Chapter 4

Vector Control

This chapter reviews (i) adoption of national policies for malaria vector control (ii) coverage and progress towards the goal of universal access and utilization, and (iii) the monitoring and management of insecticide resistance.

4.1 ITN policy and implementation

4.1.1 Policy adoption

Adoption and implementation of policies for ITN/LLIN programmes by WHO Regions is shown in Table 4.1 and adoption of policies by country is shown in Annex 4A.

ITNs are distributed free of charge in 82 countries, mainly in Africa and South-East Asia. In some of these countries, programmes are targeted to specific age groups but in a majority – 67 of the 82 countries – ITNs are distributed free of charge to all age groups. In 28 countries, mainly in Africa, they are sold at subsidized prices through social marketing or routine delivery with vouchers, usually in parallel with free distribution campaigns.

The most common strategy for distribution of ITNs is through mass campaigns, which are used in 57 countries, followed by distribution through antenatal clinics in 56 countries. Antenatal clinics are the most widely used channel in the African Region, although greater quantities of ITNs are distributed through mass campaigns.

The Alliance for Malaria Prevention (AMP) collates information on the number of LLINs delivered by seven manufacturers which are believed to supply almost all ITNs for public sector distribution in Africa. While almost all ITNs distributed in Africa are long-lasting insecticidal nets (LLINs), this chapter refers to all treated nets as ITNs.

The number of nets delivered by manufacturers increased from 5.6 million in 2004 to 145 million in 2010 in sub-Saharan Africa (Figure 4.1), with a further 75 million ITNs supplied in 2011 to the end of September. While the number of ITNs supplied increased annually through 2010, the rate of supply from January to September 2011 suggests that the total number supplied in 2011 will be lower.

Table 4.1
Adoption of Policies for ITN Programmes by WHO Region, 2010

<table>
<thead>
<tr>
<th>Policy</th>
<th>Africa</th>
<th>Americas</th>
<th>Eastern Mediterranean</th>
<th>Europe</th>
<th>South-East Asia</th>
<th>Western Pacific</th>
<th>Grand Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITNs/LLINs are distributed for free</td>
<td>38</td>
<td>13</td>
<td>8</td>
<td>3</td>
<td>10</td>
<td>10</td>
<td>82</td>
</tr>
<tr>
<td>ITNs/LLINs are sold at subsidized prices</td>
<td>21</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>28</td>
</tr>
<tr>
<td>ITNs/LLINs are distributed to all age groups</td>
<td>27</td>
<td>12</td>
<td>7</td>
<td>2</td>
<td>10</td>
<td>9</td>
<td>67</td>
</tr>
<tr>
<td>ITNs/LLINs distributed through mass campaigns to all age groups</td>
<td>27</td>
<td>12</td>
<td>4</td>
<td>6</td>
<td>8</td>
<td>5</td>
<td>57</td>
</tr>
<tr>
<td>ITNs/LLINs distributed through mass campaigns to under 5 only</td>
<td>9</td>
<td>4</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>17</td>
<td></td>
</tr>
<tr>
<td>ITNs/LLINs are distributed through antenatal clinics</td>
<td>38</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>ITNs/LLINs are distributed through EPI clinics</td>
<td>29</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>32</td>
</tr>
</tbody>
</table>

Number of endemic countries/areas: 45 23 12 8 10 10 106
Number of P. falciparum endemic countries/areas: 43 18 8 0 9 9 87

Source: NMCP reports.
Between 2008 and 2010 a cumulative total of 294 million ITNs were supplied by manufacturers to countries in sub-Saharan Africa. Assuming all ITNs last three years, this would be enough to cover 73% of the 800 million persons at risk in 2011 (assuming an average of 1.8 people sleeping under each ITN). Such an estimate does not take into account delays in delivering ITNs within countries or loss of ITNs after delivery to households (due to wear and tear) and therefore produces an optimistic estimate of the availability of ITNs.

Outside Africa, available records show that 60 million ITNs were supplied between 2008 and September 2011, with six countries accounting for 66% of deliveries (India 13.7 million, Indonesia 7.9 million, Afghanistan 6.3 million, Pakistan 3.3 million, Papua New Guinea 2.8 million, Philippines 2.8 million).

