Update on implementation of the *Global plan for insecticide resistance management in malaria vectors*¹

- The *Global plan for insecticide resistance management in malaria vectors* (GPIRM) was launched in May 2012 in response to widespread insecticide resistance.
- Resistance particularly to pyrethroids has since increased at an alarming rate.
- Some progress has been made in implementing GPIRM technical recommendations.
- Yet adoption to policy and operational implementation at country level have generally been poor due to a lack of political will coupled with major financial, human and infrastructural resource deficiencies.
- Urgent efforts are needed to ensure correct use of existing interventions and availability of new tools in order to maintain the effectiveness of malaria vector control.
- A comprehensive situation analysis should be conducted and a global response plan developed.

**INTRODUCTION**

Recent reductions in malaria transmission have largely been achieved due to widespread deployment of long-lasting insecticidal nets (LLINs) and indoor residual spraying (IRS).² However, these are threatened by the rapid increase in the distribution and the intensity of malaria vector resistance to insecticides. This is of particular concern for pyrethroids, which are the only insecticides currently used in LLINs and are widely used for IRS.

The *Global plan for insecticide resistance management in malaria vectors* (GPIRM)³ was released in May 2012 and outlines a comprehensive five-pillar plan for global, regional and national action. The five pillars of GPIRM are: 1) Plan and implement insecticide resistance management strategies in malaria-endemic countries; 2) Ensure proper, timely entomological and resistance monitoring and effective data management; 3) Develop new, innovative vector control tools; 4) Fill gaps in knowledge on mechanisms of insecticide resistance and the impact of current insecticide resistance management strategies; and, 5) Ensure that enabling mechanisms (advocacy, human and financial resources) are in place. This plan is not only for countries with ongoing malaria transmission, but also those for which malaria transmission re-establishment is possible.

In the two years since the launch of GPIRM, the insecticide resistance situation has worsened significantly, particularly in the African Region. Pyrethroid resistance has continued to spread in the major African malaria vectors of *Anopheles gambiae* and *Anopheles funestus*. New resistance mechanisms have been detected in *An. gambiae* from West Africa in addition to those formerly

---

¹ This document was prepared as a pre-read for the September 2014 meeting of the Malaria Policy Advisory Committee (MPAC) and is not an official document of the World Health Organization.
PILLAR I. Plan and implement insecticide resistance management strategies in malaria endemic countries

Pyrethroid resistance is rapidly spreading geographically and in intensity. To manage insecticide resistance using current tools, GPIRM recommends rotational or mosaic use of insecticides in IRS, and where LLINs are present, combination with targeted IRS using non-pyrethroids. However, the rapidly escalating pyrethroid resistance situation and the paucity of affordable non-pyrethroid alternatives for IRS mean that countries and implementing partners have faced challenges in the adoption of these recommendations.

Of the 55 countries that reported the insecticide class selected for malaria IRS implemented in 2013, 25 used non-pyrethroid insecticides, 30 used pyrethroids and 7 used both. While the continued use of pyrethroid IRS may be justified as part of a resistance management strategy (such as on a rotational basis) and in the absence of LLINs, this was usually not the case. Of the 30 countries that continued to use pyrethroids for IRS in 2013, 14 were supported by the Global Fund, 9 by government, 5 by private sector and 2 by the US President’s Malaria Initiative.

For those countries implementing non-pyrethroid IRS, this was often driven by the detection of high level pyrethroid resistance rather than pro-active implementation of good resistance management practice as part of a long-term national strategy. In general, for those countries that changed to non-pyrethroid IRS, there was an associated reduction in the overall proportion of the at-risk population

