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A promising role of Insecticide Treated Bed-Nets (ITNs) against Malaria: A Way Forward

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Abstract

Malaria is both preventable and treatable yet the disease has continued to cause high death tolls annually. This picture is eminent in low income countries of the world where the disease is endemic although close to half of the world's population is at risk. To date, malaria is still one of the most serious global health threats, exerting grave misery upon mankind. Africa is worst hit. The surest tool with proven potential of yielding low transmission rates of close to zero from very high is vector control. The protective benefits of vector control are principally protecting people from infective mosquito bites. Insecticide-treated bed nets (ITNs) are the most widely used vector control tool used since World War II. In the recent past, treated bed nets have been widely scaled-up. Despite the obvious proven benefits, the initiatives have not been without challenges; the community which is the major stake-holder seems left out in this battle of more than a century.

Keywords: Malaria, Vector control, Insecticide-Treated Bed Nets

1. Introduction

Despite malaria being preventable and treatable (White, Conteh, Cibulskis, & Ghani, 2011), the dreadful disease has continued to cause high death tolls annually (White, *et al*., 2011; WHO, 2010). This picture is more eminent in low income countries of the world where the disease is endemic although close to half of the world's population are at risk (WHO, 2008). To date, malaria is still one of the most serious global health threats (Adedotun, *et al*., 2010), exerting grave misery upon mankind (Nyarango, *et al*., 2006), with Africa being the worst hit (Al-Adhroey, *et al*., 2010). Not only does malaria have direct health effects, but it also yields serious economic dislocation worldwide (Adedotun, *et al*., 2010)) by crippling economic growths of poor nations throughout Africa. The World Health Organisation (WHO) estimates that this infectious disease causes a US $12 billion loss in Gross Domestic Product (GDP).

2. The unchanged pattern of malaria epidemiology

Measuring the burden of malaria is not as accurate but as from 1990, the World Health Organisation (WHO) measures this by disability-adjusted life years (DALYs), which encompasses both morbidity and mortality. Conversely, this is a problematic indicator as it is totally dependent on available data especially for a number of tropical diseases and as such, makes DALYs an underestimate (Vanderelst & Speybroeck, 2010). This then points out that the recorded magnitude of malaria burden is an illusion as it is purely based on scientific estimates. On the other hand and however, one fact for sure is that Africa bears the greatest (about 90%) of this burden (Fig 1.0 and 2.0) and the most affected (85%) are children below 5 years of age and pregnant women (Talisuna, *et al*., 2004; WHO, 2011). In terms of DALYs, malaria ranks highest amongst tropical diseases, seconded by lymphatic filariasis which infects more than 120 million people annually in 83 endemic countries (De Las Heras, 2011; Njenga, ., 2011).

The World Health Reports 1999 to 2004 estimate global deaths due to malaria at 1.1 to 1.3 million and the WHO world malaria report (2010) indicates that malaria is still prevalent in about 106 countries placing at risk about 3.3 billion people around the globe (WHO, 2010).

The devastating effects of malaria in various parts of the globe, though mainly sub-Saharan Africa (Figure 2.0) are compounded by the geographical overlap between malaria itself with HIV/AIDS and tuberculosis which yields a terrible disease burden resulting from HIV-associated tuberculosis and complicated malaria. Although the battle against malaria has been a longstanding one, the disease is emerging as one of man's 21st century tragedies (Hotez, *et al*., 2006). Apart from that, malaria is also now considered a re-emerging infectious disease said to be causing more deaths now than in previous decades (Figure 3.0) (Miller, 2009; Sexton, 2011). Smith and Colleague (2012) recorded that malariologist Lewis Wendell Hackett likened malaria to "the game of chess" which although played with few pieces, has the potential to yield myriad of situations.

Endemic in 106 countries (Alonso, *et al*., 2011; WHO, 2010), or is it 108 countries (De Las Heras, 2011) or indeed 109 countries (Ouattara, *et al*., 2011) as there are variations but whichever the case, malaria is comparable to no other infectious disease in terms of impact on world history. In fact, it has been said that "malaria has had the greatest impact on world history than any other infectious disease" (Suh, Kain, & Keystone, 2004). This is so even in the face of there being diverse global efforts implemented towards controlling the disease (Alonso, *et al*., 2011; Suh, *et al*., 2004; WHO, 2011).

