Efficacy of Permethrin-Treated Uniforms in Combination with DEET Topical Repellent for Protection of French Military Troops in Côte d'Ivoire

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ABSTRACT In 2000, 22,000 French military personnel were deployed overseas. The French military health service implemented a vector control strategy including personal protection by the use of permethrin preimpregnated battlefield uniforms (BFUs) and the application on the skin of a topical repellent (50% DEET). In 2000, French forces used an industrial process to impregnate cloth with permethrin by soaking it before cut-out of the BFU. A study was implemented in four experimental huts in Côte d'Ivoire to assess the field efficacy of the impregnated BFUs and their resistance to washing. Taking into account the systematic variations in each variable in the field and using a modeling based on logistic regression and discriminant analysis, this study showed that after 6 h without reapplication, the protective effects of the use of DEET as skin repellent was not significant, perhaps due to the high density of *Anopheles* mosquitoes during the night catching sessions and an average time of effective repellency of <2 or 3 h in the field. The analysis also showed that the French process of industrial impregnation of permethrin of the BFU offered in 2000 some protection from mosquito bites but not enough to reduce significantly the incidence of malaria among nonimmune troops. No positive or negative interaction was noted when DEET and the impregnated BFUs were used together.

KEY WORDS impregnated cloth, vector control strategy, permethrin, DEET

FOR EACH OF THE PAST FIVE years, the French army has deployed nearly 22,000 military personnel overseas. Of these, some 11,500 were posted in areas of malaria transmission. Among the arthropod-borne diseases, malaria, dengue fever, and cutaneous leishmaniasis have the greatest impact on French forces (Deparis et al. 2001). Each year, between 400 and 600 cases of malaria have been reported by the French military epidemiological surveillance network. During the dengue fever epidemics in 1997 in the West Indies and in the Pacific, 387 cases were reported in the French forces. Among the troops in French Guiana, 326 cases of cutaneous leishmaniasis were registered during the 1998–1999 outbreak. Malaria, which is the only lethal vectorial disease in the French army, is responsible for one death every 2 yr. Days missed from work due to malaria, dengue fever, and cutaneous leishmaniasis represent, respectively, 7, 8, and 26 d for each registered case (Deparis et al. 2001).

Except for yellow fever, for which an efficient vaccine exists, vector control is the main available strategy against vector-borne diseases. Personal protection also can offer a promising strategy by limiting contacts between humans and vectors, thus reducing the risks of infectious bites and hence the risk for the exposed troops to contract the vector-borne diseases.

The French military health service has implemented a vector control strategy that consists of individual and collective measures suited to soldiers' living conditions in the field. Individual measures include the use of mosquito bed nets impregnated with deltamethrin, the use of diethyltoluamide as an insect repellent applied directly to the skin (50% diethyltoluamide [DEET]), and the wear of battlefield uniforms (BFUs) impregnated with permethrin (Deparis et al. 2001). For obvious reasons, soldiers in the field at night cannot sleep under bed nets nor can they use head nets during military operations. The only remaining personal protection for this nonimmune military population from malaria is to wear impregnated BFUs and to apply insect repellent.

The cloth of the French army BFU is impregnated with permethrin by soaking it at a concentration of 1 g/m^2 before cutting and manufacturing. This technique, used exclusively by the French forces in 2000,

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gives a homogenous concentration of permethrin in the treated cloth.

Many studies have demonstrated the effectiveness of permethrin-impregnated cloth in combination with the use of repellents (Schreck et al. 1984, Gupta et al. 1987, Sholdt et al. 1988, Mafong and Kaplan 1997, Dick 1998, Young and Evans 1998). With regard to the industrial-impregnation method used by the French military forces, the lack of data concerning this technique meant that the effectiveness of the permethrin-impregnated BFUs and their resistance to washing had to be assessed in the field.

