Global **Malaria** Programme

Framework for a national plan for monitoring and management of insecticide resistance in malaria vectors

World Health Organization

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Table of contents

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ABBREVIATIONS

CDC	United States Centers for Disease Control and Prevention
GMP	WHO Global Malaria Programme
GPIRM	Global plan for insecticide resistance management in malaria vectors
IRMMP	insecticide resistance monitoring and management plan
IRS	indoor residual spraying
ITN	insecticide-treated mosquito net
LLIN	long-lasting insecticidal net
NMCP	national malaria control (or elimination) programme
PCR	polymerase chain reaction
WHO	World Health Organization
WHOPES	World Health Organization Pesticide Evaluation Scheme

INTRODUCTION

Effective malaria vector control is threatened by widespread and increasing insecticide resistance as well as other biological challenges such as residual transmission. Failure to mitigate insecticide resistance is likely to result in an increased burden of disease, with significant cost implications for malaria prevention. Hence, the *Global plan for insecticide resistance management in malaria vectors* (GPIRM), released in 2012 *(1)*, outlines a comprehensive plan for global, regional and national action to address insecticide resistance. However, implementation of the GPIRM has been slow at national level for various reasons, including critical deficiencies of financial, human and infrastructural resources, and the lack of available vector control tools with different modes of action *(2)*. National malaria control (or elimination) programmes (NMCPs) require more concrete guidance to assist them in developing plans for insecticide resistance monitoring and for comprehensive management activities with clearly defined resource requirements. There is a particular need for concrete guidance now, because new vector control tools will soon be available that will provide further options for insecticide resistance management.

This document provides support for the development of a national insecticide resistance monitoring and management plan (IRMMP) as part of a national malaria strategic plan. It outlines the content to be included and the key considerations to be taken into account when developing an IRMMP. The guidance given here is not intended to be rigid and prescriptive; rather, it is designed to offer countries a framework that ensures adherence to the objectives and recommendations of the GPIRM, and allows standardization across countries in the structure and content of IRMMPs. It must be reiterated that an IRMMP should be an integral part of the vector control component of any national malaria strategic plan. An IRMMP can form a basis around which to build a comprehensive programme for monitoring entomological surveillance and vector control interventions, as shown in Fig. 1.

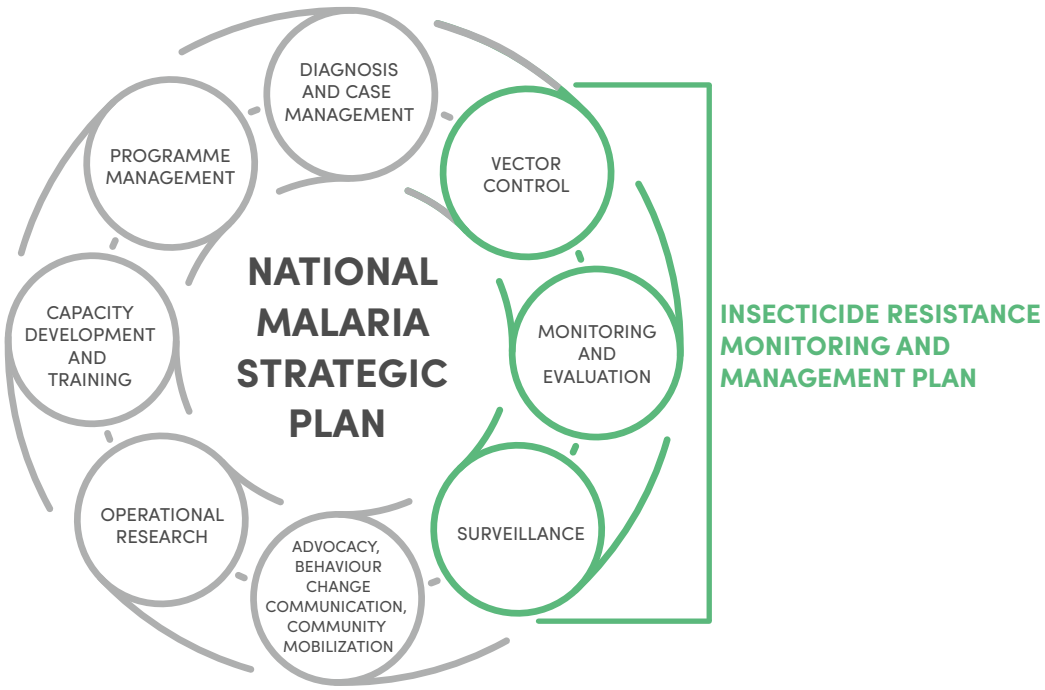

FIG. 1
Simple graphical representation of how an IRMMP feeds into the national malaria strategic plan

Section A of this document outlines the structure and content of a national IRMMP, explaining what should be included in the executive summary, situation analysis and implementation framework. Where necessary, Section A also provides key points (in shaded boxes) and guidance notes about factors to be taken into account when preparing the IRMMP. Section B deals with implementation, outlining the information to be included in an annual IRMMP workplan.