During the last three years mass campaigns have been the main channel used by NMCPs to deliver ITNs, accounting for 71% of ITNs delivered (Figure 4.2), followed by antenatal care clinics (15%), immunization clinics (7%) and other channels (7%). The proportions vary by WHO Region.

4.1.2 Trend in ITN coverage

Household surveys are the preferred means of assessing whether or not sufficient ITNs have been delivered to cover populations at risk of malaria, although surveys are not conducted frequently enough to provide up-to-date estimates for most countries. In the absence of a recent household survey, it is possible to estimate the ITN coverage by combining data from manufacturers’ reports on ITNs delivered to countries, NMCP reports on ITNs distributed within countries, and previous household surveys as described in the World Malaria Report 2009 and by Flaxman et al (1). The advantage of such an approach is that it uses all available data to estimate ITN coverage for years in which no survey was carried out.

From this analysis it is estimated that the proportion of households owning at least one ITN in sub-Saharan Africa has risen from 3% in 2000 to 50% in 2011 (Figure 4.3). Estimates are for 30 June of each year, the estimate for 2011 assumes that all nets delivered by manufacturers by December 2010 were distributed by NMCPs. Some countries appear to have made considerable advances towards achieving universal access to ITNs (e.g. Burundi, Madagascar, Namibia, Niger, Rwanda, Sierra Leone, United Republic of Tanzania) while others have yet to expand programmes to the scale required (Figure 4.4).

The estimate is lower than that obtained by simply considering the numbers of ITNs supplied by manufacturers in relation to the population at risk (73%). This may be partly because the ITN coverage model reflects lags in the delivery of ITNs by NMCPs after they have been procured from manufacturers, and takes into account the loss of ITNs occurring at household level after delivery. It may also be due in part to the fact that household surveys for several countries are more than three years old, and while the model summarizes the relationship between the numbers of ITNs delivered and household survey results over the entire period 2000–2010, it may not adequately reflect the rapid increases in coverage that are possible when mass campaigns are undertaken. There is a need for more up-to-date information on the availability and use of ITNs at household level, particularly after mass campaigns.
4.1.3 Coverage and use at population level

With the gains in malaria control over the past decade, and in line with recommendations by WHO in 2007 for universal coverage of all populations at risk (2), programmes have advanced from providing ITNs only to the population groups at greatest risk (children < 5 years of age and pregnant women) to seeking coverage for all people at risk in the population. To meet this target several intermediate steps need to be accomplished to ensure that: (i) ITN programmes have sufficient geographical reach to provide ITNs to all households; (ii) sufficient nets are provided to households to cover all people living in them; and (iii) people within households use the available nets.

In reviewing 15 household surveys with data on ITN coverage for the period 2008–2010, it was evident that modest proportions of households own at least one ITN (median 56%, lower quartile 39%, upper quartile 59%) (Figure 4.5). In almost all these countries less than half of households that had received ITNs had enough for all occupants (median 15%, lower quartile 11%, upper quartile 19%). It is possible that household surveys conducted from 2008 to 2010 do not yet adequately reflect the change in policy to provide ITNs to all persons living in households rather than focusing on pregnant women and children under 5 years of age.

In all surveys, a high proportion of available ITNs within households appear to be used; the median proportion of persons with access to an ITN who use it is 96% (lower quartile 93%, upper quartile 99%) assuming that one net can cover two people (Figure 4.6). Some countries have lower rates of use than others. These results are consistent with previous analyses which suggest that the main constraint to enabling persons at risk of malaria to sleep under an ITN is lack of availability of nets (3).

While many countries have adopted policies to achieve universal access to ITNs, and there has been considerable progress in increasing the supply of ITNs to endemic countries, evidence suggests that there is long way to go before the goal of universal access to ITNs will be reached. Where ITNs are available however, there appears to be a high rate of use.