---

4 Mixed function oxidases and kdr target site mutations.
6 Use of mixtures is also recommended but currently no WHO-recommended IRS or LLIN mixture formulations are available.
7 Data compilation is ongoing by the WHO Global Malaria Programme.
8 The continued use of pyrethroids in IRS rotations will be heavily dependent on the intensity and mechanisms of resistance in the local vectors and the speed at which resistance reverts once the pyrethroid selection pressure is relaxed.
10 Christen Fornadel, personal communication, 26 July 2014.
protected by IRS due to the increased cost of procuring and deploying the non-pyrethroid alternatives. For instance, in Liberia the detection of significant pyrethroid and DDT resistance in 2011 led to spraying in 2012 with a pyrethroid and a carbamate in different areas of the country for coverage of 23% of the at-risk population. In 2013, use of a long-lasting organophosphate formulation showed significant entomological impact, but due to the higher cost of this insecticide IRS coverage was reduced to 9.7% of the at-risk population. Subsequent consultations between the national programme and the donor led to a decision to suspend IRS and shift resources to support LLIN procurements. Donor support for IRS has been similarly discontinued in three other countries in Africa due to an inability to achieve economies of scale using a pyrethroid alternative.

While countries are currently at different stages of planning and implementing national insecticide resistance monitoring and management strategies, some have done so in a form that may serve as a useful example to countries undertaking this process. Brief examples are outlined in Annex 1.

### PILLAR II. Ensure proper, timely entomological and resistance monitoring and effective data management

GPIRM highlighted the importance of routinely collecting, analysing, managing and sharing data on insecticide resistance to support timely and informed programmatic decision-making. As part of the normative role of WHO, a key document was developed to guide countries and partners on how to conduct insecticide resistance testing and interpret data for informing appropriate vector control. One of the most important functions of this document has been to guide and standardise the reporting of insecticide resistance data in line with GPIRM recommendations to support pre-emptive action for resistance management. However, current procedures for monitoring insecticide resistance are not sufficient for measuring resistance intensity or predicting impact on intervention efficacy, and new test methods are needed.

In order to enhance national capacity to monitor and manage insecticide resistance, countries indicated a need for more concrete guidance on how to systematically plan and budget required activities and how best to integrate these into their national malaria strategic plans. WHO consequently developed a planning framework for insecticide resistance monitoring and management. The document promotes adherence to the objectives of GPIRM and allows standardization across countries in the structure and content of national plans as well as in data collection tools. These plans are meant to form a basis around which to build a more comprehensive entomological monitoring programme that can address issues and answer questions pertaining to the targeting and effectiveness of malaria vector control interventions. Plans can also be used to request financial support from The Global Fund to Fight AIDS, Tuberculosis and Malaria (Global Fund) and other donors.

An effective global tracking system for insecticide resistance in malaria vectors is in the process of being established by WHO. A baseline survey to obtain data from 2000 to date has been linked to the World Malaria Report data collection process. By December 2014, data from countries will be consolidated into a global database which will be linked to regional databases. The global database will provide data aggregated to the country level and will allow for the online generation of reports and


maps by users to facilitate a rapid and up-to-date overview of resistance status. Databases managed by WHO regional offices will provide summaries for the countries of respective regions. These platforms will facilitate data sharing and will ensure timely availability of data to guide national and global malaria policy. Whereas in GPIRM the proposal was for the global database to be managed by a partner institution, countries indicated their preference for data management and database hosting to be conducted by WHO. Resources were therefore mobilized by WHO to implement this request from countries. Plans are also underway to include the rich historical data available in the WHO archives.

Development of technical competency through training is also key to supporting insecticide resistance monitoring and management. A number of regional as well as national training courses have been conducted since the launch of GPIRM. Partners, in particular the US President’s Malaria Initiative, have been commendably involved in coordinating training workshops and the supply of bottle bioassay kits in countries where they operate. These have focussed on imparting knowledge and skills to national technicians on the collection of insecticide resistance data and on how to correctly analyse and interpret such data. The latter has been identified as a key issue given the complexity of correctly assessing all factors related to resistance required to correctly inform control interventions. In countries where PMI has been operating, capacity has been built in entomological surveillance including insecticide resistance monitoring as well as LLIN distribution and IRS implementation, monitoring and evaluation. Other partners have also supported capacity building and regional initiatives.