A study was set up by the Service de Santé des Armées in collaboration with a laboratory of the Service Central d'Etude et de Recherche du Commissariat de l'Armée de Terre (SCERCAT), a laboratory of the French Army Research Department of the quartermaster's office in charge of the assessment of the industrial impregnation process and the laboratoire de Lutte contre les Insectes Nuisibles (LIN) in Montpellier, France. Field evaluations have been carried out at the Institut Pierre Richet in Bouaké, Côte d'Ivoire. Bouaké is located in a savannah area of West Africa (8° N and 5° E).

The aim of this study was to assess under tropical field conditions the efficacy of the permethrin impregnated BFU which were washed up to 50 times with or without the simultaneous use of DEET as a skin repellent. Two effects of the use of the impregnated BFU associated or not with repellent have been assessed. The first is the protective effect from the mosquitos bites and the second is the reduction in malaria incidence. For the French army, the reduction in the number of mosquito bites is only a positive effect whose effectiveness is assessed with the reduction of malaria incidence. Positive effect and effectiveness are not directly proportional. If the effect of the personal protection is multiplied by 2, that does not mean inevitably that malaria incidence will decrease by 50%.

Materials and Methods

Study Area and Experimental Huts. The study was conducted from March to April 2001 in Bouaké. Impregnated BFUs were evaluated in four experimental huts belonging to the Institut Pierre Richet at M'Bé, a village located near a rice-growing area that constitutes adequate breeding sites for *Anopheles gambiae*, the main malaria vector in Africa. Most of the mosquitoes found at this site belong to this species, which presents a low level of resistance to permethrin (<5%) as demonstrated by Darriet et al. 1999. The huts were located in the corners of a square ≈5 m apart from each other, each on its own square concrete base, the site being located beside rice fields. Each concrete base was surrounded by a water-filled ditch designed to prevent scavengers of dead mosquitoes, such as ants or spiders, from entering the huts. Access was only possible through four 60 by 30-cm windows (chicanes) that were designed to allow mosquitoes to come in but inhibited them from exiting. The chicanes were constructed from pieces of plywood, set at an angle to create a funnel shape with a gap of ≈1 cm at the end. Mosquitoes that attempted to enter the hut had to fly up to pass through the gap, but down to exit. Inside the hut, mosquitoes bothered by the insecticide could take refuge on a veranda. This was done to simulate the fact that the mosquitoes could normally enter or leave a house at will. To leave the hut, they had to go through an opening the size of a door. This opening led out onto a veranda enclosed in mosquito netting. The mosquitoes, once on the veranda, were free to return into the experimental hut. This veranda, called the veranda-trap, allowed the mosquitoes to remain as far as possible from the effects of the insecticide inside the hut. All huts were cleaned before the trial.

Repellents. The repellent used was Insect Ecran Peau adulte (Laboratoire Oscer, Ottawa, ON, Canada), a French brand-name commercial fluid, containing a controlled-release formulation of 50% DEET.

BFUs. The BFU were designed for tropical areas and provided by the French Army (composition 65% cotton and 35% polyester). ATHANOR S.A. (Vieux-Thann, France), a French industrial company, was in charge of the process of impregnation. Of the 120 BFUs, 60 were treated by industrial preimpregnation with a pyrethroid insecticide, permethrin 25/75 (25% *cis*-isomer and 75% *trans*-isomer). The 60 treated and the 60 untreated BFUs were grouped into five loads for washing, with one load washed 10 times, another 20 times, 30 times, and 50 times, with the last load not washed. Washing and drying was done according to an International Organization for Standardization (IOS) procedure: 60°C in a washing machine with detergent for color fabrics but without perborate followed by drying in a clothes dryer. Washing and impregnation with permethrin were carried out under the supervision of the SCERCAT to respect IOS standard n°105. During washing, the impregnated uniforms were never mixed with nonimpregnated uniforms. An identification number was allocated to each jacket and trouser. Each number was permanent and easy to read according to a blind protocol, to prevent any researcher from knowing the type of impregnation or the number of times the uniforms had been washed. Each uniform was packaged in a tight-fitting plastic bag after its treatment. On the bag, the identification numbers of the jackets and trousers were marked in a permanent and visible way. These bags were packed in cartons each containing 12 uniforms. After the field experiment, the concentration of permethrin in the cloth of each BFU was measured by the SCERCAT.