3. Impact on households

Expenditure on malaria falls disproportionately on poor households who despite spending relatively less amounts per malaria episode on treatment than their richer counterparts; do actually sacrifice a greater portion (28 to 34%) of their annual earnings. The actual figures may sound low but in reality, are more than the 1 to 2% spent by the well- off households. In addition, there is also forgone income which results when adults fall too ill to work or must take time away from income-producing activities in order to care for sick children (Russell, 2004; White, *et al*., 2011).

4. Available preventive measures

Being a vector-borne disease, vector control stands out as the primary and most effective public health intervention for reducing malaria transmission at community level (Kelly-Hope, *et al*., 2008)**.** The vector directed interventions (Table 1.0) are considered the surest tool that can lead to a reduction in malaria transmission from very high levels to close to zero (WHO, 2010). In areas of high transmission, vector control has documented evidence of lowering child mortality rates and anaemia prevalence significantly (WHO, 2010). There are dual goals in controlling the vector; (i) Protecting the people against infective mosquito bites and (ii) Reduction of local malaria transmission by reducing vector life-span and population, eventually human-vector contact (WHO, 2011). As the malaria burden has continued to be a great threat to developing countries especially sub-Saharan Africa (Figure 1.0), reducing mosquito bites is a sure way to prevent or eradicate the disease (Nyarango, *et al*., 2006; WHO, 2010). In doing so, although there are various methods, ITNs and Indoor Residual Spraying (IRS) are the cornerstones of vector targeted interventions which are effective in a wide range of settings (WHO, 2010)**.** Vector control and vaccines are referred to as "non-drug approaches" in combating Diseases of the Developing World; in this case; malaria. At the moment, the methods mainly encompass the use of ITNs and IRS of a variety of insecticides (Table 1.0) (De Las Heras, 2011), screens, environmental management, traps, and biological control (Billingsley, *et al*.,2008). Most programmes are however centred on ITNs and IRS which have been considered of equal effectiveness and efficaciousness (Lengler, 2004) despite there being a limited number of insecticide types available (Kelly-Hope, *et al*., 2008). Suffice to say that the dual are key interventions in malaria control in that, apart from them being potent, are "durable and robust" (WHO, 2011). The most widely employed insecticides (Table 2.0) for malaria control are pyrethroids and dichlorodiphenyltrichloroethane (DDT) (WHO, 2011).

5. Inconclusive battle against malaria

In order to be successful in controlling any disease, it is vital to have sufficient knowledge of its natural history, aetiology and mode of transmission and as such, vector control has proved to be an effective means to reducing malaria transmission (Kelly-Hope, *et al.,* 2008). While it was a huge problem in the 1930s the disease was almost totally gone in the 1940s (McCutchan, 2008). In 1955, the first programme towards eradication of this scourge was initiated by WHO soon after massive use of DDT during World War II for malaria and other vector-borne disease control. Astounding achievements of this programme were that Australia and North America were free of malaria in the 1950s, and several European countries at least managed to keep the disease under control. Stemming from this too were huge declines reported in India, Asia and Sri Lanka. This programme was not all inclusive as Africa was left out though earmarked for inclusion towards the programme end which still did not take effect (Breman & Brandling-Bennett, 2012).

Despite the remarkable outcomes from this global initiative, the campaign was disbanded in 1969. This led to the realization that eradication was a somewhat over-ambitious goal, especially in Africa were there was no adequate political support, human and material resources, surveillance systems and administration. (Breman & Brandling-Bennett, 2012; Talisuna, *et al*., 2004) and also the vector had developed resistance to the used methods (Cessay, *et al*., 2011). This programme disbanding did not yield any pleasant results as it gave way to overwhelming malaria epidemics even in countries which had managed to achieve notable successes like India and Sri Lanka. Throughout programme implementation, lack of prioritization of disease surveillance was one of the major challenges (Breman & Brandling-Bennett, 2012). After a while of neglect, malaria control has now received attention from the International Community. The result of which is that it has now become a priority on political agenda of many wealthy countries and funding is being availed through Global Fund to Fight AIDS, Tuberculosis and Malaria Initiative, The World Bank and other donors on a much more higher scale than during the first eradication campaign of the 1950 and 1960s. This immerse funding has eventually led to an increase in bed net production globally, distribution and use. Evidence of this is that ITN production spiked by more than threefold from 30 million to 100 million from 2004 to 2008 respectively (O'Meara, *et* al., 2010). Coverage of all at risk of malaria with approved interventions for disease prevention and management was set to be achieved by the year 2010. The same year was also set for halving disease burden by about 50% of the year 2000 levels. However, the data presented in Figures 1.0, 2.0 and 3.0, reflect shortfalls in achieving these set targets in full (WHO, 2011).