**Pillar III. Develop new innovative vector control tools**

While current resistance management efforts focus on judicious use of insecticides through rotations and combinations, in the medium-term the development of new active ingredients for use in LLINs and IRS based on validated target product profiles is essential. To further reduce the insecticide selection pressure exerted by effective vector control tools, new interventions are needed to address residual transmission maintained by mosquito species exhibiting behaviour that allows them to avoid LLINs and IRS, such as by outdoor biting and resting or early-evening biting. Genetically modified (GM) mosquitoes may provide effective options in the longer term.

In response to the need for improved mechanisms for assessing the public health value of new vector control tools and technologies, and to aid the development of appropriate technical recommendations, the Malaria Policy Advisory Committee constituted the Vector Control Advisory Group (VCAG) in 2012. The group is jointly managed by the WHO Global Malaria Programme and the Neglected Tropical Diseases departments and is responsible for proposing recommendations on new forms/ tools/ technologies of vector control after reviewing their public health benefit. With the initial recommendation, WHOPES will then proceed with the development of product specifications for safety and efficacy by building on relevant data from potential innovators. The outcome of the VCAG process will be to shorten the time it takes to deploy validated vector control tools to protect populations from malaria and other vector-borne diseases.

To date, VCAG has established its working procedures and has reviewed 12 dossiers for potential products from innovators. VCAG is currently preparing guidelines for the minimum data set that will be required for innovators wishing to develop products to address pyrethroid resistance, and the appropriate product claims of effectiveness and resistance management.

The global pipeline of new insecticide-based vector control products has dramatically improved in the past five years, mainly due to the Innovative Vector Control Consortium (IVCC) programme with
industry (See Box 1). Although the different production development initiatives are a major step forward, the successful deployment of the existing core interventions and new products will require multi-sectoral coordination across many stakeholder groups. Specialist technical assistance is a necessity to ensure the limited number of tools available remains effective. Alongside innovation in product development and harmonisation of policy and regulatory processes, the funding mechanisms, cost, efficacy and benefits assessments and supply chains will all need to be managed to achieve a cost-effective and sustainable outcome for vector control.

**Pillar IV. Fill gaps in knowledge on mechanisms of insecticide resistance and impact**

**BOX 1. DEVELOPMENT OF NEW PRODUCTS FOR MALARIA VECTOR CONTROL**

*Indoor residual sprays:* Two new long-lasting formulations of existing IRS insecticides that exceed the 2–4 month established benchmark to last 6–12 months have already reached the market. Other formulations of repurposed agro-chemicals are under development, but are at best 12–24 months from becoming available for deployment. IVCC has established a portfolio of novel active ingredient candidates that should deliver new public health insecticides by 2022. If these novel insecticides are to reach the market in the predicted timeframe, the global and national regulatory framework will need to be adapted in order to avoid delays in availing these insecticides for use.

*Long-lasting insecticidal nets:* New formulations are in preparation, with the first generation of these containing a pyrethroid plus a synergist or growth regulator. An important step will be to examine potential additional benefits against pyrethroid-resistant *Anopheles*. A second generation of non-pyrethroid multi-insecticide nets is in early stage development but it is likely to be several years before these are available for wide-scale deployment.

*Spatial repellents:* Currently there are insufficient data to assess whether spatial repellents could play a substantive role in disease prevention. A multi-country coordinated field trial of the effectiveness of repellents is under way which should establish whether repellents work against most or just a small sub-set of mosquito vectors, but this study is unlikely to alone provide sufficient evidence to recommend wide-scale usage of repellent as part of national control programmes. Continued commitment from industry and research groups will be required to identify and validate any promising new candidates.

GPIRM set out some priorities for research in the short-, medium- and long-term, though it was acknowledged that the lack of full information and evidence in some key areas does not preclude immediate action to pre-emptively address insecticide resistance. Progress has been made in some but not in all identified areas.

