

# INSECTICIDE TREATED BED NETS

## INSECTICIDE TREATED BED NETS: A SIGNIFICANT CONTRIBUTION TOWARDS MALARIA CONTROL

John Invest, Consultant – Vector Environmental Science describes the development and benefits that have followed the introduction of insecticide treated bed nets into regions of Africa for malaria prevention

**Key words:** malaria, bednets, LLIN, pyrethroids

### Introduction

Malaria remains today one of the modern day scourges of the tropical world alongside HIV/AIDS. The number of malaria cases has actually increased over the last three decades. About 40% of the world's population, mostly those living in the poorest countries, are at risk of malaria. Of these 2.5 billion people at risk, more than 500 million become severely ill with malaria every year and more than 1 million die from the effects of the disease.

Malaria is especially a serious problem in Africa where there are very efficient mosquito vectors, increasing drug resistance and struggling health systems. An African child has on average between 1.6 and 5.4 episodes of malaria fever each year and one in every five (20%) childhood deaths are due to the effects of the disease – every 30 seconds a child dies from malaria. The vast majority of malaria deaths occur in Africa, south of the Sahara, where malaria also presents major obstacles to social and economic development. Malaria has been estimated to cost Africa more than US\$ 12 billion every year in lost GDP, even though it could be controlled for a fraction of that sum.

One of the greatest challenges facing Africa in the fight against malaria is drug resistance. Resistance to chloroquine, the cheapest and most widely used antimalarial, is common throughout Africa (particularly in southern and eastern parts of the continent). Resistance to sulfadoxine-pyrimethamine



**Manufacture of Olyset LLIN nets in Arusha, Tanzania**  
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**Distribution of Olyset bed nets in Madagascar**  
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(SP), often seen as the first and least expensive alternative to chloroquine, is also increasing in east and southern Africa. Over the past decade, a new group of antimalarials – the artemisinin compounds, especially artesunate, artemether and dihydroartemisinin – have been deployed on an increasingly large scale. These compounds produce a very rapid therapeutic response and are active against multi-drug resistant *P. falciparum* and are well tolerated by the patients. To control malaria efficiently, a co-ordinated approach is required, this includes prevention through control of the vector mosquitoes, early diagnosis and treatment through a good health care system and provision of anti-malaria drugs. Since the most vulnerable groups of the population are pregnant mothers and children <5 years old, this group must be provided with better antenatal care and education to protect the young children. While work and trials continue on the development of a malaria vaccine, an effective final product is still a long way off, so we have to rely on and use the tools we have available today efficiently.

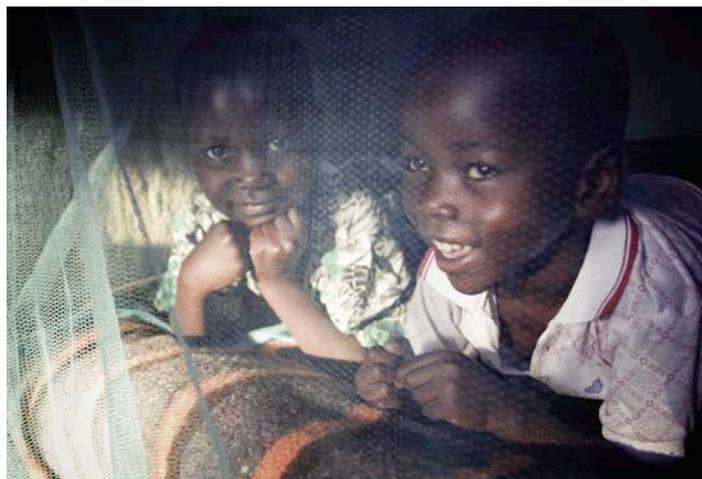
### Vector Control

The old saying 'Prevention is better than cure' holds true for malaria and if cases can be averted then there are huge savings in the costs of drugs and hospitalization. In addition, amongst adults, malaria causes a loss of ability to work and earn income while children suffering from malaria have their education seriously impaired due to repeated absences from school.

The control of malaria vector mosquitoes has long been an ongoing battle. The first breakthrough was the discovery



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of DDT which at one time was thought to enable the eradication of malaria, this was used widely around the world to spray the internal walls of houses. Unfortunately, mosquitoes cannot be eliminated so easily. At first there were massive reductions in mosquitoes and consequently malaria in countries such as India, however the mosquitoes developed resistance. The publication in 1962 of *'Silent Spring'* by Rachel Carson highlighted some of the environmental risks of using such a persistent insecticide – albeit in situations other than indoor residual spraying. As additional studies recorded human risks such as DDT in mother's breast milk, the anti-DDT lobby gained strength and DDT was phased out from most countries. While indoor residual spraying continues today using more sophisticated insecticides such as pyrethroids, mosquitoes have, in turn, developed resistance to these compounds, causing the revival of the use of DDT in countries where it is not resisted or where resistance in mosquitoes has regressed, such as South Africa.