SECTION A: ELEMENTS OF A NATIONAL INSECTICIDE RESISTANCE MONITORING AND MANAGEMENT PLAN

A1. Executive summary

- **Briefly describe malaria epidemiology and vector control interventions in the country.**
- **Provide an overview of available insecticide susceptibility information for the main malaria vectors in the country.**
- **Indicate the key implications of the situation analysis, such as the need for enhanced entomological monitoring, an urgent review of vector control policy, or critical knowledge gaps that need to be addressed.**
- **Clearly describe the objective, rationale and key elements of the proposed IRMMP.**

The executive summary of the national IRMMP should include sufficient detail to provide a senior manager with a concise overview of the plan's objectives, rationale, monitoring methodology and decision-making process, and of the human and other resources required for implementation of the IRMMP.

A2. Situation analysis

The situation analysis should provide:

- a brief overview of the country's malaria epidemiology and current vector control interventions (including relevant information on historical use of insecticides, if desired);
- a brief summary of insecticide compounds and formulations registered and the amounts used in public health and agriculture in the country;
- a detailed description of the malaria vector species that are present, their insecticide susceptibility status and their resistance mechanisms, where known;
- a brief summary of key evidence on malaria vector control and of any knowledge gaps;
- a list of the partners involved in insecticide resistance monitoring or management activities;
- identification of risks, and of financial, human and other resource constraints that may impede the implementation of a comprehensive IRMMP; and
- an indication of the measures in place to address the various challenges.

Since a national IRMMP constitutes part of existing national malaria strategies, some of the relevant information may already be detailed in the overarching strategy document. In such cases, the IRMMP should provide a brief overview or reference to the strategy document. However, in the absence of updated information in the national malaria strategic plan, the IRMMP should include detailed descriptions, as necessary.

A2.1 Epidemiology of malaria

This section should give a brief overview of the malaria situation in the country. It should reference other sources where these provide more detailed up-to-date information; examples of such sources include national malaria strategic plans, malaria indicator surveys and annual malaria reports.

A2.2 Vector control interventions

- **Describe the current status of malaria vector control interventions implemented in the country, including insecticide-treated mosquito nets/ long-lasting insecticidal nets (ITNs/LLINs), indoor residual spraying (IRS), larval source management and other tools and approaches used either alone or in combination.**[1]

A2.2.1 Implementation

For IRS, the document should provide information on the insecticides in use, their formulations and target doses, the timing of the spray rounds, geographical and population coverage, amounts of insecticides used per year and approximate annual costs of the programme. For ITNs, the plan should capture features of the net, including type (LLIN or retreated ITN), material (polyester, polyethylene or polypropylene), insecticide and target dose. Where available, the document should include data on number of nets distributed annually, distribution mechanisms used, at-risk population coverage, access and use rates, and approximate annual costs. Where LLINs and IRS are being implemented together in the same location or the same households, the rationale for this strategy should be indicated. The locations should be specified, along with information such as the insecticides used for each intervention and the timing of the IRS spray rounds. For larviciding, the document should provide information on the biologicals or insecticides in use, and their amounts, the locations where they are applied and the approximate annual costs.

Where relevant, a brief overview of historical public health or agricultural insecticide use can be included.

A2.2.2 Monitoring

If not provided elsewhere, data from assessments of interventions during and after implementation should be included, such as:

- summary data from insecticide residual efficacy testing of sprayed walls and nets, as well as LLIN field durability information;
- information on the timing of spray rounds in relation to peak malaria transmission, household and population coverage and use, supervisory visit reports, internal or external assessments and so on;

1 Non-pyrethroid IRS may be implemented in areas where there are LLINs as part of an insecticide resistance management strategy. For more information, see WHO (2014) *(3)*.

- data from implementation of other interventions; and
- where limitations or challenges were identified during implementation, measures taken to address these.

A2.2.3 Evaluation

If not provided elsewhere, data from assessments of the impact of vector control interventions on malaria transmission and disease outcomes in the country should be summarized in the evaluation section of the plan.