6. Why Insecticide Treated Bed Nets?

Although close to all ITNs distributed in Africa are long-life insecticidal nets, we will refer to all treated nets as Insecticide-treated bed nets (ITNs) (WHO, 2011). Mosquito nets have been used since ancient times for protection against insect annoyance. During World War II, American, Russian and German soldiers impregnated their combats and mosquito nets with residual insecticides to shield from vector-borne diseases vis-à-vis malaria and Leishmaniasis mainly. Studies on mosquito nets continued till 1970 when entomologists started to use pyrethroids to treat nets and in the 1980s, were certified of minimal toxicity to humans hence, safe (Lengler, 2009). Whether treated or not, bed nets are able to confer protection from mosquito bites. However, the nets impregnated with insecticides have advantages over the untreated ones. The ITNs are actually the most recently developed intervention tools for malaria prevention and have proved entomologically efficacious, cost-effective and high above all, safe to humans (Kilama, 2009)**.** These bed nets have demonstrated capacity of reducing mosquito bites and subsequently preventing malaria transmission (Nyarango, *et al*., 2006)**.**

The most predominant species in Africa; *P. falciparum*, requires 8 days to complete its development from gametocyte to infective sporozoites in the salivary glands of the female Anopheles mosquito vector. Therefore, attempts to feed on ITN-protected humans result in reduced vector life-span and increased mortality which in turn yields a reduction in vectoral populations (Killeen, *et al*., 2007). The protective effects of treated nets are synergized by the excito-repellence property of the pyrethroids which is obviously reduces the frequency of the mosquito managing human blood meals. As a result the vector is left with no choice but to opt for non-malaria host animals and as such, reducing the prevalence of sporozoites in mosquitoes (Killeen, *et al*., 2007).

Vector control is the main thrust in malaria control which principally aims at protecting the individual from infected mosquito bites. This results in bringing down local transmission intensity at community level and subsequently reducing the mosquito vector's life-span, density and the contact between humans and vectors (Billingsley, *et al*., 2008; WHO, 2011). In as much as protection against vector borne diseases is seemingly an easy concept, it is so complicated to practice (Kester, *et al*., 2008)**.** As such, malaria-vector control and prevention methods ought to be used complementarily to each other and the most applicable and effective methods of intervention ought to be employed in any specific setting (Nyarango, *et al*., 2006).

Indoor residual spraying and ITNs are the most broadly applied interventions which do not only minimise vector-human contact, but also reduce vector life-span (WHO, 2011). This led to scale-up of ITNs as one of the main strategies to bringing down both morbidity and mortality due to malaria (Lengler, 2009) with an initial 60%, then80% coverage of vulnerable groups target set by African Leaders (WHO, 2008).

Widespread coverage with ITNs were an integral component in the Roll Back Malaria Partnership's Global Strategy Plan to ensuring that 80% of people at risk from malaria are protected by the year 2015 (Dunn, Mare, & Makungu, 2011). In fact, they are considered the most important means of achieving the 6th Millennium Development Goal (MDG 6) of reducing child mortality by the year 2015 (Noor, Mutheu, Tatem, Hay, & Snow, 2009). In this respect, there has been accelerated distribution of ITNs to help fight malaria in the sub-Saharan Africa over the past 5 years (Kelly-Hope, *et al*., 2008). The result of which has been a significant increase in the proportion of households who owned at least one net in Africa from 17% in 2006 to 31% in 2008 and with at least 24% sleeping under ITNs in 2008 (Crawley, *et al*., 2010a).

7. Positive outcomes- impact on morbidity and mortality

Substantial declines in malaria disease burden have been reported from several sub Saharan countries although this may be apparent in some countries which have not published like Senegal. It has therefore not been that easy to prove that the reduction in disease burden were purely an outcome of control interventions. In this case therefore, it is quite complicated to measure whether the scale-up of an intervention impacts on clinical disease burden than prevalence (O'Meara, *et al*., 2010). In global the efforts to controlling morbidity and mortality due to malaria, particularly among the young African children, ITNs are a key tool (WHO, 2009). In his review, Lengler approximates that the protective effects of ITNs could avert 370,000 deaths of young children if every child was protected by a treated bed net. Lengler also pointed out that ITNs can potentially halve malaria episodes under majority of transmission settings (Lengler, 2009).

