, 416 children under 5 years were counted.

The insecticide-treated plastic sheeting (ITPS)

The insecticide-treated plastic sheeting (ITPS) are in the form of sheets of polyethylene impregnated with deltamethrin. This insecticide is released at a predetermined rate over a period of up to 12 to 18 months. The polyethylene sheets are of dimensions 4m x 5m, 4m x 6m, 4m x 7m. The insecticide-treated plastic sheeting is supposed to kill mosquitoes that land on it, to the difference of nets that are around the beds to keep out of the bites. The insecticide-treated plastic sheeting have been used in March 2011 on the inside walls of 291 dwellings in the treated zone, where the mosquitoes land after biting.

When not to use insecticide-treated plastic sheeting treated with insecticide?

- Do not use insecticide-treated plastic sheeting to cover the floor of dwellings.
- Avoid exposing the treated plastic sheeting in contact with foods, which may be contaminated.
- Avoid plastic sheeting treated to structures which people are in regular contact, such as doors we need to push with hand.

The insecticide-treated plastic sheeting is obtained from the Red Cross of Nigeria.

Population of mosquitoes

The sampling of mosquito populations was performed by diurnal collection of fauna residual. The diurnal collection were conducted in the morning (7 am - 9 am) and afternoon (4 pm-6 pm) for semi-gravid females) in the treated village. The sampling of mosquito populations was done by night capture on human adult volunteers (under chemoprophylaxis drug). The night captures were made from 9 pm to 7 am inside the rooms. Female vectors were dissected to determine their physiological age by examining the tracheoles of the ovaries and search sporozoites in their salivary glands.

Sensibility to deltamethrin

Sensibility of *Anopheles gambiae S.I.* to deltamethrin was evaluated with females captured on humans and females maintained in insectary from larvae collected from gites. The tests were performed by contacting the female fasting with a polyethylene sheet impregnated with deltamethrin. The tests were conducted with a lot of 10 females. After 5 minutes of contact, females were recovered by a vacuum and delivered in goblets where they received food as a solution of 10% of sucrose. Mortality was assessed 24 hours later. A control group of 10 females was also observed.

Table 1: Results of night catches on human in Akpadon (treated village) and Djèkpé (control village) of internal catch (I) and external (E)), from June to October 2010 and 2011.

Entomological parameters	Akpadon (Treated village)						Djèkpé (Control village)			Reduction rate (%)	
	2010			2011			2011			Crude	Corrected
	I	E	Total	I	E	Total	I	E	Total	Total	Total
Aggressive density on human (m.a)	45	426	471	15	45	60	42	380	422	87.26	85.78
Nb of females examined	25	250	275	15	35	50	20	200	220	81.8	77.3
Nb of parous	12	95	107	2	10	12	10	86	96	88.78	87.5
Parous rate (%)	48	38	38.9	13.33	28.55	24	50	43	43.64	38.3	45
Nb of dissected females	20	30	50	10	30	40	22	26	48	20	16.66
Nb of infected females	3	2	5	1	2	3	3	3	6	40	50
Sporozoitic index (%)	15	6.66	10	10	6.66	7.5	13.63	11.53	12.58	25	40
Nb of infectious bites per man	7	3	10	1	0	1	5	4	9	90	88.88

Research of parasites and dosage of hemoglobin level

We conducted research of parasites and determination of hemoglobin in blood taken from children less than 5 years in dwellings selected in the two study zones.

The thick film is the technique used. Sampling is done to the pulp of a finger, either at the ear or venipuncture in elbow creases. For the coloration slides, we used 3% of Giemsa for 45 minutes. The reading is made at the objective 100. Research on parasites and counting are carried out in the thick film. Parasite density was determined in 100 microscopic fields, corresponding to 0.25 µl of blood. The number of parasites per microliter of blood, parasite density, is obtained by multiplying the number of parasites in 100 fields by 4.

We practiced the technique of direct reading of the absorbance of the eluates of blood at 550 nm which is to collect capillary blood on filter paper.

Statistical analysis

The crude reduction in anopheles population densities, parasite densities and the correction of hemoglobin levels after the introduction of plastic sheeting was estimated by comparing the data obtained in Akpadon before and during the intervention. By considering corrected values (or expected) those obtained in Djèkpé, the control village, the corrected reduction was estimated by

comparing the data obtained during the intervention in Akpadon to those collected in Djèkpé. The chi square analysis was used for statistical treatment of data

Table 2. Results of residual morning fauna harvests (RMF) in Akpadon (Treated village and Djèkpé (Control village) from June to October 2010 and 2011.