A2.3 Registration of insecticides

- **Describe regional or national institutions responsible for pesticide registration (if any) and regulatory processes.**
- **List insecticides currently registered for use in public health and agriculture.**

The current process for registration of insecticides in the country should be outlined; this should be done in collaboration or consultation with the relevant regulatory body. A table of relevant insecticides currently registered for use in the country should be formulated, as shown in Fig. 2. The table should include insecticide formulations and compounds used in public health against malaria and other vector-borne diseases, including those used for IRS, ITNs, LLINs, space spraying and larviciding. It should also list insecticides registered for agricultural use, and insecticides currently pending registration, along with an approximate date of likely registration, if known.

FIG. 2
Example of a table summarizing the insecticides registered in a country for public health vector control and agriculture

INSECTICIDE CLASS	INSECTICIDE TYPE	PRODUCT NAME	USE (IRS, ITN, LLIN, LARVICIDE, SPACE SPRAYING, AGRICULTURE, ETC.)	FORMULATION	DATE OF REGISTRATION
Pyrethroid	Permethrin	xx	LLIN	Incorporated polyethylene	01/01/2008
Pyrethroid	Deltamethrin	xx	LLIN	Coated polyester	01/01/2009
Pyrethroid	Deltamethrin	xx	IRS	WP	01/01/2010
Organochlorine	DDT	xx	IRS	WP	01/01/2011
Organophosphate	Pirimiphos-methyl	xx	IRS	EC	01/01/2012
Organophosphate	Temephos	xx	Larvicide	GR	01/01/2013
Carbamate	Bendiocarb	xx	IRS	WP	01/01/2016
Carbamate	Propoxur	xx	IRS	WP	Expected 01/12/2017
Pyrethroid	Deltamethrin	xx	Agriculture	EC	01/01/2009
Organophosphate	Fenitrothion	xx	Agriculture	EC	01/01/2010

DDT, dichlorodiphenyltrichloroethane; EC, emulsifiable concentrate; GR, granule; IRS, indoor residual spraying; ITN, insecticide-treated mosquito net; LLIN, long-lasting insecticidal net; WP, wettable powder

Additional rows or columns can be added to the table as required. An indication of the areas or populations to which specific LLIN products or IRS formulations were deployed can also be included.

A2.4 Entomological surveillance, including insecticide resistance monitoring

A2.4.1 Main vector species

Distribution

- **Summarize the malaria vector mosquito species present in the country, their geographical distribution and key larval habitat characteristics.**

The focus should be on proven malaria vector species, with data presented in a table such as that shown in Fig. 3. Additional information for other anophelines can be noted. Distribution maps should be included if they are informative. The plan should also note the seasonality of vector species densities and composition.

FIG. 3
Example of a table summarizing malaria vectors present in a country and their geographical distribution

SPECIES	VECTOR STATUS (MAIN OR SECONDARY)	METHOD USED TO CONFIRM SPECIES PRESENCE [a]	GEOGRAPHICAL DISTRIBUTION [b]	KEY LARVAL HABITAT CHARACTERISTICS
An. barbirostris s.l.	Main	Morphology [c]	Countrywide, especially coastal areas	Freshwater stream bed; irrigated rice fields and swamps with vegetation
An. subpictus s.l.	Main	Morphology	Countrywide, coastal to inland	As above; brackish water pools with vegetation
An. sinensis s.l.	Main	Morphology	Countrywide, coastal to inland	Rice fields; freshwater pools
An. vagus genotype B	Secondary	Morphology, PCR [c]	Coastal and hinterland	Rice fields
An. culicifacies s.l.	Secondary	Morphology, PCR	Countrywide, coastal to inland	Unshaded pools with moderate amounts of vegetation; stream margins; rice fields; swamps

Notes: [a] For example, morphology, polymerase chain reaction (PCR) and cytogenetic methods; [b] For example, national, northern region, coastal areas, forest areas, and provinces x, y and z. For certain regions (e.g. parts of South-East Asia and the Western Pacific), geographical distribution could be tabulated as follows: up to 2 km from forest edge, inside forest, foothills, rubber plantations, land and water development ecosystems, coastal areas, beyond 2 km from the coastal margin; [c] If informative, include citation for morphological identification keys used.

More rows can be added to the table in cases where additional vector species are present.

Behaviour

- **Provide brief information on key behaviours relevant to malaria transmission and control for the main vector species present in the country.**

The plan should include relevant information on biting times, anthropophily or zoophily (i.e. propensity to feed on humans or other animals), endophagy or exophagy (i.e. propensity to feed indoors or outdoors), and endophily or exophily (i.e. propensity to rest indoors or outdoors after feeding).