Towards achieving the 6th[th] Millennium Development Goal (MDG 6)" whose target in part is to have halted and begun to reverse the incidences of malaria by the year 2015, ITNs are considered the most important means (Noor, *et al*., 2009). This is also central to in MDG 4 of "reducing child mortality by the year 2015" (WHO, 2011). Once malaria has been controlled, it is expected to in turn make feasible the achievement of MDG 1 (eradication of poverty and hunger), MDG 2 (achievement of universal primary education), MDG 3 (promotion of gender equality and women empowerment), MDG 5 (improvement of maternal Health) and eventually MDG 8 (development of a global partnership for development) (WHO, 2011).

8. ITNs and the "Unseen" resistance in the community

The way a community perceives malaria illness, most especially perceptions of susceptibility and beliefs about the seriousness of the disease exerts weighty influence on the decision to take preventive and curative actions against the disease (Legesse, *et al*., 2007). In as much as prevention is considered to be better and more so, cheaper than cure, it has been observed that preventive knowledge and practices have been considered low and complicated where the disease is deemed low risky (Erhun, *et al*., 2005). In fact, it is sometimes taken for granted that net ownership is synonymous with use but this was not so with for ownership (Erhun, *et al*., 2005).

ITNs were an integral component in the RBM Partnership's Global Strategy Plan to ensuring an 80 percent coverage of people at risk of malaria are protected by the year 2015 (Dunn, *et al*., 2011). The treated bed nets have a demonstrable noteworthy effect in bringing down morbidity and mortality related to malaria. However, the desired results have not been achieved due to challenges with their utilization. Apparently, much emphasis appears to have been placed on increasing coverage when the core problem seemingly goes beyond net availability possession (Deribew, *etal*., 2012).

Furthermore, ITNs have been described as effective tools for preventing malaria even when used as a single means of intervention (Iwashita, *et al*., 2010), and community sensitization and participation are undoubtedly vital for compliance to use (J. Atkinson, *et al*., 2009 ; M. J. Atkinson, *et al*., 2010)**.**

9. Additional benefits of ITNs use

Apart from being used for malaria control, ITNs are also likely to yield other positive outcomes alongside like; controlling Bancroftian filariasis which is transmitted mainly by the same female Anopheline vector. The community benefits of ITN use are apparently more important than individual protection from inoculations. Hence, although an individual net may not adequately prevent inoculation of the user, it may still yield a reduction in vector lifespan and thereby affecting transmission at community and population level (Crawley, *et al*., 2010b; Hawley, *et al*., 2003; Teklehaimanot, *et al*., 2007).

10. Potential threats

With the recent call by Bill and Melinda Gates Foundation for yet another malaria eradication campaign; there has been widespread scale-up of ITNs and IRS in affected countries. However, the most ideal would be to learn from the previous global campaign as failure to which is likely to give way to resistance (Kelly-Hope, *et al*., 2008). This programme disbanding did not yield any pleasant results as it gave way to overwhelming malaria epidemics even in countries which had managed to achieve notable successes like India and Sri Lanka. Throughout programme implementation, lack of prioritization of disease surveillance was one of the major challenges (Breman & Brandling-Bennett, 2012).The other issue of concern is that the famous insecticides (DDT and pyrethroids) have similar modes of action meaning, cross-resistance may develop (WHO, 2011).

11. The way forward

Malaria ecology is different in various parts of the world and IRS-only strategies did not successfully interrupt transmission in regions of endemicity in Africa and forest areas of Asia or indeed New Guinea and South America. This is said to have potential of bringing about malaria elimination in some countries but despite all efforts, eradication still seems to be a somewhat over-zealous goal (Alonso, *et al*., 2011). As malaria eradication seems far-reached (Alonso, *et al*., 2011; Mendis*, et al*., 2009), ambitions to bring down local transmission to zero globally are no longer a necessity (Alonso, *et al*., 2011). This then entails that the battle to control and possibly eliminate malaria needs a widened coverage of access to effective malaria control interventions particularly; ITNs, IRS and intermittent preventive therapy (IPT), accompanied with early diagnosis and prompt and appropriate treatment (White, *et al*., 2011).