Entomological parameters	Akpadon		Djèkpé	Reduction rate (%)	
	2010	2011	2011	Crude	corrected
Nb of collected females	6425	865	5867	86.54	85.25
Anopheline indoor residual density	22	2.97	30.55	86.5	90.3
Nb of female unfed	80	10	106	87.5	90.5
Nb of engorged females	1207	60	648	95	90.7
Nb of gravid females	1817	20	789	98.9	97.5
Nb of examined females	435	40	421	90.8	90.5
Nb of parous	313	10	260	96.8	96.15
Parous rate (%)	72	25	61.8	65.27	60

Results

Impact of insecticide treated plastic sheeting on entomological parameters

In the commune of Aguégués, the main vectors of malaria transmission are *An. melas* and *An. gambiae*. *Anopheles gambiae* was predominant in the night captures as the harvests of the residual fauna. Human aggressive density (m.a) of anophelines has been a crude reduction to 87.26%. Corrected reduction was 85.78%. The crude reduction of the parous rate of *Anopheles gambiae S.I.* was 38.3%. Corrected reduction was 45%. The crude reduction of sporozoite index is 25% and the corrected reduction was 40%. The crude reduction for the number of infective bites per man is 90% and the corrected reduction was 88.88% (Table 1).

In residual fauna, the crude reduction of indoor residual density (IRD) was 86.5%. The corrected reduction was 90.3%. For *Anopheles gambiae S.I.*, the corrected reduction of IRD has been very important throughout the evaluation period. It was 90.7% and 97.5% respectively for females engorged and females gravid (Table 2).

The proportion of females examined and parous rates were not significantly different at Akpadon in 2010 and Djèkpé in 2011 ($P > 0.10$). The effect of insecticide-treated plastic sheeting (ITPS) on population densities of *Anopheles gambiae S.I.* has varied during the evaluation, the reduction of biting rate on human (TAH) was lower in October (Table 3).

The parous rate (TP) of *Anopheles gambiae S.I.* was significantly higher in Djèkpé in 2011 and Akpadon in 2010 than Akpadon in 2011, both for biting females ($P < 0.001$) and those collected in the residual fauna ($p < 0.02$).

The sporozoitic index (IS) of females *Anopheles gambiae S.I.* captured in Akpadon on man in 2011 was significantly lower than that observed in Akpadon 2010 and Djèkpé 2011 ($p < 0.001$).

The tests conducted in the intervention zone with plastic sheeting impregnated with insecticides showed normal sensitivity of *An. gambiae* to deltamethrin. Mortality was 100% after 5 minutes of contact, and 24 hrs of observation. For mosquitoes from insectary, mortality was complete after 7 months of installing plastic sheets. For wild mosquitoes, the rate of morbid mosquitoes was 3% after 24 hrs of observation in September and 10% in October (Table 4).

Table 3: Monthly variations on human biting rate (TAH) expressed in number of bites/ man/night (PHN), the parous rate (TP), the sporozoitic index (IS) and the number of infected bites per human. (PIH) in Akpadon (Treated village) and Djèkpé (Control village) from June-October 2010-2011, before and during surgery.

M	Akpadon (Treated village)												Djèkpé (Control village)					
	2010						2011						2011					
	TAH (PHN)	D (O)	TP (%)	D (G)	IS (%)	PIH (N)	TAH PHN	D (O)	TP (%)	D (G)	IS (%)	PIH (N)	TAH (PHN)	D (O)	TP (%)	D (G)	IS (%)	PIH (N)
J	45	13	42.1	118	11,2	12	16	12	28,9	11	9.3	1	42	15	44.8	47	14.8	11
J	56	11	41.6	114	11	11	14	12	27,5	11	8.8	0	55	13	44.1	48	14.1	11
A	81	10	38.9	87	10,1	10	12	10	24	9	6.6	0	90	10	43.2	44	12.9	10
S	56	9	36.2	60	9	9	10	10	20.5	6	4.4	0	52	6	42.7	41	11	9
O	32	7	35.7	56	8.7	8	8	6	19.1	3	4	0	33	4	42.5	40	11.7	9

M = month, D = number of dissected females, (O) = ovaries, (G) = salivary glands

Table 4. Results of sensibility tests of *Anopheles gambiae S.I.* to Insecticide Treated Plastic Sheeting comparing wild females from Akpadon and from insectary.