*Evidence on subregional and regional trends in the spread of resistance in locally important vector species.* As outlined for Pillar II above, global and regional database are currently being constructed to consolidate all evidence on resistance status and mechanisms in malaria vectors. A regional meeting of the African Network on Vector Resistance is planned for late September 2014 at which representatives from NMCPs, WHO and/or national research institutes will present and discuss resistance data, and share experiences on development of national IRM plans. A similar process is planned for WHO South-East Asia Region in November 2014.
New knowledge on resistance mechanisms. Significant investment in defining and rapidly monitoring metabolic resistance mechanisms have been made by various institutes in recent years. This has essentially reduced the time required to assess the underlying causes of resistance from 6–12 months to a matter of weeks. While the methodology was published in 2011, the complexity of metabolic pathways impedes simplification of the monitoring system. Most malaria endemic countries therefore do not have the capacity for full characterization of resistance mechanisms. Indeed, many have yet to even conduct simple synergist bioassays as an indicator of underlying metabolic mechanisms even though these mechanisms are of vital importance in conferring operationally-significant resistance. The establishment or strengthening of country reference centres where possible, or regional centres of excellence and mechanisms to support malaria endemic scientists with resources will help address this problem.

Impact of resistance on malaria control. Assessing the impact of insecticide resistance on the effectiveness of interventions is an essential but difficult task. A number of studies on LLINs claiming to have evaluated this have yielded differing results. The Roll Back Malaria Partnership, via the Vector Control Working Group, commissioned a systematic review to assess the evidence on the impact of resistance on disease transmission and insecticide-treated net efficacy which was published in 2014. In summary, despite numerous studies there are still insufficient data to ascertain the impact of resistance on disease transmission. Likewise, evaluations of the added impact of IRS in areas with LLINs and resistant Anopheles have provided inconsistent results and further evaluations are in progress. Poor standardisation of methodologies, inadequate controls and poor or no characterization of underlying resistance mechanisms in most studies mean that even conclusions on entomological impact are limited.

Accurate assessment of resistance impact requires greater standardisation of methodologies, with studies undertaken of sufficient scale and power to generate meaningful conclusions. To this end, a 5-country project is being implemented in Benin, Cameroon, India, Kenya and Sudan with support from the Bill & Melinda Gates Foundation and coordination by GMP. With completion expected in 2016, interim results indicate the importance of adhering to GPIRM recommendations. They also point to the complexity of insecticide resistance and variations in impact on malaria transmission across different eco-epidemiological settings. (See Box 2 for example data from Sudan)

New evidence on insecticide resistance management methods. There is also a paucity of evidence on the utility of resistance management strategies on restoring the susceptibility of malaria vectors. In addition to studies on resistance impact, there is a need for carefully designed assessments of the operational implications of combination of chemical and non-chemical based interventions. Such strategies include rotational or mosaic application of insecticides of different modes of action in IRS implemented either broadly or on a targeted basis. Outcomes are likely to be dependent on the levels of malaria parasite transmission and the insecticide susceptibility or resistance mechanisms of local mosquitoes. These need to focus on validated cost-effective interventions that can be undertaken at scale within the constraints of the national malaria control programmes.

---


Pillar V. Ensure that enabling mechanisms (advocacy, human and financial resources) are in place

The GPIRM launch event brought together high-level representatives of all key constituencies within the global malaria community. Speakers urged affected countries and partners to take immediate action to preserve the effectiveness of current vector control tools, and to ensure that new public health interventions are made available soon and at an affordable cost. As part of a wider dissemination plan, the executive summary of GPIRM was translated into three of the six UN official languages and the document was circulated widely. WHO and partners also used every opportunity in both national and international forums to present GPIRM to ensure that it reached all intended audiences.