Vector Collectors. Four adult men vaccinated against yellow fever slept separately in one of the four huts every night during the trial and collected mosquitoes the next morning. They had been previously hired by the Institut Pierre Richet for this purpose and for the collection of mosquitoes. They gave their informed consent to testing the impregnated BFUs and the repellent and were provided with antimalarial prophylaxis. The vector collectors wore long-sleeved uniforms and a pair of athletic shoes laced up with socks covering the feet and ankles. The use of repel-

lent was defined as a single application on the uncovered part of the body that remained exposed, head and hands, at the beginning of each catching session.

Data Collection. The catching sessions lasted 6 h (10 p.m.–4 a.m.). Each morning at 4 a.m., all mosquitoes were collected from each hut by the person who had slept in the hut. Mosquitoes were hand-collected with an aspirator from both the hut and the veranda-trap at 4 a.m. the day after and then brought to the laboratory. The mosquitoes were identified and numbered according to catching session, collector, and hut number and whether they had chosen refuge on the veranda. The few male mosquitoes were not recorded. Female mosquitoes were classified and numbered by species, whether they were blood fed, and noted as being dead or alive. Living mosquitoes were confined into plastic cups, provided with honey-soaked cotton wool, and kept for 24 h and then classified and numbered by species and abdominal condition and again noted as dead or alive.

Design and Statistical Analysis. Twenty catching sessions after a precise timetable were carried out with the four collectors and using a blind study protocol. The 20 session events were randomized according to a predefined protocol. The scenario of each session event depended on the results of the randomized drawing up of the blind study protocol. For example, in session 1, collector 3 wore impregnated BFU with repellent in the first hut, collector 1 wore impregnated BFU without repellent in a second hut, collector 4 wore nonimpregnated BFU with repellent in a third hut, and collector 2 wore nonimpregnated BFU without repellent in the fourth hut. The 120 BFU and the use of repellent were rotated between huts and collectors.

We used BMDP statistical software for the statistical analysis (BMDP Statistical Software 1992). We performed a chi-square test to compare proportions.

It was not possible to avoid systematic differences in mosquito abundance and biting rate among the four huts, the four collectors, and the 20 session events. Taking into account the systematic variations in each parameters, a logistic regression and a stepwise discriminant analysis analyzed the protective effects of the use of DEET as skin repellent and of the residual concentration of permethrin in the cloth of the BFU (in milligrams per square meter), which varied with the number of washings (Concato et al. 1993, Flanders and Kleinbaum 1995).

After having checked that the model fit the data adequately, considering that each collected female mosquito either was fed or unfed, the logistic regression provided the adjusted odd ratio (OR) of the protective effect on mosquito bites of the concentration of permethrin in impregnated BFUs and of the use of repellent. The analysis provided also the adjusted OR of the risk of being bitten by a mosquito according to the fact that the mosquito was dead or alive 24 h after being collected and to the systematic variations in individual attractiveness (data not shown) of the collectors, the night catching sessions, and the huts.

Next, we assessed the reduction of malaria incidence caused by the protective effect of the concentration of permethrin in impregnated BFUs with/without use of repellent. The discriminant analysis provided for a given collector and for a given experimental hut during a given night catching session, the probability b to get bitten by each collected mosquito according to the level of protection of the collector (Concato et al. 1993, Hoen et al.1995). If c was the number of collected mosquitoes in the hut, then the number of mosquito bites received during the night's catching session n is equal to $b*c$.