Months	Wild *An. gambiaes*			*An. gambiaes* from insectary		
	Nb of An exposed to ITPS	KD after 24 h	Corrected mortality	Nb of An exposed to ITPS	KD after 24 h	Corrected mortality
June	80	80	100%	100	100	100%
July	70	70	100%	80	80	100%
August	80	80	100%	90	90	100%
September	70	68	97%	100	100	100%
October	60	54	88.9%	80	80	100%

KD = effect of shock (Knock-Down)

Impact of insecticide treated plastic sheeting on parasitological parameters

Data are presented in Table 5 on the number of households surveyed for fever cases, number of slides made up and the number of positive cases for Plasmodium. Before surgery, the incidence of fever associated with parasitaemia was slightly higher than 37% in the two villages that do not show statistically significant difference. The introduction of Insecticide Treated Plastic Sheeting has significantly reduced the incidence of positive slides which is 2.69%. The crude reduction was 92.8% and the corrected reduction was 92.76% (Table 5).

Table 5. Number of households surveyed for fever cases, number of collected slides and the number of positive cases for Plasmodium.

Parasitological parameters	Akpadon		Djèkpé	Taux de réduction (%)	
	2010	2011	2011	Crude	Corrected
Number of households surveyed	180	291	192		
Number of thick film/blood smears made	960	2970	1188		
Number of positive slides in plasmodium	360 (37.5%)	80 (2.69%)	442 (37.2%)	92.8%	92.76%

Table 6. Impact of Insecticide-Treated Plastic Sheeting on the hemoglobin level in Akpadon (Treated village) and Djèkpé (Control village) from June to October 2010 and 2011, before and during the surgery.

Hemoglobin level	Akpadon 2010 Nb of children (%)	Akpadon 2011 Nb of children (%)	Djèkpé 2011 Nb of children (%)
Mild 10.0-10.9 g/dl	31 (24.21%)	386 (65%)	35 (24.13%)
Moderate 8.0-9.9 g/dl	62 (48.43%)	160 (27%)	71 (48.96%)
severe <8.0 g/dl	35 (27.34%)	48 (8%)	39 (26.9%)

Impact of insecticide treated plastic sheeting on hemoglobin

Hemoglobin levels observed in Akpadon in 2010 and Djèkpé in 2011 were not significantly different. However, with the installation of insecticide-treated plastic sheeting in Akpadon in 2011, the hemoglobin level observed is significantly different (Table 6).

Discussion

The knock down effect was recorded after five minutes of exposure, and mortality was recorded after 24 hours post-exposure. Mortality of *An. gambiae S.S.* from insectary colony was 100% while wild populations had reduced mortality. These results are similar to those obtained by Kweka in 2011 (Kweka *et al.*, 2011) with Long-lasting Insecticidal Net (LLINs). The mortality of anophelines of the insectary was 100%. Wild anophelines develop a little resistance to the insecticide used in the plastic sheeting. The study revealed high efficacy of ITPS against *An. gambiae*, the major malaria vector in the commune of Aguégués in Bénin. In bioassay tests, the 24-hrs mortality in almost all anophelines exposed for 5 mins was 100% during the first three months of use. Nguyen reported that *An. aegypti* were knocked down after 9-16 mins of exposure to the Olyset Nets and the adulticidal activity remained 100% up to 8 months (Nguyen *et al.*, 1996). In trials in Tanzania, it was reported that 3 mins of exposure induced 70-80% mortality in *An. gambiae* after 6 months as well as after 12 months. Time for 80% knock down was about 5-6 mins even after 12 months of use. In entomological studies, it was observed that the density of mosquitoes in structures with ITPS was drastically reduced when compared to structures with ITPS and without ITPS. This may be due to the repellent action, killing action, and excitorepellent action of the ITPS. In trials of Olyset Nets in M'bé village in Côte d'Ivoire, 60% and 90% reduction in density of *An. gambiae* and *An. funestus*, respectively, was reported (N'Guessan *et al.*, 2001). In a study carried out in Cambodia, > 70% decline in indoor-resting density of vector ~ 60% decline in parous rate of mosquitoes was reported where Olyset Net were used (WHO, 2001). Our results also are in conformity with these results. It may be pointed out that no toxic, irritation, and allergic effects were observed in volunteers sleeping inside the rooms with ITPS and in technicians doing bioassay tests on the ITPS. In view of these observations, it may be

concluded that ITPS have shown a high degree of efficacy against malaria and malaria vector and can be safety used to prevent mosquito bites. The ITPS provide a shelter "zero fly" which play an important role in reducing malaria transmission. However, large-scale trials are indicated to evaluate the impact of use of ITPS on transmission of diseases, particularly malaria, and their cost-effectiveness in comparison to conventional indoor residual spraying.

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