Attempts by WHO to engage industry partners on potential price concessions for existing or new IRS products have had limited success. The US President’s Malaria Initiative also attempted to discuss pricing with industry, and advocated for insecticide manufacturers to look into price elasticity models i.e. if price goes down, quantity purchased goes up to reach an equilibrium point. This has not been successful in part because a high commodity price and single supplier for the only long-lasting, non-pyrethroid IRS formulation has led to a small and chaotic marketplace and low uptake, which results in a lack of reliable, long-term demand forecasting. Using their experience with LLIN procurement, the Global Fund is considering engaging with industry on a new procurement strategy for IRS in 2015. It should be noted that the basic cost of manufacture of the non-pyrethroid alternatives, whatever the volume, will nevertheless be significantly higher than that of pyrethroids.

The result of the ongoing high costs is that at country level there is a lack of access to affordable, quality non-pyrethroid insecticides. This provides a barrier to their widespread use, and means that when they are deployed overall reductions in IRS coverage rates may result. A key factor reinforcing this barrier is the lack of evidence on the cost-effectiveness of different insecticides, and limited capacity at the country level to use such evidence for local decision-making. For example, while pyrethroids are approximately 2–3 US dollars per sachet (requiring two spray rounds in areas with a transmission season beyond six months), bendiocarb is about 11 US dollars per sachet (requiring up to 3 spray rounds in areas with a transmission season beyond 9 months) and the new long-lasting organophosphate (pirimiphos-methyl) formulation is approximately 24 US dollars for a sachet.

BOX 2. EMERGING EVIDENCE ON THE IMPACT OF INSECTICIDE RESISTANCE

In a cluster randomised trial in Sudan, 140 clusters in four study areas were randomly allocated to either full coverage with LLINs, or full coverage with LLINs plus IRS. Entomological indices and malaria prevalence and incidence were measured. Bendiocarb (carbamate) IRS was used in three of the four study areas. In the highest transmission areas of Galabat in Gedarif state, deltamethrin (pyrethroid) was used in 2011 and 2012 with a change to bendiocarb in 2013 following the detection of pyrethroid resistance.

The switch to bendiocarb in Gabalat was associated with a significant decline in malaria incidence, suggesting that resistance was compromising the efficacy of the pyrethroid IRS. While this indicates a higher efficacy of bendiocarb, it may not necessarily have resulted in an impact on the pyrethroid susceptibility status of the local vectors. Rotational application of insecticides should continue on the basis of local data in order to minimize the selection that would result from continuous use of a carbamate. Monitoring of resistance mechanisms is ongoing, and may be used to ascertain the impact of the initial and subsequent rotations resistance.
equivalent (requiring one spray round per season). However, once application costs are taken into account, the cost of spraying one round of the long-lasting organophosphate formulation may be similar to that required for two rounds of a pyrethroid. Unless the factors limiting programme access to non-pyrethroids are addressed, including reduction in costs for overall management and implementation of IRS, it is unlikely that the objective of GPIRM to maintain the effectiveness of vector control will be sustainable. Strategic transitioning of ownership to national programmes and building national capacity for and investment in IRS is vital.

In addition to the wide dissemination of GPIRM, concurrent efforts were undertaken for example by WHO and USA Centers for Disease Control and Prevention to mobilize financial resources. These included approaching traditional donors as well as exploring innovative ways to engage non-traditional donors such as through CDC Foundation for independent management of funds from sources including the private sector. These efforts were largely unsuccessful.

The critical need remains for resources to build the capacity of countries to collect, analyse, manage and share entomological data including on insecticide resistance\(^{16}\) as well as use the data appropriately to guide the management of insecticide resistance. The World Malaria Report data collection process will be used to track global progress on GPIRM implementation including capacity building, with the baseline human and infrastructural capacity assessment currently ongoing. Resources are also required within WHO to support countries in coordinating the implementation of technical recommendations outlined in GPIRM and other relevant policies.