A2.4.2 Vector insecticide susceptibility status

- **Provide a concise summary of recent insecticide susceptibility data available for all malaria vector species in the country.**
- **Provide a visual summary of the geographical distribution of insecticide resistance.**

The focus should be on data for the previous 2-year period with data for previous years also reported with a clear indication of the year. This should incorporate data collected by the NMCP and other partners, including national and international research institutes in routine monitoring and research projects. The document should present data from WHO susceptibility bioassays or United States Centers for Disease Control and Prevention (CDC) bottle bioassays that used discriminating concentrations and intensity concentrations. Data from insecticide mechanisms tests including synergist-insecticide bioassays should also be reported. Summaries can be presented in tables, graphs, text or maps. Data from different species and years should be presented separately, and sample sizes (number of mosquitoes tested) should be given.

The inclusion of data from border areas with neighbouring countries will enable the design of appropriate strategies to minimize the risk of resistance spreading across international boundaries. Such information may be obtained through direct contact with NMCPs, or from other sources such as scientific publications or regional databases.

It is important to report all data, including where susceptibility was detected. Additional rows or columns can be added to the table as required. The column on test method should be included if more than one bioassay method was used for susceptibility testing (e.g. WHO susceptibility tests and CDC bottle bioassays), because results from different procedures are not directly comparable.

Data mapping

A map should be generated for each individual vector species; the aim is to examine the distribution of available information and identify any spatial and temporal trends as well as data gaps. The known or predicted distribution of the species could be overlaid on the same map to further identify data gaps. Symbols can be used to indicate insecticide susceptibility status (i.e. confirmed resistance, possible resistance and susceptibility), as determined via standard WHO test procedures *(4)*. Different symbols or separate maps should be used to represent different insecticide classes[2]

2 Reports of resistance (confirmed, possible) and susceptibility must be included because the latter are also useful for informing control decisions. If such reports are not included, monitoring coverage may appear to be lower than it actually is.

FIG. 4A.

Example of a table summarizing insecticide susceptibility bioassay data (including for discriminating and intensity concentrations)

COLLECTION			DISCRIMINATING OR INTENSITY CONCENTRATION BIOASSAY				
LOCALITY [a]	MONTH AND YEAR	VECTOR SPECIES	TEST METHOD	INSECTICIDE AND CONCENTRATION	NUMBER OF MOSQUITOES EXPOSED	% MORTALITY [b]	STATUS (INTERPRETATION)
A	January 2017	*An. arabiensis*	WHO susceptibility test [c]	Deltamethrin (0.05%)	100	98%	Susceptible
B	January 2017	*An. arabiensis*	WHO susceptibility test	Deltamethrin (0.05%)	100	100%	Susceptible
C	January 2017	*An. arabiensis*	WHO susceptibility test	Deltamethrin (0.05%)	100	50%	Confirmed resistance
C	January 2017	*An. arabiensis*	WHO susceptibility test	Deltamethrin (0.25%)	100	65%	High intensity
C	January 2017	*An. arabiensis*	WHO susceptibility test	Deltamethrin (0.50%)	100	85%	

An, Anopheles; WHO, World Health Organization

Notes: [a] Ideally, list state or province, district, subdistrict and village name; [b] Adjusted for control mortality using Abbott's formula; [c] Also known as the WHO "tube" assays.

FIG. 4B

Example of a table summarizing insecticide resistance mechanisms data

COLLECTION			RESISTANCE BIOASSAY		MECHANISMS ASSAY			
LOCALITY [a]	MONTH AND YEAR	VECTOR SPECIES	INSECTICIDE TESTED	STATUS	MECHANISM	METHOD	STATUS	ALLELIC FREQUENCY
A	January 2017	*An. gambiae s.s.*	Deltamethrin and permethrin	Confirmed resistant	*kdr* L1014F	HOLA-PCR	Detected	27%
A	January 2017	*An. gambiae s.s.*	Deltamethrin	Confirmed resistant	Mono oxygenases	WHO synergist-insecticide bioassay with deltamethrin	Full involvement	NA
A	January 2017	*An. gambiae s.s.*	DDT	Confirmed resistant	Mono oxygenases	WHO synergist-insecticide bioassay	Partial involvement	NA

An, Anopheles; DDT, dichlorodiphenyltrichloroethane; HOLA-PCR, heated oligonucleotide ligation assay polymerase chain reaction; *kdr*, knockdown resistance; NA, not applicable; WHO, World Health Organization

Notes: [a] Ideally, list state or province, district, subdistrict and village name

and resistance mechanisms. Data available for border regions of neighbouring countries can also be displayed.

Where spatial information is available, it can be overlaid with insecticide susceptibility data; relevant spatial information includes epidemiological stratification, vector control intervention distribution, entomological inoculation rates, vector species distribution and land use patterns. Countries may also choose to analyse and map cross-resistance patterns, which can be helpful in determining appropriate changes to the insecticide resistance management strategy.