Next, we calculated the hazard, h, for one no immune soldier exposed during the night catching session to contract malaria using the following formula (Bouyer et al. 1993): $h = [1 - (1 - si)^n] * r$, where r is the percentage of parasites resistant to the drug used in chemoprophylaxis among the French troops and si is sporozoitic index.

Because h may be considered as the nightly infection rate, we assessed the predicted incidence, I_m, of malarial cases among 1000 soldiers exposed during one night with the following formula (Bouyer et al. 1993): $I_m = (1 - e^{-h}) * 1000$.

Then, in the conditions of exposure of a given night catching session and for a given hut, we calculated the number of malarial cases that could be avoided in a troop of 1000 nonimmune soldiers wearing impregnated BFUs that had never been washed. This number was equal to the difference of the predicted incidence of malaria if the soldiers had worn unimpregnated uniforms or if they had worn impregnated BFUs. The number of cases of malaria avoided by soldiers wearing impregnated uniforms was divided by the incidence of malaria that would have occurred if they had not been wearing impregnated uniforms to give an indication of effectiveness, that is, the proportion of avoided cases.

This model may be a good representation of malarial transmission under conditions of exposure within the experimental hut, and it was likely close to the conditions of exposure of troops in the field in an area of malarial transmission. We presented the results in the conditions of exposure of the first session, in the first hut.

To assess the sensitivity of the model, we tested several values for each parameter. Predicted incidence was obtained with si varying from 0.5 to 5%. These values correspond to a hypoendemic region like the Republic of Chad (si close to 0.5%) and a hyperendemic region like Côte d'Ivoire (si ranging from 2 to 5%), with French troops being posted in each of these regions. The value of r varied from 0.5 to 10%, because a proportion of the population is noncompliant to the chemoprophylaxis, leading to an apparent increase of parasite resistance. The number of collected mosquitoes after a catching session varied from 50 to 300, close to the minimum and the maximum value observed during the study.

Table 1. Assessment of the effectiveness of the French impregnated BFUs in Bouaké in 2001 (Côte d'Ivoire)

Collected mosquitoes	No. (%)	Distribution parameters/collector				
		Median	Mean	Standard deviation	Minimum	Maximum
Collected blood-fed	3,782 (56.9)	32.5	47.3	43.7	0	252
Collected unfed	2,868 (43.1)	18	35.8	45.4	0	213
Total	6,650	62.5	82	75	0	341

Distribution parameters of the number of blood-fed/unfed *Anopheles* mosquitoes collected per collector for 12 nights and without taking into account the wearing of permethrin-impregnated BFUs and the use of repellent (50% DEET).

Results

Most of the mosquitoes collected in the experimental huts were *An. gambiae* and *Anopheles funestus.* Occasionally, we found a few *Anopheles pharoensis* and *Mansonia africana* and *Mansonia uniformis.*

In amount, 6,650 mosquitoes were collected and among them 3,782 were blood fed (56.9%). Table 1 presents the main parameters of the distribution of the number of blood-fed/unfed mosquitoes collected per collector.

Results of Bivariate Analysis. The mortality rate was 10% (665 mosquitoes). Table 2 presents the distribution of mosquito mortality among their physiological status. Mortality among unfed mosquitoes was significantly higher than among the blood-fed mosquitoes (17.1 versus 4.6%, $P < 10^{-4}$). Mortality was significantly higher when collector used DEET repellent (11.3 versus 8.9%, $P = 0.03$) or wore impregnated BFU (11.3 versus 6.8%, $P < 10^{-4}$).

A significant decrease in the proportion of collected blood-fed mosquitoes was observed with the use of repellent (58.9 versus 44.6%, $P < 10^{-2}$) and the use of impregnated BFU (76.8 versus 48.4%, $P < 10^{-4}$) (Table 3). The proportion of blood-fed mosquitoes collected varied significantly, depending on different factors: collectors ($CHI^2 = 115$, ddl = 3, $P < 10^{-4}$), huts ($CHI^2 = 522$, df = 3, $P < 10^{-4}$) and night catching sessions ($CHI^2 = 318$, df = 19, $P < 10^{-4}$) (data not shown).