As the world strives for an improved livelihood for the poor, prevention of malaria deserves utmost attention and ITNs are a representative of tangible ways to curb the scourge in Africa (Lengler, 2004). Sad to say, but malaria is considered a disease of poverty (Sachs & Malaney, 2002) as in cause and effect and disease transmission is said to be much higher in rural than urban areas (Neville, 2007). In view of this therefore, scaling up coverage of ITN use to at least 80% by 2010 of vulnerable risky groups (pregnant women and young children) were the agreed target of the Millennium Development Goals (MDGs), the Roll Back Malaria Partnership, and the US President's Malaria Initiative (Killeen, *et al*., 2007). These three initiatives were quite profound because young children and pregnant women make up the greatest fraction of malaria illnesses and deaths although the strategy did not consider the protection benefits at entire community level (Hawley, *et al*., 2003).

Based on the progress made by 2010, the existing targets were amended to (i) bringing down global malaria burden by close to zero by end of 2015, (ii) bringing down global malaria morbidity by 75% from the 2000 records by end of 2015 and also (iii) eliminating malaria from 10 new countries by end of 2015 (WHO, 2011).The extension of ITNs to the larger community (universal coverage) that are exposed to risk of malaria (apart from pregnant women and young children) would be the next intensive phase to control malaria in all of the high risk areas (WHO, 2011).

12. Conclusion

It is noteworthy that malaria infection and risk of disease appear to be transiting parts of Africa, partly due to the ITN scale-up programmes and introduction of effective therapy combinations (Bhattarai, *et al*., 2007; O'maera, *et al*., 2008). At the same time however, malaria has made inroads into areas where it had been eradicated or indeed successfully controlled thereby counteracting the gains of the latter half of the past century (Njau, *et al.*, 2009). It is a great idea that now the disease is now is on top priority on the International community (O'Meara, *et al*., 2010) with aims of universal coverage of ITNs to all at risk of malaria (WHO, 2011). The fragility of malaria control is reflected by the 2009 resurgences thence highlighting the need to maintain control programmes even when incidences seem to be reduced (WHO, 2010). It is therefore eminent that the red alerts being issued by the disease and also, the scientific prediction of a broadening malaria curtain (Miller, 2009) are granted careful scrutiny and upfront attack if the 1970s epidemic story is not to repeat itself (Breman & Brandling-Bennett, 2012). Of importance also is bearing in mind the role of climate change due to global warming in vector populations (Richie & Parekh, 2009)**.** If ITNs are the ultimate, then the users (community) need to be in the battlefront and this can only be done if they get the right message right and the right time.

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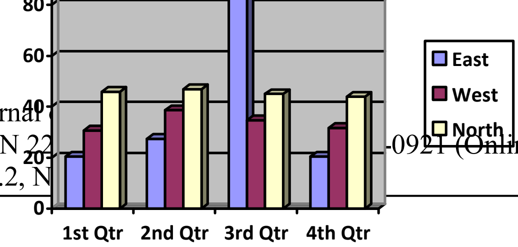