A2.5 Data management and dissemination

- **Outline current processes for collating and reporting data from all insecticide resistance monitoring activities in the country.**

Responsibility for the collection, collation, analysis and reporting of data ultimately lies with the NMCP. The plan should:

- indicate those tasked with collecting data;
- outline the mechanisms for collating and sharing data, and the frequency of doing so;
- give a brief description of the process of managing and maintaining the full national database;
- outline the means by which data are shared with and reviewed by the decision-making bodies responsible for vector control and insecticide resistance management; and
- give a brief indication of the issues and challenges encountered in any step of the process.

A2.6 Evidence and knowledge gaps

- **Identify the key informational gaps that need to be addressed to strengthen the IRMMP in the short, medium and long term, and outline the strategy for addressing these gaps.**

This section of the plan should include a description of any key and immediate evidence gaps that need to be addressed in the short term (i.e. over the next 12 months). For instance, it may be found that insecticide susceptibility data are not available or are not current for certain ecological zones or vector species, in which case susceptibility testing will be needed to fill these gaps. The plan should also highlight any knowledge gaps that need to be addressed in the medium term (i.e. 12–36 months) and the long term (over 36 months), and should explain how these gaps will be addressed. Examples of such gaps include situations where more information is required about the behaviour of a specific vector species or incrimination of a suspected vector. Costing of both the immediate and longer term plans to fill knowledge gaps should be included in the budget.

FIG. 5

Example of a table summarizing current human resources at national and subnational levels

ADMINISTRATIVE LEVEL	ROLE	QUALIFICATION [a]	NUMBER ENGAGED	PROPORTION OF TIME FOR CURRENT INSECTICIDE RESISTANCE MONITORING AND MANAGEMENT ACTIVITIES	TOTAL FOR CURRENT INSECTICIDE RESISTANCE MONITORING AND MANAGEMENT ACTIVITIES, IN FTE
National	Senior public health entomologist / senior supervisor	PhD	1	25%	0.25
National	Insectary manager / laboratory manager	MSc	2	25%	0.50
National	Insectary technician	MSc	1	25%	0.25
National	Laboratory technician	MSc	2	50%	1
National	Epidemiologist	PhD	1	10%	0.10
National	Statistician	PhD	1	10%	0.10
National	Database manager / GIS specialist	MSc	1	25%	0.25
Subnational	Public health entomologist / supervisor	MSc	4	25%	1
Subnational	Field personnel / environmental health technician	High school	40	25%	10
Subnational	Insectary technician	High school	4	25%	1
Subnational	Laboratory technician	High school	4	25%	1
Subnational	Data entry clerk	High school	4	25%	1

BSc, bachelor of science; FTE, full-time equivalent; GIS, geographic information system; MSc, master of science; PhD, doctor of philosophy

Note: [a] Tertiary postgraduate (e.g. PhD or MSc), tertiary graduate (e.g. BSc), secondary graduate (e.g. high school).

A2.7 Human resources

- **Summarize the current national and subnational human capacity devoted to insecticide resistance monitoring and management activities.**

Data should be provided for both national and subnational levels; the best format for presenting such data may be a summary table.

A2.8 Partner contributions

- **Provide an overview of all partners active in insecticide resistance monitoring and management in support of the NMCP.**

This section should include an overview of partners from all sectors, including those beyond the health sector. Contributions to be considered include those from research and academic institutions, private sector, nongovernmental organizations, agencies of the United Nations and other partners; in each case, the specific field of activity should be indicated. Relevant activities include initiatives to improve human and infrastructural capacity, as well as support for the implementation of insecticide resistance monitoring and management strategies.

A2.9 Current constraints

- **Describe any current financial gaps or other resource gaps that may have constrained implementation of effective insecticide resistance monitoring and management.**

Current constraints can include lack of sufficient financial, human and logistical resources; limited availability or stock-outs of key laboratory equipment, consumables and reagents; and lack of awareness of insecticide resistance.

A3. Implementation framework

This section should outline the overall and specific objectives of the IRMMP, as well as the structures and mechanisms for supporting effective implementation of the IRMMP in the country.

A3.1 Goals and objectives

- **State clearly the overall and specific objectives and rationale of the IRMMP.**

This section should also state the target audience and duration of the IRMMP.

A3.2 Insecticide resistance monitoring

- **Summarize the proposed monitoring activities.**

A3.2.1 Sentinel sites

- **Describe the criteria used to select established and proposed insecticide resistance monitoring sites, including details of the locations and characteristics of each site, and the frequency and proposed times of year for monitoring.**

A comprehensive and thorough situation analysis will assist in defining the ideal location and number of sentinel sites for routine insecticide resistance monitoring. Although the GPIRM provides criteria for the selection of such sites, locally specific advice should be sought from the relevant decision-making body. The distribution and number of sites should be reviewed periodically and adapted according to epidemiological data, identified patterns of resistance, and available human and financial resources. An example of a table for recording information about monitoring sites is given in Fig. 6, and an example of criteria used for selection of sites in Sudan is provided in Annex 1.