Results of Multivariate Analysis. By excluding the variable of "mosquitoes collected on the veranda," the logistic regression model fit the data adequately. The significant variables entered in the model were the collectors, the huts, the night catching sessions, the interaction between huts and catching sessions, the survival of the mosquitoes after 24 h, and the use of impregnated BFU.

Figure 1 shows that the use of DEET as insect repellent did not seem to bring of additional protection to that offered by the impregnated BFU, regardless of the number of times the BFU had been washed. The results of the logistic regression emphasized that the protection offered by the use of DEET was not significant for our study. There was no significant interaction between the use of DEET and the wearing of permethrin-impregnated BFUs. There was a significantly higher risk of being bitten by mosquitoes that survived (OR = 3.98, 95% CI of 3.25–4.88). The risk of

Table 2. Assessment of the effectiveness of the French impregnated BFUs in Bouaké in 2001 (Côte d'Ivoire)

Mortality among mosquitoes	No. (%)	*P* Value of ?^{2} test	RR ($CI_{95\%}$)
Total mortality	665 (10)		
Mosquitoes unfed	490 (17.1)	$<10^{-4}$	3.70
Mosquitoes blood-fed	175 (4.6)		(3.12–4.35)
When collector used repellent	352 (11.3)	0.0011	1.27
When collector did not use repellent	313 (8.9)		(1.1–1.47)
When collector wore impregnated BFU	530 (11.3)	$<10^{-4}$	1.66
When collector did not wear impregnated BFU	135 (6.8)		(1.39–2)

Distribution and comparisons of mortality between the blood-fed/unfed *Anopheles* mosquitoes and when the collectors used repellent (50% DEET) and permethrin-impregnated BFU.

RR, relative risk; $CI_{95\%}$, confidence interval at 95%.

Table 3. Assessment of the effectiveness of the French impregnated BFUs in Bouaké in 2001 (Côte d'Ivoire)

Blood-fed mosquitoes	No. (%)	*P* Value of ?^{2} test	RR of biting ($CI_{95\%}$)
When collector used repellent	1,705 (44.6%)	$<10^{-2}$	0.93
When collector did not use repellent	2,077 (58.9%)		(0.89–0.97)
When collector wore impregnated BFU	2,261 (48.4%)	$<10^{-4}$	0.63**
When collector did not wear impregnated BFU	1,521 (76.8%)		(0.61–0.65)

Comparisons of the proportions of blood-fed *Anopheles* mosquitoes according to the use of repellent (50% DEET) and permethrin-impregnated BFUs.

** If OR = 0.63, then the risk to be bitten is 1/0.63, or ~1.6 times less low while wearing an impregnated BFU.

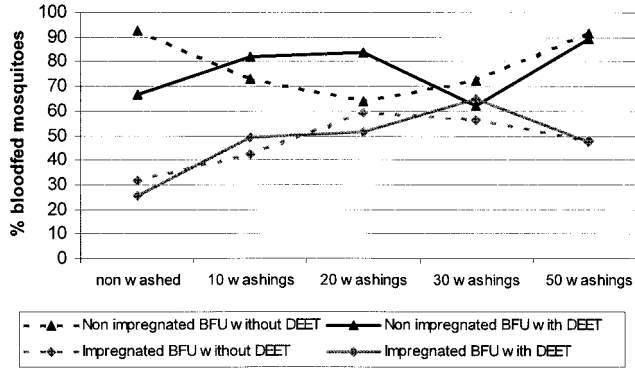

Fig. 1. Proportion of blood-fed *Anopheles* females collected during the 20 night catching sessions by the four collectors, exposed for 6 h according to whether a permethrin-impregnated BFU was worn, on the number of washings of the BFU, and whether the formulation of 50% DEET applied directly to the skin was used.

being bitten was lower with impregnated BFUs however many times they had been washed, despite that the level of protection of impregnated BFUs steadily decreased with the number of washes.