**Table 4.2**

Adoption of policies for IRS programmes by WHO Region, 2010

<table>
<thead>
<tr>
<th>Policy</th>
<th>Africa</th>
<th>Americas</th>
<th>Eastern Mediterranean</th>
<th>Europe</th>
<th>South-East Asia</th>
<th>Western Pacific</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRS is recommended by malaria control programme</td>
<td>36</td>
<td>15</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>73</td>
</tr>
<tr>
<td>IRS is used for the prevention and control of epidemics</td>
<td>21</td>
<td>9</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>7</td>
<td>51</td>
</tr>
<tr>
<td>IRS and ITNs used together for malaria control in at least some areas</td>
<td>31</td>
<td>11</td>
<td>3</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>62</td>
</tr>
<tr>
<td>DDT is used for IRS</td>
<td>12</td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Insecticide resistance monitoring is undertaken</td>
<td>35</td>
<td>12</td>
<td>6</td>
<td>6</td>
<td>10</td>
<td>9</td>
<td>78</td>
</tr>
</tbody>
</table>

| Number of endemic countries/areas          | 43     | 23       | 12                   | 8      | 10              | 10            | 106       |
| Number of *P. falciparum* endemic countries/areas | 43     | 18       | 8                    | 0      | 9               | 9             | 87        |

Source: NMCP data
4.2 IRS policy and implementation

4.2.1 IRS policy adoption

Adoption and implementation of policies for IRS programmes by WHO Region are shown in Table 4.2. Adoption of policies by country is shown in Annex 4A.

IRS is recommended for the control of malaria by 73 countries, 36 of which are in Africa. IRS is sometimes used for control of epidemics in 51 countries and in combination with ITNs in 62 countries, including 31 in Africa. DDT is reported to be used for IRS in 13 countries, of which 12 are in Africa. Approximately three quarters of endemic countries report that they are carrying out insecticide resistance monitoring.

4.2.2 IRS coverage achieved

National malaria control programmes in malaria-endemic countries reported that a total of 185 million people were protected by IRS in 2010, representing 6% of the global population at risk. The use of IRS for vector control has continued to increase since 2006, particularly in the African Region where 78 million people, or 11% of the population at risk, were protected in 2010 (Figure 4.7). Including the African countries in the Eastern Mediterranean Region, 81 million people were protected by IRS, representing 11% of the at risk population in sub-Saharan Africa. The rate of increase in IRS coverage in Africa appears to have slowed over the past two years, after rapid scale up of IRS operations during 2006 to 2008. IRS coverage in the Western Pacific Region has increased in 2010, largely due to an increased number of people covered by IRS in China, and is equivalent to the proportion of the population covered by IRS in the Regions of the Americas and South-East Asia.

The proportion of the population at risk covered by IRS varies by country in the African Region (Figure 4.8). South Africa employed IRS to protect more than 80% of the population at risk, while Ethiopia, Madagascar, Zambia, and Zimbabwe protected at least 40%, and several countries used IRS in a more limited fashion. In other WHO Regions, Bhutan (26%) and Solomon Islands (36%) cover a substantial proportion of their population at risk of malaria through IRS.

In 2009, pyrethroids were estimated to account for approximately 77% of IRS coverage in terms of spray area covered. DDT was the second most widely used insecticide for IRS, accounting for approximately 20% of sprayed areas in covered households. Carbamates and organophosphates represented a very small proportion of global usage for vector control (4). There has been a move away from using pyrethroids since 2009, largely because of increases in ITN coverage and concerns about potential development of insecticide resistance. For example, PMI supported the use of pyrethroids for IRS in 13 of 15 countries in 2009, but in only 12 of 16 countries in 2010; spraying with non-pyrethroid insecticides is being implemented in approximately half of the countries supported by PMI in 2011 (5).

4.3 Malaria vector insecticide resistance

4.3.1 Insecticide resistance

Current malaria vector control uses insecticides from four chemical classes: pyrethroids, organochlorines (including DDT), organophosphates (OPs), and carbamates. The use of one class, the pyrethroids, far exceeds that of the other three due to its rapid and durable effect and its low toxicity and cost (Box 4.1). IRS can be conducted with any of the four classes of insecticides, whereas pyrethroids are the only insecticide class used for ITNs. Vector control can be rendered less effective by anopheline mosquitoes developing resistance to insecticides used in IRS and ITNs. Given the importance of vector control in combating malaria, retaining the susceptibility of malaria vectors to pyrethroids, and the other classes of currently available insecticides, is of critical importance.