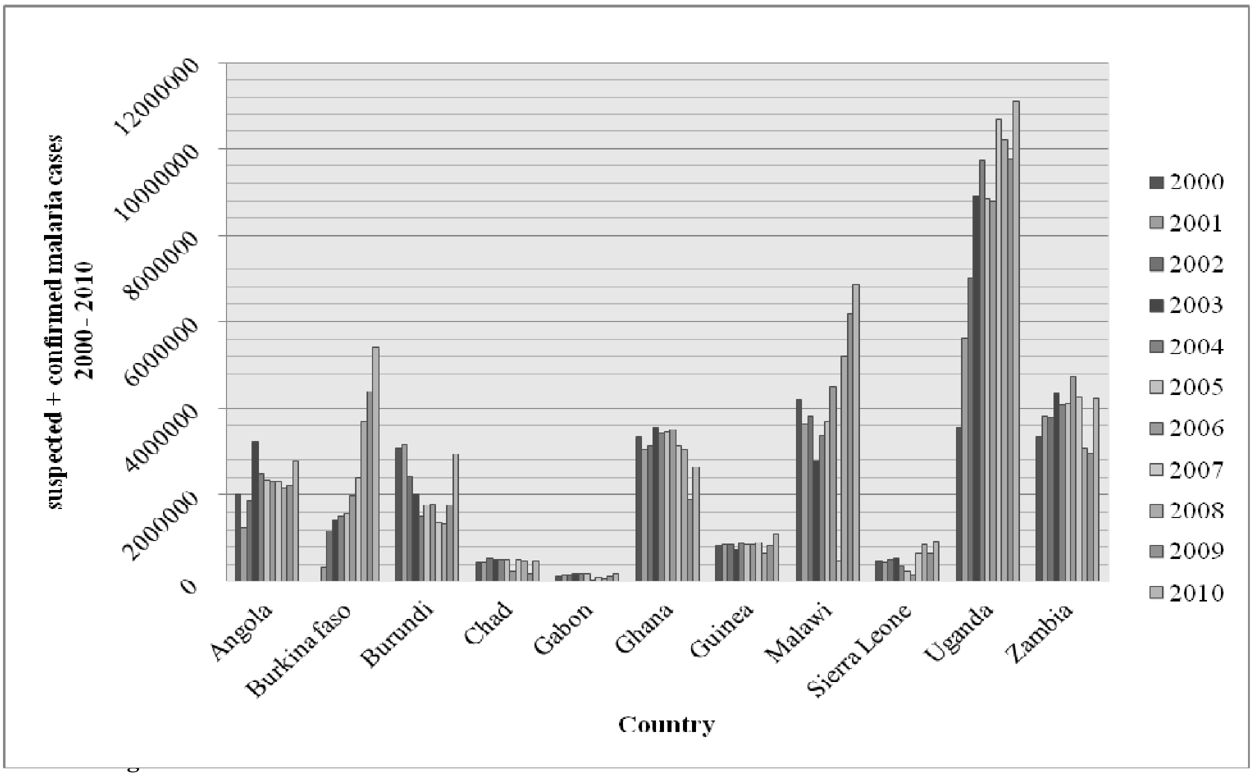

(WHO, 2011)

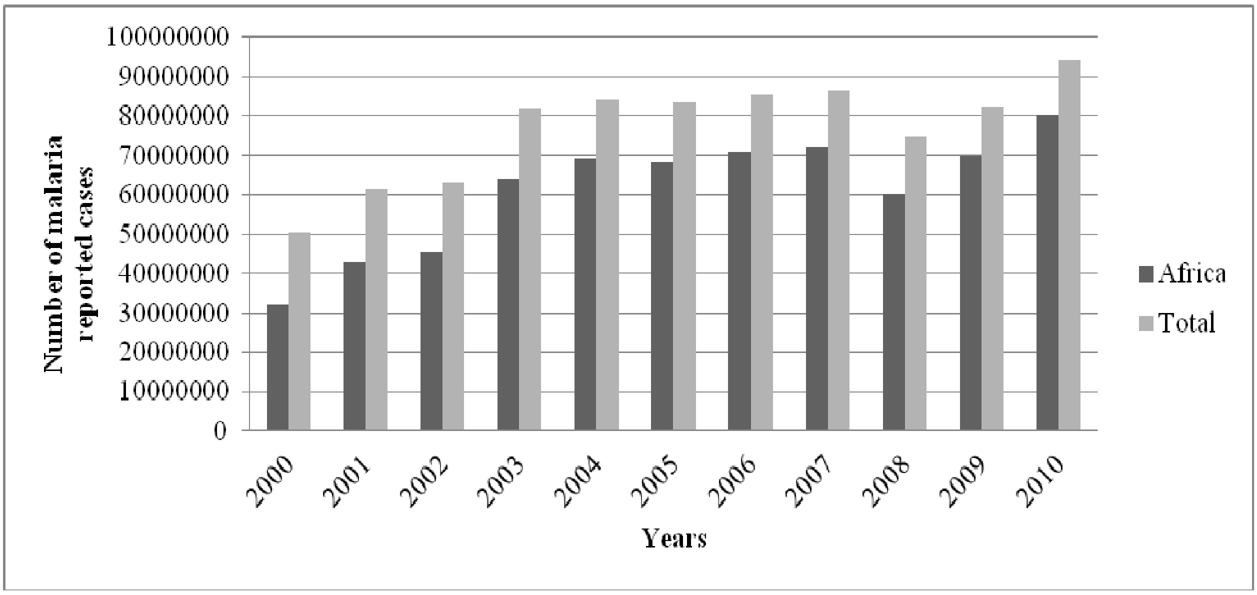

Figure 2: Global malaria trends 2000 to 2010 (Data obtained from WHO, 2011)