Figure 2 shows the calculated probabilities of being bitten by a mosquito. In the discriminant analysis, the use of repellent also was shown to have a nonsignificant protective effect. The probabilities of being bitten were higher by surviving mosquitoes, and by mosquitoes collected on the veranda. With the use of impregnated BFU, the probability of receiving a mosquito bite was lower than without protection regardless of the number of washings. It also was lower when the impregnated BFU had never been washed compared with washed uniforms (Fig. 2).

Assessment of Effectiveness of Impregnated BFUs That Had Never Been Washed. It was noted that the higher the sporozoitic index, the higher the level of resistance to chemoprophylaxis and the greater the number of collected mosquitoes, the higher the incidence of malaria among the 1000 exposed soldiers, whatever the level of protection used. For a given number of collected mosquitoes and a given parasite resistance level, the increase of the sporozoitic index from 0.5 to 5% resulted in an increase of malarial cases by 3 or 4 times whatever the level of protection used by the soldiers.

Using the proportion of avoided cases of malaria to assess the effectiveness of the impregnated BFUs, the higher the sporozoitic index the lower the proportion of avoided cases. To simplify, a single value of 3% for the sporozoitic index was used for the study of the influence of the number of collected mosquitoes and the level of resistance of the parasite on the proportion of avoided cases (Fig. 3). The higher the number of collected mosquitoes after a night session, the lower the proportion of avoided cases. The incidence of malarial cases increased with resistance to chemoprophylaxis but then, for a given number of collected mosquitoes, the proportion of avoided cases remained stable whatever the level of parasite resistance.

In short, the lower the number of collected mosquitoes and the lower the sporozoitic index, the higher the proportion of avoided cases due to the impregnated BFUs, i.e., the lower the endemic level of malaria, the higher the effectiveness of impregnated BFUs.

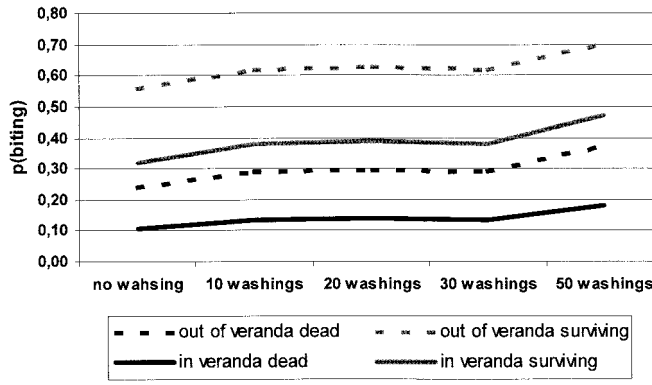

Fig. 2. Assessment of the effectiveness of the French impregnated BFUs in Bouaké in 2001 (Côte d'Ivoire). Probability of being bitten by surviving or dead *Anopheles* mosquitoes collected in either the hut or on the veranda when the collector wore impregnated BFU. Change according to the number of washings of the impregnated BFU.