Two main mechanisms of insecticide resistance have been identified: target site resistance and metabolic resistance. Target site resistance occurs when the site of action of an insecticide (typically within the nervous system of the anopheline mosquito) is
modified in resistant mosquito populations so that the insecticide no longer binds effectively and the insect is therefore unaffected, or less affected, by the insecticide. Target site resistant mutations can affect acetylcholinesterase, which is the molecular target of OPs and carbamates, or voltage-gated sodium channels (for pyrethroids and DDT), which is known as knock-down resistance (kdr). Metabolic resistance occurs when increased levels or modified activities of a detoxifying enzyme system prevent the insecticide from reaching its intended site of action.

Both metabolic and target site resistance can be found in the same vector populations and sometimes within the same vector.

Insecticides used for malaria vector control

Key attributes of the chemicals used for vector control insecticides are summarized below:

Pyrethroids. Pyrethroids are the only insecticides that are used for both IRS and LLINs, in the form of alphacypermethrin, bifenthrin, cyfluthrin, deltamethrin, lambdacyhalothrin and etofenprox. It has been the chemical class of choice in agriculture and public health applications over the last several decades because of its relatively low toxicity to humans, rapid knock-down effect, relative longevity (duration of 3–6 months when used as IRS), and low cost. It is also the only insecticide class used currently in recommended LLINs.

Pyrethroids have multiple modes of action on the mosquito vector. They open sodium channels, which leads to continuous nerve excitation, paralysis and death of the vector. They also have an irritant effect, resulting in hyperactivity, rapid knock-down, feeding inhibition, shorter landing times and undirected flight, all of which reduce vector biting ability.

Organochlorines. Organochlorines are used for IRS vector control in the form of DDT, which was the primary insecticide used in the eradication campaigns in the 1950s. At the Stockholm Convention in 2001, usage of DDT was banned for all applications except for disease control, due to concerns over its long-term toxicity. Because of limited options of equally effective and efficient alternative insecticides, continued use of DDT was permitted in public health until “locally safe, effective, and affordable alternatives are available for a sustainable transition from DDT”. The 2006 WHO position statement reasserted the public health value of DDT when used for IRS.

As for pyrethroids, DDT has been popular because of its rapid ability to “knock down” mosquitoes, relative longevity (duration of 6–12 months when used for IRS), and low cost. DDT is not used on ITNs or LLINs.

Despite chemical structural differences, DDT and pyrethroids have similar modes of action, and therefore cross-resistance to these two classes of insecticide may occur.

Organophosphates. Organophosphates comprise a vast range of chemicals, but are used for IRS vector control in the form of fenitrothion, malathion and pirimiphos-methyl. This insecticide class is highly effective, but has relatively short residual activity (duration of 2–3 months when used for IRS) compared to pyrethroids and DDT. At current price levels, it is also significantly more expensive. Because of the risk of accidental human overexposure to organophosphates and subsequent toxicity, toxicological monitoring is recommended. Those handling organophosphates during spray operations have the highest risk of exposure, and toxicity can be monitored through measurement of blood acetylcholinesterase enzyme levels.

The mode of action on the mosquito vector differs from that of pyrethroids and organochlorines. Organophosphates inhibit cholinesterase, thereby preventing neurotransmitter acetylcholine breakdown, resulting in neuromuscular over-stimulation and subsequent death of the vector.

Carbamates. Carbamates are used for IRS vector control, in the form of bendiocarb and propoxur. Carbamates have a similar mode of action to organophosphates, and as with organophosphates, they are highly effective. However, they have short residual activity (duration of 2–6 months when used for IRS) and are more expensive than pyrethroids and DDT.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Current ITN products</th>
<th>Current IRS products</th>
<th>Molecules recommended for use in IRS</th>
<th>Toxicity</th>
<th>Duration of effect per spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyrethroid</td>
<td>✓</td>
<td>✓</td>
<td>Class I/II</td>
<td>U</td>
<td>3-6 months</td>
</tr>
<tr>
<td>Organochlorine (DDT)</td>
<td>✓</td>
<td>✓</td>
<td>Class II</td>
<td>U</td>
<td>6-12 months</td>
</tr>
<tr>
<td>Organophosphate</td>
<td>✓</td>
<td>✓</td>
<td>Class II/III</td>
<td>2-3 months</td>
<td>2-3 months</td>
</tr>
<tr>
<td>Carbamate</td>
<td>✓</td>
<td>✓</td>
<td>Class II</td>
<td>U</td>
<td>2-6 months</td>
</tr>
</tbody>
</table>