Bednets have been around for a long time and their use in protecting people against malaria was recognized long ago, as shown below from an extract of a letter from Sir Ronald Ross, who was the first person to identify the malaria parasite in mosquitoes and inform the world on how malaria was transmitted. Before that it was thought the cause was 'bad air' from swamps, hence the name *mal-aria*.

### Calcutta, 24th August 1898

Extract of letter from Sir Ronald Ross to Brigadier General Sternberg, US Army,

*'My object in writing this letter may appear rather startling to you. It is to suggest the use of mosquito nets when practicable for your troops in Cuba and elsewhere, where I understand they are suffering severely from malarial fever. In light of my experiments with birds no cases of malaria should be allowed to remain without mosquito nets in hospitals, barracks etc. where mosquitoes abound or exist. A mosquito which has once bitten a malaria case can probably subsequently infect some dozen or so healthy persons by its bite'*

Bednets work by creating a protective barrier against mosquitoes at night, when the vast majority of transmissions

occur. The African malaria mosquitoes generally bite late at night or early morning, between 10pm and 4am when people are sleeping, so mosquito nets provide protection through the critical time of exposure risk. Most mosquito nets can accommodate more than one person – a mother and an infant or a few siblings.

However it was not until the synthetic pyrethroids were first discovered in the early 1960s by Michael Elliott at Rothamsted Research Station in UK that things changed. These insecticides, which have a structural resemblance to natural pyrethrins from certain chrysanthemum plants, have very low mammalian toxicity, but are highly toxic to insects and have a rapid knock-down effect, even at very low doses. The first pyrethroids were not light stable but Elliott subsequently synthesized permethrin and deltamethrin in the early '70s which were light stable. This created the opportunity to apply these insecticides to bednets. Insecticides were not applied to nets before, due to the risks associated with more toxic insecticides on nets and their inherent risks in close proximity to people, especially children. Even today only pyrethroid insecticides are approved for use on bednets. Initially bednets were treated using existing emulsifiable concentrates of pyrethroids which were diluted with water and then the nets were dipped in the solution and allowed to dry leaving an insecticidal deposit on the fibres. These dip treated nets are generally known as Insecticide Treated Nets or ITNs. A net treated with insecticide offers about twice the protection of an untreated net, and through its repellency and insecticidal activity, can even protect other people in the room outside the net.

Early trials conducted in The Gambia, West Africa showed that dipping a bednet in a simple emulsion of permethrin more than doubled its efficacy and had a huge impact on malaria incidence. Trials of insecticide-treated nets (ITNs) in the 1980s and 1990s showed that ITNs reduced deaths in young children by an average of 20%. This led to the commercial production of several 'dip' products for treating polyester or cotton nets.

On the basis of five community-randomized trials it was concluded that when full coverage is achieved, ITNs reduce all-cause child mortality by an average of 18% (range 14-

29%) in sub-Saharan Africa. The general implication of this is that 5.5 lives could be saved per year for every 1000 children under 5 years of age protected. It was concluded that ITNs reduce clinical episodes of malaria caused by *Plasmodium falciparum* and *P. vivax* infections by 50% on average (range 39-62%), as well as reducing the prevalence of high density parasitemia. (Lengler 2000 & 2004)

However there were drawbacks to ITNs: the chemicals required diluting and the nets needed to be dipped every 6-12 months in the solution; this required huge programmes in training people to handle chemicals safely and for teams to visit villages regularly to ensure nets were re-dipped at the appropriate time. While these early products clearly demonstrated the value of adding insecticide to bednets, the programmes often failed due to the cost and logistics of regular dipping.

The answer came in the form of long lasting insecticidal nets (LLINs). WHO define an LLIN as a net which will remain biologically active after 20 standard washes and last 3 or more years under field conditions.

LLINs come in two technologies, one using existing polyester nets to factory dip but using a resin to bind the insecticide to the surface of the fibre making it wash resistant. The other methodology, pioneered by Sumitomo Chemical, was to add pyrethroid insecticide to raw polyethylene and then extrude it into fibres which subsequently evolve the insecticide to the fibre surface by migration and therefore replenish the surface concentration whenever the net is washed. Sumitomo Chemical's product is called 'Olyset®' and uses the highly repellent and long lasting pyrethroid insecticide permethrin.

The World Health Organization (WHO) has an excellent scheme (WHO Pesticide Evaluation Scheme, WHOPES) to evaluate and confirm the efficacy of any public health insecticide. Therefore, for a WHOPES-recommended product its efficacy and safety are both assured. WHOPES recommendations are delivered in two stages. An interim recommendation is delivered after an accelerated wash-resistance and small scale field testing. Subsequently, this interim recommendation is changed to full recommendation based on large scale performance of efficacy and durability of the product over a three year period under field conditions. At present, only one LLIN (Olyset) has received full recommendation implying a minimum of three years efficacy; all the others have interim recommendation while field efficacy and durability tests are ongoing (*see: [http://www.who.int/whopes/Long-lasting\\_insecticidal\\_nets\\_ok2.pdf](http://www.who.int/whopes/Long-lasting_insecticidal_nets_ok2.pdf)*).