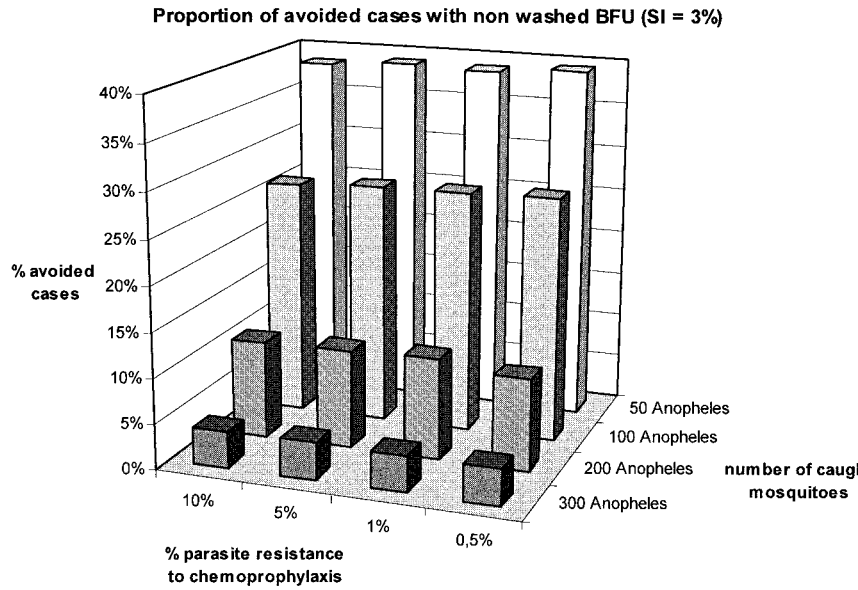

Fig. 3. Assessment of the effectiveness of the French impregnated BFU in Bouaké in 2001 (Côte d'Ivoire). Proportion of avoided malarial cases among a troop of 1000 soldiers wearing impregnated BFUs according to the variations of parasite resistance to chemoprophylaxis and the number of collected *Anopheles* mosquitoes after a night session in the experimental hut. Sporozoitic index (SI) was considered as being constant and equal to 3%.

Discussion

The excellent conditions under which this study was carried out owe much to the experience of the Institut Pierre Richet, which did numerous studies using experimental huts to assess the efficacy of impregnated cloth and repellents (Darriet et al. 1999, Kolaczinski et al. 2000).

The risk of being bitten by mosquitoes that survived was higher (OR = 3.98). Analysis showed that the mosquito death rate increased slowly but significantly when collectors used repellent (relative risk [RR] = 1.27) or when they wore an impregnated BFU (RR = 1.66). Both the permethrin impregnated BFU and the use of repellent significantly increased the death rate of anopheles and reduced the number of blood-fed mosquitoes and consequently the risk of contracting the disease. But, as noticed previously with the use of permethrin-impregnated bed nets (Quinones et al. 1998), induced mosquito mortality rate was too low (10%) to be able to significant reduce mosquito populations.

For most of the studies, DEET remains the first choice as repellent because its effectiveness has been well established and the number of toxic accidents reported is very low despite its widespread use (Schreck and McGovern 1989, Gupta and Rutledge 1991, Brown and Hebert 1997, Mafong et al. 1997, Fradin 1998, Goodyer and Behrens 1998). But, in our study, during an exposure lasting for 6 h, a single use of cutaneous DEET repellent gave no significant protection. In the field, it has already been reported that there were highly significant differences in protective effect between mosquitoes species (Curtis et al. 1987) and that with high densities of biting mosquitoes (*Anopheles* or *Aedes*), as in our study, a good level of repellency of the DEET formulation did not necessarily indicate a low number of bites (Schreck and Kline 1989). The average time that DEET protects against several species of *Anopheles* has been assessed as being shorter than 2 h (Coleman et al. 1993, Barnard 1998). Other studies have cited a Russian study that showed that DEET vapors attracted *Anopheles hyrcanus* (Pallas) (Mehr et al.1990) and another study showed that *An. dirus* tolerated low concentrations of DEET (Frances et al. 1993). At low doses, it is known that DEET can attract *Aedes* mosquitoes (Mehr et al. 1990, Dogan et al. 1999). If DEET was not reapplied, it seemed the diminishing concentration on the surface of the skin lost its repellency (Frances et al. 1993) or even attracted some mosquito species (Mehr et al. 1990, Dogan et al. 1999) explaining that after exposure, it seems necessary to wash off the repellent (Dogan et al. 1999). In our study the absence of significant protection of DEET applied directly to the skin could be due to different factors: the high density of *Anopheles* mosquitoes during the night catching sessions and an average time of effective repellency of <2 or 3 h in the field. Thus, even if the protection from bites of *Aedes* seems to last for 4–8 h without reapplication of DEET on the skin (Schreck and McGovern 1989, Xue et al. 1995), in the experimental hut DEET protection from bites of *An. gambiae* and *An. funestus* would certainly have depended on reapplying repellent every 2 or 3 h. In this study, in view of the results of the logistic regression, no positive or negative interaction was noted when DEET and the impregnated BFU were