1. Analysis calculated for a household of 6 people (150 sqm sprayed) and based on WHOPES spraying guidelines and PMI cost data
2. Lambdacyhalothrin is WHO class III; Etofenprox is WHO class U
3. Malathion, pirimiphos-methyl are class III
4. Duration as based on typical formulation for use in malaria control

Note: Toxicity ratings: Class I: Moderately hazardous; Class III: Slightly hazardous; Class U: Unlikely to present acute hazard in normal use

In 2011, WHO regional entomologists collected available data on insecticide resistance from malaria endemic countries which are conducting resistance monitoring. Among 87 countries for which information was available, 45 countries reported that resistance had been detected to at least one insecticide used for malaria vector control in at least one malaria vector in at least one monitoring site. The vast majority (39) of these reported resistance to pyrethroids, 27 of which are in sub-Saharan Africa (Figure 4.9). DDT resistance is also prevalent worldwide (14 countries), and there are some instances of resistance to organophosphates (5 countries) and carbamates (8 countries).

These data may underestimate the extent of insecticide resistance globally as regional entomologists may not have access to all information on all monitoring activities within any given country. Also, these resistance reports encompass a range of monitoring approaches by different investigators. However, other sources of information on insecticide resistance reveal a similar pattern. A review of recently published literature on the distribution of pyrethroid resistance in Africa reflecting data from 23 countries found evidence of resistance in 17 of them (6). Widespread reports of pyrethroid resistance in sub-Saharan Africa are of particular concern since this region has the highest malaria burden, and a reduction in vector control effectiveness could have serious consequences. In the South-East Asia Region the resistance situation in India is of greatest concern as there is widespread DDT resistance and patches of pyrethroid and OP (malathion) resistance (7).

In some cases, the increasing reports of resistance are partly a reflection of increased monitoring of insecticide resistance, but there are also many reports of resistance in places where it is known to have been absent before. However, the presence of resistance is of concern whether or not it developed recently. Building entomological capacity in all malaria endemic countries (both human and physical infrastructures) - including the capacity to conduct routine monitoring of insecticide resistance, analyse and use the data to take appropriate decisions on management of resistance in a multisectoral approach - will be crucial for the success of global insecticide resistance management (Box 4.2). Systematic, comprehensive tracking of resistance among insecticides used for malaria control, nationally and globally, has long been a priority activity for WHO, malaria endemic countries, and other global malaria control partners. A global plan for insecticide resistance management will address limitations of previous resistance monitoring systems and build on regional efforts such as the African Network on Vector Resistance to insecticides.¹

The level of insecticide resistance at which the effectiveness of malaria vector control is compromised remains uncertain. Resistance is not a factor that can be randomly allocated to communities and withheld from others in field trials, so it is difficult to isolate the effect of resistance from that of other factors such as variations over time and space in background transmission intensity, and in vector control intervention coverage (IRS and LLINs). With at least one form of resistance, LLIN use can still have a valuable effect on malaria despite high frequencies of the resistance gene in local vector populations (8). On the other hand, in some situations, resistance has led to failure of IRS and a serious resurgence in malaria (9).

¹ https://apps.who.int/tdr/topics/mol_entomology/files/anvr_1.pdf
BOX 4.2

Insecticide resistance monitoring in Sudan

Sudan established sentinel sites for insecticide resistance monitoring in 2006. There are a total of 64 sentinel sites in 12 of 15 states (provinces) (the remaining 3 states are either desert or inaccessible for security reasons). As part of a Regional initiative a total of 74 entomologists have received postgraduate training. Consequently, all the endemic states have at least 2 qualified entomologists whose responsibility is to carry out insecticide resistance monitoring. The field staff is supported by a core of 14 entomologists at the central level to guide decisions on vector control based on collected data. A multisectoral steering committee, including representatives from relevant ministries, academic and research institutions, and WHO, was set up to guide the vector control programme.