**Conclusions and the way forward**

For most malaria endemic countries, particularly those in Africa south of the Sahara, pyrethroid resistance is spreading and there are increasing reports of resistance to organophosphates, carbamates and DDT. Pre-emptive action, as emphasised in GPIRM, has now been overtaken: immediate measures are needed to address resistance. Even where resistance is yet to be detected, resistance management must be implemented in order to preserve the effectiveness of available insecticide classes. This is imperative given the need for sustained universal access to LLINs and the limited options currently available for malaria vector control.\(^{17}\)

Until new tools such as the second generation of non-pyrethroid multi-insecticide LLINs are available, insecticide resistance will to a great extent rely on the targeted use of IRS with insecticides of different modes of action in rotation. However, in areas of high pyrethroid resistance, such rotation options are now severely limited. A decline in the global at-risk population protected with IRS from 153 to 135 million (5% to 4%) in 2012\(^{18}\) was largely attributable to the high cost of non-pyrethroid alternative insecticides. Thus, with the paucity and cost of alternatives as the main barriers to implementing GPIRM technical recommendations, it is vital that affordable options for vector control are urgently explored. Better global forecasting of insecticide requirements, pooled procurement and long term agreements and tax-free incentives have been successfully applied to the LLIN market. These approaches may be feasible to enhance the confidence of IRS chemical manufacturers, help stabilise the market and eventually lead to price reductions. Together, these actions may support the maintenance and/or scale-up of IRS for insecticide resistance management purposes, which must be

---


conducted in parallel to enhanced entomological surveillance and insecticide susceptibility monitoring. The challenges of introducing IRS in countries with no previous experience should also be taken into account.

Countries and partners are urged to continue to develop and implement national insecticide resistance monitoring and management plans that include contingencies for more expensive alternative IRS insecticides as part of national strategic plans and funding submissions to the Global Fund. They are also encouraged to pursue resource mobilization to secure additional funds from elsewhere to cover the costs of deploying IRS alternatives. As the majority of countries implementing IRS depend heavily on external support - especially in high burden countries in Africa - there is a need to advocate for investments by hosting countries and donors that are coupled with national malaria strategic plans in order to transition to full country ownership and management.

In parallel with these efforts, additional investments should be made to build country capacity to monitor insecticide resistance, including quantifying resistance intensity and assessing its operational impact. Country reference centres run in collaboration with the national malaria control programme should be established, potentially by upgrading existing institutions with the necessary facilities. The complexity of characterizing the underlying resistance mechanisms means that establishing capacity for these assessments will not be practical in all malaria endemic countries. Country, regional or global centres that can rapidly assess mechanisms and feed-back results in a timely manner should be established to work alongside national programmes to ensure optimal uptake and use of information. This will help in building capacity of scientists from developing countries, particularly those working in national malaria control programmes. A mechanism is also needed to ensure that scientists who may have been trained internationally have the opportunity to utilise their technical and management skills to maximum effect in their own countries. Specialised re-entry grants, such as those previously issued by the WHO Special Programme for Research and Training in Tropical Diseases, or similar grant schemes should be implemented to address this.

WHO through MPAC must support these initiatives by building awareness and consensus around the extent of the problem of insecticide resistance - similar to those efforts with artemisinin resistance - and should explore ways to ensure that alternative products for managing insecticide resistance are affordable. The inclusion of a WHA resolution in the upcoming discussion of the draft Malaria Global Technical Strategy will need to request Member States to commit additional financial, infrastructural and human resources to address the threat of insecticide resistance to malaria control and elimination.

With the current knowledge and experience, it would be irresponsible for the global community to wait until malaria programmes report increases in malaria cases due to insecticide resistance before there is a significant response. Moreover, it is unacceptable to merely stand by and witness declines in IRS coverage due to a lack of resources for rotating with more expensive non-pyrethroid alternatives. Global inaction deprives affected communities of their basic right to universal access to effective prevention against malaria. It is therefore recommended that mechanisms are explored to develop a global emergency response plan for insecticide resistance in malaria vectors.
ANNEX 1. Examples of countries with experience in implementing insecticide resistance management