Table 4. Assessment of the effectiveness of the French impregnated BFUs in Bouaké in 2001 (Côte d'Ivoire)

Variables	Odds ratio of risk of *Anopheles* bites[a]	$CI_{95\%}$
From surviving mosquitoes	3.98	3.25–4.88
With use of impregnated BFU		
Never washed	0.13[b]	0.07–0.25
10 washings	0.20	0.12–0.33
20 washings	0.21	0.13–0.34
30 washings	0.20	0.12–0.33
50 washings	0.36	0.27–0.50

Results of the logistic regression performed to assess the risk of *Anopheles* bites from surviving mosquitoes and the conditions of exposure to the *Anopheles* bites.

[a] All odds were significantly different from 1.

[b] If OR = 0.13, then the risk to be bitten is 1/0.13, or ~8 times less low while wearing an impregnated BFU.

used together. Thus, the protective effects of permethrin impregnated cloth and the protective effects of DEET, at best coexisted rather than offering any additional protection.

The protection against *Anopheles* offered by permethrin-impregnated clothes has been shown by many studies (Schreck et al. 1984, Gupta et al. 1987, Mafong and Kaplan 1997, Dick 1998, Young and Evans 1998). The permethrin-impregnated BFUs provided protection that decreased with the number of washings (Gupta et al. 1989, 1990; Eamsila et al. 1994). In the experimental hut, the relative risk of being bitten by an anopheline mosquito increased from 0.13 (8 times less bitten) for an impregnated BFU that had never been washed to 0.36 (3 times less bitten) for an impregnated BFU washed 50 times. The main interest of our study was to demonstrate that cloth that was impregnated industrially by soaking provided a significant protection, even after 50 washings, that is to say, the lifetime of the cloth.

If the collectors who wore the impregnated BFUs had decreasing protection with each washing, the rate of blood-fed mosquitoes remained 4 times higher among the surviving mosquitoes than among the dead mosquitoes within the first 24 h after having been collected. With washing, the toxic effect of the industrially impregnated cloth decreased but the risk of being bitten by surviving mosquitoes remained stable with that of being bitten by mosquitoes that had died.

Results of the predicted incidence among exposed nonimmune troops showed that it still remained high despite the wearing of permethrin-impregnated BFUs. For example, in an endemic region where there was a 3% sporozoitic index and where the level of parasite resistance to chemoprophylaxis was equal to 5% and where a level of vector density corresponded to 200 mosquitoes collected after a night catching session, the avoided incidence among a troop of 1000 soldiers wearing impregnated BFUs would be equal to five cases, i.e., 10% of the 50 predicted cases of malaria incidence without impregnated BFUs. That this ratio is so low emphasizes that industrially impregnated BFUs are not yet fully effective in the field. Recent work of LIN and SCERCAT has shown that insecticide molecules in the cloth may not be freely available, given a resultant low insecticide bioavailability.

In conclusion, this study showed that industrial impregnation of cloth by soaking before the cut-out of the BFU offered some protection from mosquito bites but not enough protection to reduce significantly the incidence of malaria among nonimmune troops. Other processes for industrial impregnation are being researched and assessed and the effectiveness of other insecticides such as etofenprox (a nonester pyrethroid) will soon be evaluated.

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