At each site, insecticide resistance monitoring was carried out every one to two years according to the availability of funds. Anopheline mosquito larvae were collected by dipping from a range of breeding sites and larvae were reared to adults in the field laboratories, under standard conditions (25 +/- 2 °C and 64%–80% relative humidity (RH)). Insecticide susceptibility tests were performed using the WHO standard procedures and test kits for adult mosquitoes under optimum conditions (temperature 26–29 °C and 70%–80% RH).

This investment in capacity building and data systems began to yield benefits soon after the programme was established. Resistance to organochlorines and organophosphates was already widespread, especially in irrigated agricultural areas, prior to 2006. In 2006 resistance to pyrethroids was detected in 13 of 17 sites in Gezira and Sennar state, at levels of kdr allele frequency of 0.47 to 0.68. The multisectoral steering committee was called upon to propose recommendations for the IRS programme in 2006. The input of international experts was sought in making this decision. In 2007 a rotation plan for IRS, replacing pyrethroids with a more expensive alternative (carbamate), was recommended by the committee and subsequently implemented in Gezira state through the state's governmental budgeting and support. In 2008, following decentralization of some governmental operations, vector control activities were devolved to states. Due to the high cost of carbamate, IRS was stopped in Gezira state after the first round. With comprehensive political advocacy to raise awareness of the threat to malaria control posed by cessation of IRS, state financial support was obtained and spraying resumed with carbamates in 2011.

TABLE BOX 4.2

Republic of Sudan, Federal Ministry of Health, National Malaria Control Programme:
Sites for monitoring of insecticides resistance 2010–2011

<table>
<thead>
<tr>
<th>State</th>
<th>No. of sites</th>
<th>Sites Investigated</th>
</tr>
</thead>
<tbody>
<tr>
<td>Khartoum</td>
<td>13</td>
<td>Kafuri, Al Faki Hasim, Shambat, El Giraf Sharg, Soba east, Soba West, Jabra, Arkweet, Al Salama Al Jadida, Al Shgailab, Al Ameir</td>
</tr>
<tr>
<td>Gezira</td>
<td>9</td>
<td>El Masalamia, Tabat, El Hoosh, Haj Abdellah, Medani,Mobi,Rofaa,Wad Rawa,El Managil</td>
</tr>
<tr>
<td>Sennar</td>
<td>2</td>
<td>Sennar Sugar area, El Soki</td>
</tr>
<tr>
<td>Blue Nile</td>
<td>1</td>
<td>Damazin</td>
</tr>
<tr>
<td>White Nile</td>
<td>4</td>
<td>Kosti, Kennan sugar area, Assalaya sugar area, El Duwaim, Rebak</td>
</tr>
<tr>
<td>N. Kordofan</td>
<td>7</td>
<td>Bara, elnuhood, elbied, el rahad,abuzabadel khowai, umrwaba</td>
</tr>
<tr>
<td>Gedarif</td>
<td>2</td>
<td>Gedarif, Galabat East</td>
</tr>
<tr>
<td>Kassala</td>
<td>3</td>
<td>Kassala, El Gerba, New Halfa</td>
</tr>
<tr>
<td>River Nile</td>
<td>4</td>
<td>Abu Hamad, Attbara, El Damar, Shendi</td>
</tr>
<tr>
<td>Northern</td>
<td>6</td>
<td>Meowe,Kareema,Al Daba,Dongola,Burgerage, Dalgo</td>
</tr>
<tr>
<td>West Darfu</td>
<td>5</td>
<td>Genain,Fur Baranga,Zalengi,Garsilla,Um Dokhon</td>
</tr>
<tr>
<td>S. Dar Fur</td>
<td>9</td>
<td>Nyala, Eid Effiran, Rehad elberdi, Kas, Tulus, sharia, Eldaient, Adella and Elburam</td>
</tr>
</tbody>
</table>

The 2011 World Health Assembly resolution on malaria\(^1\) included the provision that WHO should “provide support to Member States in identifying new opportunities for malaria control, as well as combating major threats, notably plasmodial resistance to antimalarial agents and mosquito resistance to insecticides, through the development and implementation of the Global Plan for Artemisinin Resistance Containment and a global plan for the prevention and management of insecticide resistance”.