**Equatorial Guinea**
On Bioko, the main island of Equatorial Guinea, IRS was first conducted using deltamethrin in 2004. While *An. funestus* and *An. gambiae* appear to have been eliminated from the island, high levels of a target-site resistance mechanism (L1014F kdr alleles) were rapidly detected in *An. Coluzzii*. This resistance mechanism conferred DDT resistance and a low level of cross-resistance to all pyrethroids. The high frequency of this mechanism coupled with an apparent lack of response of the vector to the IRS, prompted the malaria control programme to change from pyrethroid usage. IRS was subsequently conducted with bendiocarb from 2005 to 2012. However, retrospective analysis of bioassay and infection data indicated that the initial deltamethrin IRS had in fact imparted a substantial epidemiological effect and that the *An. gambiae* kdr status alone was not operationally significant. Following continuous bendiocarb usage for 7 years, an annual rotation of insecticides was instigated in 2013 with pyrethroids reintroduced despite a high frequency of *kdr*. For 2014-2015, IRS with both deltamethrin and bendiocarb is planned. Continuous monitoring of insecticide susceptibility and transmission will be undertaken. The national insecticide resistance management plan was finalized in 2012 by the National Malaria Control programme and will be approved by the Ministry of Health in September 2014 and published in both English and Spanish.

**India**
Implementation of malaria vector control in India is based on data from routine monitoring of insecticide resistance. The National Vector Borne Disease Control Programme has come up with a stratified plan in which DDT is sprayed in a total of 255 districts, malathion in 35 districts and deltamethrin in 111 districts. In Surat district in Gujarat province, the local malaria vector species *An. culicifacies* was reported to be resistant to all three of these insecticides. Follow up monitoring showed that vectors were still resistant to DDT and malathion 30 and 9 years after withdrawal of IRS, respectively. On the other hand, susceptibility to deltamethrin returned by 3 years after its withdrawal in the area. It is important that programmes in such a similar situation do not merely switch insecticides but rather rotate the use of insecticides as recommended in GPIRM.

**Senegal**
IRS was conducted in seven districts of Senegal using the pyrethroids lambda-cyhalothrin (2007 to 2009) and deltamethrin (2010). High levels of resistance to both pyrethroids and DDT were detected in species of *An. gambiae* s.l. but susceptibility to carbamates and organophosphates remained. After reviewing these data, a national technical committee on vector control recommended replacement (not rotation *per se*) of pyrethroids with bendiocarb in 2011. Subsequent routine monitoring of vector susceptibility has indicated a gradual restoration of pyrethroid and DDT susceptibility in some districts. Species composition, *kdr* frequency and data on malaria cases are currently being evaluated. It is hoped that restoration of susceptibility to pyrethroids will allow the inclusion of this insecticide class in future rotations for IRS in Senegal.

---

19 Formerly *An. gambiae* S form.
20 Formerly *An. gambiae* M form.
19
23 Ousmane Faye, personal communication, 18 July 2014.
Sudan
An Intersectoral Steering Committee for Vector Control was established in 2005 that provides the Sudanese Government with policy and operational recommendations on vector control. Membership includes representatives from the National Vector Control Programme, ministries of health, agriculture, environment and industry, as well as regional malaria coordinators. Research and other academic intuitions, WHO technical advisory staff and other relevant experts are also members. Meetings are conducted quarterly to discuss and decide on vector control interventions, and insecticide resistance data are reviewed at least annually in order to inform operational planning. Further detail can be found in Box 2 on research to assess the impact of insecticide resistance on malaria transmission.

Zambia
Zambia has formed a multi-sectoral insecticide resistance management technical working group, under the auspices of the National Malaria Control Centre. This group includes research and academia, public and private sector, donors and other partners. They review all published and unpublished data for the three main malaria vectors (An. gambiae, An. arabiensis and An. funestus) and have established a long term resistance management plan against which progress is monitored. Spatio-temporal national maps of resistance are produced by combining all data from numerous sources. Based on a review of these data, a country-level mosaic of IRS driven by the local vector susceptibility profiles has been instigated, with bendiocarb IRS in the Copperbelt and pirimiphos-methyl in Eastern provinces. The impact of rotating the IRS insecticides is being closely monitored.