Published data as well as observations related to durability of mosquito nets under field conditions are limited. However, surveys carried out in Senegal by WHO and in Tanzania by the Swiss Tropical Institute (STI) (Tami et al., 2004) showed that the majority of polyethylene (Olyset) nets distributed 7 years ago in villages were still hanging over the beds and in reasonably good condition and provided good residual efficacy in laboratory tests against mosquitoes after seven years of use. A survey carried out in Tanzania concluded that the effective life of polyester nets was 2 to 3 years (Erlanger et al. 2004), confirming observations made by PSI (Population Services International) in the same area (*unpublished*).

The choice of LLIN by malaria control programmes varies according to their preferences, but a request for nets based on expected duration is technically correct and operationally justified, especially in the context of mass distribution campaigns. A LLIN that lasts five years instead of three and costs 1 US \$ more per unit is 40 % cheaper to use (cost per person protected per year) and its distribution is easier to manage (campaign every 5 years instead of every 3 years). Olyset polyethylene nets are guaranteed by the manufacturer for 5 years. (*Durability of long-lasting insecticidal mosquito nets (LLINs)*).

*Note on programmatic aspects relevant to procurement, Vector Control and Prevention, Global Malaria Programme, WHO Geneva, 26 June 2008).*

### Summary

Mosquito LLINs have revolutionized vector control today because of their simplicity. They do not require specialist spray teams or equipment, are easy to distribute, repel and kill mosquitoes, reduce malaria and cost about \$5 and can last 5 years – which is only \$1/year to protect a mother and her child. In addition, LLINs are generally well-received by the population, as recipients consequently get a good nights sleep free from mosquitoes.

The following summary from The Global Malaria Programme – World Health Organization position statement notes the following:

*“The effectiveness of ITN interventions in reducing the burden of malaria has been amply demonstrated in a variety of epidemiological settings. Now, the advent of LLINs and treatment technologies has opened up prospects for improving ITN interventions by addressing the issue of treatment and re-treatment. It is critical to seize this opportunity and rapidly expand access to these new technologies for all populations at risk of malaria.”*

The WHO Global Malaria Programme issued the following recommendations:

- Purchase only long-lasting nets.
- Distribute free of charge or highly subsidized LLINs, either directly or through voucher/coupon schemes.
- Achieve full LLIN coverage, including in high-transmission areas, by distributing LLINs through existing public health services.
- Develop and implement locally appropriate communication and advocacy strategies to promote effective use of LLINs.
- Implement strategies to sustain high levels of LLIN coverage in parallel with strategies for achieving rapid scale up.

LLINs provide a simple but effective tool to reduce malaria and this has been widely recognized by Governments and Donor Fund agencies who have committed to funding their provision and distribution. However, even these are not perfect and industry is still developing improved LLINs to increase their efficacy.

New technologies for controlling mosquito vectors are few and far between due to the staggering costs of developing a new insecticide – today estimated at \$200 million. Therefore,

new innovations such as the LLINs should be valued and used wisely as part of an integrated programme against malaria.

There have been many unsung scientists who have contributed to the development of insecticide treated bednets and their subsequent impact on reducing malaria and saving thousands of lives, but a mention should be made of Prof.C.F. Curtis of the London School of Hygiene and Tropical Medicine who passed away recently and with whom I had the honour of working on several occasions. His passion and dedication to developing and promoting insecticide treated bednets undoubtedly contributed greatly to their subsequent adoption for malaria control.

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Durability of long-lasting insecticidal mosquito nets (LLINs).

Note on programmatic aspects relevant to procurement

Vector Control and Prevention, Global Malaria Programme, WHO Geneva. 26 June 2008

*John Invest* is a Medical Entomologist who trained at the London School of Hygiene & Tropical Medicine and then joined Wellcome Research Laboratories Entomology Laboratories in insecticide Research & Development. He stayed with the company through its many transitions to Roussel-Uclaf Environmental Health, AgrEvo Environmental Health, Aventis Environmental Health and finally Bayer Environmental Health. His career went from responsibility for the technical support in the entomology laboratories to acting as liaison for Global Business Support and finally Field Technical Manager for Vector Control. John held the last post for about 12 years and travelled the world giving advice, training and technical support on all aspects of vector control. He finally took voluntary redundancy in 2003 and set up his own consultancy company 'Vector Environmental Health'. He has worked on various projects for several industrial companies as well as assisting WHO with some publications and sitting on one of the Gates Foundation committees.

- The UN has a Millennium Development Goal to halt and reverse the increase in malaria by 2015. It has recently been stated that this is unlikely to be met despite the fact that there is more funding available today than ever before. This follows a detailed scientific analysis of where this funding is being spent. The Kenya Medical Research Institute in Nairobi concluded that the global spend on malaria prevention of about \$1 billion per year is 50% to 450% below what is required. Funding of \$1 billion represents less than \$1 per person at risk when the bare minimum needed is \$4. In addition, the analysis found that the funding is not spread equally with some countries receiving far less per person at risk than others. For example, Burma receives about 1 cent per person at risk whereas Surinam spent \$147. These results emphasise the importance of efforts such as insecticide treated bed nets to aid control.

Editor

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