Consequently, the WHO Global Malaria Programme is currently developing the Global Plan for Insecticide Resistance Management (GPIRM) in consultation with almost 150 stakeholders. The plan will: (i) define what is known, what is assumed and what remains unknown with regard to insecticide resistance among malaria vectors, its spread and operational impact, and options for managing the problem; (ii) estimate the potential impact of insecticide resistance on malaria burden, and the financial cost of monitoring and managing insecticide resistance; and (iii) based on these elements, define the plan for managing insecticide resistance and the way forward, including a short-term action plan with clear responsibilities, and ongoing research and development requirements. The GPIRM is expected to be released in the first quarter of 2012.

\(^1\) [http://apps.who.int/gb/ebwha/pdf_files/WHA64/A64_R17-en.pdf](http://apps.who.int/gb/ebwha/pdf_files/WHA64/A64_R17-en.pdf)
4.4 Conclusions

Progress in increasing access to ITNs: The number of ITNs delivered by manufacturers increased dramatically from 5.6 million in 2004 to 145 million in 2010 in sub-Saharan Africa. However, the number of ITNs supplied in 2011 appears to have reduced, partly because some countries have made substantial progress towards achieving universal access to ITNs in 2010 and are not scheduled to reorder ITNs, but also because some countries are still not expanding programmes to a sufficient scale. Using a model that takes into account the number of ITNs supplied by manufacturers, the number of ITNs delivered by NMCPs, and household survey data, the percentage of households owning at least one ITN in sub-Saharan Africa is estimated to have risen from 3% in 2000 to 50% in 2011, reflecting considerable progress but also signifying there is much more work to be done.

A high proportion of available ITNs within households appear to be used; approximately 96% of persons with access to an ITN within the household use it, suggesting that the main constraint to enabling people at risk of malaria to sleep under an ITN remains lack of available nets. There is a need for more up-to-date information on the availability and use of ITNs at household level, as the timing of existing household surveys may not adequately capture the progress made after mass campaigns.

Sustainability of ITN implementation: While the rapid scale up of ITN distribution in Africa is an enormous public health achievement, it also represents a formidable challenge for the future in ensuring that the high levels of coverage are maintained. During the last three years mass campaigns have been the main channel used by NMCPs to deliver ITNs, accounting for 71% of ITNs delivered, followed by antenatal care clinics (15%). Measures need to be in place to ensure that those not benefiting from the campaigns also have access to nets. Moreover, strategies will be needed to deal with replacement of the large number of ITNs that have recently been delivered, while continuing to scale up programmes in countries that have not achieved universal access. There is uncertainty over the extent to which ITN effectiveness decays over time, but the lifespan of an LLIN is currently estimated to be 3 years. Nets delivered in 2007 and 2008 are therefore due for replacement, soon to be followed by those delivered between 2009 and 2010. Failure to replace these nets will increase the risk of a resurgence of malaria cases and deaths.

Progress in implementation of IRS: IRS programmes have also expanded considerably in recent years, with the number of people protected in the African Region increasing from 10 million in 2005 to 78 million in 2010, and to 81 million among all countries in sub-Saharan Africa, a quantity which corresponds to protection for 11% of the population at risk. In other WHO Regions IRS implementation has not been expanding as rapidly, and is generally relatively stable. With the exception of India, the proportion of the population protected by IRS tends to be smaller than in the African countries which use IRS. The less extensive use of IRS vector control may reflect the more focal nature of malaria outside Africa, where smaller proportions of the population at risk would benefit from large-scale spray programmes.

Potential for insecticide resistance: Current methods of malaria control are highly dependent on a single class of insecticides, the pyrethroids, which are the most commonly used compounds for IRS and the only insecticide class used for ITNs. Pyrethroids are exceptionally safe for people and the environment, and effective compared to other classes of insecticide used in public health. However, the widespread use of a single class of insecticide increases the risk of mosquitoes developing resistance, and this could rapidly lead to a major public health problem. The risk is of particular concern in sub-Saharan Africa, where insecticide resistance has been reported in 27 countries and where insecticidal vector control is being deployed with unprecedented levels of coverage. Interim guidance on insecticide management is available and a Global Action Plan for Insecticide Resistance Management will be released in 2012. Prudent management of insecticide use, including monitoring for resistance and adopting practices which minimize selective pressure for insecticide resistance, are required to preserve the effectiveness of this important malaria control tool.

References