FIG. 6
Example of a table listing existing and proposed sites for insecticide resistance monitoring

LOCALITY NAME	LOCATION [a]	SENTINEL SITE (YES/NO)	STATUS ESTABLISHED/PROPOSED)	DATE ESTABLISHED	PROPOSED FREQUENCY OF COLLECTIONS	ADDITIONAL INFORMATION [b]

Additional rows or columns can be added to the table as required.

Notes: [a] Use global positioning system or map coordinates when possible, or name of province, district, town or village; [b] For example, population size, known insecticide susceptibility status, LLIN or IRS coverage, ecology, epidemiology and agricultural crops.

A3.2.2 Mosquitoes to be tested

- **Describe in brief the life stages to be targeted for testing and the procedures to be used to identify individual mosquitoes to species level.**
- **Indicate the institutions or individuals responsible for carrying out the identifications.**

As per the WHO *Test procedures for insecticide resistance monitoring in malaria vector mosquitoes (2nd edition) (4)*, tests should be performed using adult non-bloodfed females aged 3–5 days derived from larval collections (this is the preferred option), or from the F1 progeny of wild-caught female mosquitoes. If these options are not available, a third option is to use wild-caught unfed females.

The bioassays should be performed with individual vector species; hence, taxonomic determination of all specimens is necessary. Morphological criteria are used to classify vectors into species complexes or groups, and polymerase chain reaction (PCR) may then be necessary to obtain species-specific identifications. If, through PCR, it is not possible to identify all test mosquitoes, then a subsample of 40–50 mosquitoes per test can be used. The subsample should include all survivors plus some dead mosquitoes; alternatively, if there are many survivors, the subsample should contain survivors only. PCR can be conducted on specimens after susceptibility testing has been conducted, and the specimens stored on silica gel, appropriately labelled with the insecticide tested and whether the mosquitoes were dead or alive. More detail on this approach is described in the current WHO test procedures *(4)*.

If species identification is to be conducted by a technical specialist or an institution outside the NMCP, the plan should provide details of logistical and other arrangements (e.g. labelling and storage of specimens, mode of transport, frequency of identification and data-collection forms).

A3.2.3 Insecticide susceptibility testing

- **Identify the specific type or types of tests that will be used to determine susceptibility status for vectors in the country.**
- **Describe in brief the method or methods, insecticides and concentrations to be used for insecticide resistance monitoring, including for discriminating and intensity concentrations. Note any deviations from standard procedures.**

Two main test protocols are currently available for assessing mosquito susceptibility to insecticides: the WHO susceptibility ("tube") test *(4)* and the CDC bottle bioassay *(5)*. Either or both tests may be used, but because of different methodologies and outcome measures, the results of the two test procedures are not directly comparable. Both protocols now include procedures to measure intensity of resistance, which may be useful for detecting changes in resistance over time and for detecting metabolic mechanisms through the use of synergists.

Vector susceptibility to all insecticide classes in use or considered for use[3] should ideally be tested at least once a year for each main vector species in each of the sentinel sites. Where resistance is suspected or confirmed, and in areas where there is significant and widespread agricultural use of pesticides, testing should be more frequent (ideally twice per year). However, where resources are limited or few mosquitoes can be collected or reared,[3] the priority should be to test insecticides that are either in use or proposed for use in vector control. The times of testing should be in accordance with the malaria transmission seasons or the calendar of agricultural crop planting and harvesting. The WHO test procedures *(4)* provide further recommendations about frequency of testing and spatial distribution of sentinel sites.

3 Using at least one insecticide from each class.

A3.2.4 Resistance mechanisms identification

- **Describe in brief the biochemical or molecular assays[4] to be used to determine resistance mechanisms.[5]**

Any resistance phenotypes detected using the discriminating insecticide concentrations can be assessed for their potential operational significance by exposing subsequent or additional mosquito samples to the applicable 5× and 10× higher concentrations of those insecticides. Exposures at the higher concentrations will yield information on the intensity of resistance, which can be defined as the "strength" of a resistance phenotype. Confirmed levels of resistance at 5× and especially at 10× the discriminating concentration may indicate or predict operational control failure, and highlight a particularly urgent need to develop and implement an appropriate resistance management strategy. Instructions on how to interpret these results can be found in the WHO test procedures *(4)*.

Biochemical assays should be conducted on "fresh" mosquitoes, or on those that have been preserved at –70 ^{0}C or in liquid nitrogen. Specimens for biochemical analysis should not have been exposed to an insecticide.