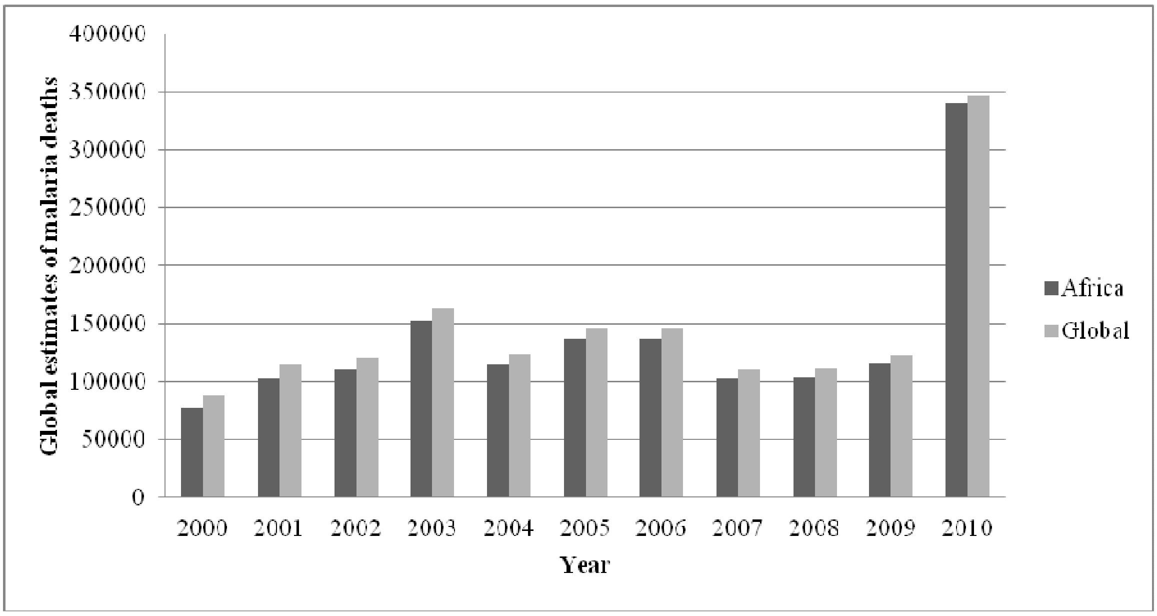

Figure 3: Death trends due to malaria from 2000 to 2010 (Data obtained from WHO, 2011)

Table 1.0: Methods used in malaria vector control

Method	**What is involved**	**Target**	**Merits**
Insecticide-treated bed nets (ITNs)	Sleeping under a mesh impregnated with insecticide	Adult mosquitoes	Reduction of mosquito bites Reduction of transmission
Indoor residual spraying (IRS)	Spraying interior walls of the house with insecticides	Eliminating adult mosquitoes	Reduction of vector population Rapid reduction of transmission
Larviciding	Application of chemicals to mosquito breeding spaces	Mosquito larvae	Larvae reduction
Chemoprevention	Intermittent Administration of anti-malarial drugs to risky groups		

(Data obtained from, Miller, 2009; Nyarango, et al., 2006; WHO, 2011)

Table 2.0 Insecticides used in malaria vector control

Insecticide	**Mode of action**	**Use**	**Residual properties**	**Merits**
Pyrethroids Alphacypermethrin Cyfluthrin Deltamethrin Lambacyalothrin Etofeprox Bifethrin	-Open Sodium channels causing nervous breakdown and paralysis and eventual death of vector -Iiritant effect causing increased activity, feeding inhibition and shorter landing times, undirected flight and then reduced biting ability	ITNs IRS	3-6 months when used for IRS	-Low toxicity to humans -Rapid “knock down” - Chemical class of choice - Low cost
Organochlorides DDT	Open Sodium channels causing nervous breakdown and paralysis and eventual death of vector Insects exposed to DDT exhibit hyperactivity	IRS	6-12 months in IRS	-Low cost Rapid “knock down” -Longer residual activity
Organophosphates Fenitron Malathion Pirimiphos-methyl	Inhibition of cholinesterase	IRS	2-3 moths in IRS	Highly effective
Carbamites Bendiocarb Propoxur	Inhibition of cholinesterase	IRS	2-6months in IRS	Highly effective

(Data source: Reinhart, 2009; WHO, 2011)