Molecular assays can be performed on specimens stored in silica gel, ethanol or other solutions. Molecular testing can be conducted on specimens that survived or did not survive insecticide exposure in bioassays.[5]

A3.2.5 Coordination with supporting institutions

- **Indicate the respective bodies or institutions responsible for collecting and processing the mosquito samples, conducting the susceptibility tests, undertaking species identification and investigating resistance mechanisms.**

Where insecticide susceptibility testing or resistance mechanism identification is to be performed by a technical specialist or institution external to the ministry of health, details of logistical, financial, reporting and other arrangements will need to be clearly outlined. These details should include, for example, labelling and storage of specimens, mode of transport, frequency of testing, forms to be used to record results and communication of results.

A3.2.6 Data recording and reporting

- **Describe the procedures to be adopted for improved data collection, collation, analysis and dissemination.**
- **Describe the structure of the existing or proposed national database, and responsibilities for housing and maintaining the database.**
- **Outline the plan for sharing consolidated data with WHO.**

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4 Molecular testing should be conducted on the basis of results from susceptibility testing.

5 Detailed methodologies can be obtained from MR4 (2014) *(6)*.

As mentioned in Section A2.5, the responsibility for the collection, collation, analysis and reporting of data ultimately lies with the NMCP. This is imperative to ensure effective use of the NMCP and partner resources in generating the necessary information to guide timely national decision-making on vector control. In the short term, while capacity is being developed within the NMCP, other institutions may be engaged in monitoring activities. Where this is the case, the NMCP must be responsible for coordinating all such activities. Appropriate arrangements will be required to cover, for example, national capacity-building initiatives, data-collection protocols, data sharing, and data use and publication. Publication of data or results arising from such arrangements must be authorized by the NMCP.

Susceptibility test results should be recorded on standardized WHO *(4)* or CDC *(5)* forms, in accordance with the testing protocol selected. All insecticide susceptibility data collected in the country for local *Anopheles* populations must be collated by the NMCP such that those data can be included in the national database. Potential linkages with existing data management functions and tools (e.g. health management information system) should also be explored. New data on insecticide susceptibility should be presented to the national decision-making body at the earliest opportunity (and certainly within 3 months of completion of the test), so that up-to-date information can be used in making decisions about vector control, as discussed below.

The structure of the national database should be harmonized with regional and global databases; the aim is to ease reporting and ensure timely availability of comprehensive information, to better understand the regional and global situation. Insecticide resistance data will feed into regional and global insecticide resistance databases in order to guide vector control policy, as outlined in the GPIRM *(1)*. A standard insecticide susceptibility template[6] is available to assist in the process of reporting to WHO.

A3.2.7 Procurement and supplies

- **Summarize procurement schedules and procedures, including customs clearance processes for IRS insecticides, LLINs, etc.**
- **Identify the roles and responsibilities of the institutions and individuals involved.**

Further guidance on requirements is provided through the WHO website;[7] for example, the publication *Guidelines for procuring public health pesticides (7)*.

A3.3 Insecticide resistance management

A3.3.1 Decision-making body

- **Provide information on the status and proposed membership of the decision-making body, as well as that body's terms of reference and standard operating procedures, including frequency of meetings and lines of reporting.**
- **Outline the process for establishing or strengthening national (or subnational) decision-making bodies.**

6 The template can be requested by emailing gmp-ir@who.int or infogmp@who.int

7 See http://www.who.int/; accessed March 2017.

The NMCP has the mandate and responsibility for malaria vector control at the country level. It should lead the establishment and functioning of a national decision-making body to support insecticide resistance monitoring and management. This body should be responsible for coordinating national activities defined in the IRMMP on insecticide resistance monitoring and its management, to ensure appropriate prioritization and use of resources, and to provide a mechanism for decision-making. Where there is already a recognized technical group with the appropriate expertise, that group's terms of reference can be extended to include activities defined in the IRMMP, or a subgroup can be formulated for this purpose. In countries where vector control decisions are decentralized, there is a need to establish appropriate local decision-making bodies to manage insecticide resistance.

This section should include any proposed changes to the structure or composition of the bodies. The NMCP should decide on the most appropriate composition of the group, and should engage and involve partners in the decision-making process. The aim is to ensure that any change in vector control policy or an IRMMP can be funded and implemented effectively. A partner mapping exercise, coordinated by the NMCP at national or local level when appropriate, must be an initial step in the process of identifying institutions that will participate in the national or subnational decision-making bodies or that can provide insecticide susceptibility and other relevant data and resources to support decision-making. Strong intersectoral involvement is recommended, and participants should include representatives of ministries of health, agriculture and environment, as well as technical experts from partners such as WHO and academic institutions, and other appropriate partners such as donors and nongovernmental organizations. Participation by the national regulatory authority is crucial to enable informed selection of appropriate insecticidal interventions. Further guidance and examples of the structure of the decision-making bodies are contained in the GPIRM.

The proposed meeting dates for the technical groups and steering committees should be outlined. The process and timeline for review of the IRMMP should be defined.

Interpretation of test results and policy implications

- **Outline the process and frequency of review of information by the local or national decision-making bodies.**
- **Review and update the national malaria strategic plan as required.**

Information to be considered should include not only data from entomological surveillance but also information on access, coverage and use, as well as quality of current interventions (e.g. residual efficacy of IRS or LLINs, and field durability of LLINs). The status, level and intensity of both phenotypic resistance and resistance mechanisms may vary over relatively short distances. Hence, detection of resistance in one area may not necessarily be indicative of the situation throughout the district, region or country. Data on the current malaria situation is important because detected upsurges may highlight areas that require specific attention. Additional informational requirements for updating the vector control strategy or the entomological surveillance plan should also be outlined.

Decision trees or stratifications developed on the basis of WHO technical guidance[8] and information compiled in the situation analysis can be used to support decisions on necessary adjustments to the national malaria strategic plan. At a minimum, these should consider:

- the localized malaria situation;
- current interventions and implementation quality;
- the insecticide resistance profile of the main vector species (including insecticide susceptibility and resistance mechanisms); and
- other entomological information including vector species distribution and bionomics.

Four strategies can theoretically be used to mitigate the impact of resistance: rotation of insecticides, combination of interventions, "mosaic" spraying and use of insecticide mixtures. Rotations using insecticides with different modes of action should be implemented for IRS, ideally with a change every 12 months. Where LLINs are deployed, IRS with a non-pyrethroid can be implemented for resistance management.[9] Where a policy decision is made to switch to an alternative insecticide formulation or to introduce additional formulations, a detailed analysis of the cost implications is required. Where domestic resources are insufficient to fully fund the proposed changes, a resource mobilization strategy and related advocacy plan will need to be developed to support access to external funding sources.

A3.3.2 Regulatory requirements and procedures

- **Describe any regulatory processes to be undertaken for the registration of insecticides not currently registered for public health use in the country.**

In countries without regulatory bodies (e.g. countries emerging from conflict), appropriate regulatory authorities need to be established at the earliest opportunity. Only those products recommended by WHOPES or pre-qualified by WHO[10] should be registered.

A3.3.3 Quality control for vector control products

- **Summarize data from quality monitor of vector control products.**

Judicious use of insecticides is imperative to support insecticide resistance management. Appropriate use and management of insecticidal vector control products can be informed through regular monitoring of product quality. The NMCP, in coordination with the regulatory body, should ensure that all vector control products imported into the country are subjected to quality-control evaluation before shipment or at point of entry, and that there are regular quality-control checks for products already in the country.

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8 Updated or new guidance will be published periodically on the WHO website (www.who.int/malaria; accessed March 2017).

9 IRS may be implemented in areas where there are LLINs as part of an insecticide resistance management strategy. For more information, see WHO (2014) *(3)*.

10 Transition from WHOPES to WHO pre-qualification is underway in 2017, whereby products with a WHOPES recommendation will be reviewed for eligibility for WHO pre-qualification.

A3.3.4. Monitoring of interventions

- **Summarize data on the implementation of vector control interventions that supports evidence-based decision-making on insecticide resistance management.**

The NMCP should establish and implement a plan for strategic monitoring of key intervention parameters during and after their deployment. The monitoring should include assessments of IRS implementation (e.g. the timing of spray rounds in relation to peak malaria transmission, household and population coverage and use, supervisory visit reports and internal or external assessments) and evaluations of residual efficacy. For LLINs, access, coverage and usage should be evaluated periodically through standard surveys, and field durability (including survivorship, fabric integrity and insecticidal activity) should be evaluated using established WHO procedures. Current test procedures for insecticidal vector control products can be found on the WHO website.[11]

Where data are collected by external institutions, they should be reported regularly to the NMCP, and should be considered by the decision-making body in conjunction with entomological and epidemiological information. Standard spreadsheets should be developed to support the data management and reporting process and, where required, a national database should be established.

A3.3.5 Operational research to support IRMMP

- **List priority operational research topics to support vector control planning and implementation in line with the IRMMP.**

The NMCP should work with the relevant partners to generate a list of priority questions related to insecticide resistance monitoring and management that can be addressed through operational research. Outcomes from research conducted by institutes other than the NMCP should be reported to the NMCP periodically, to ensure full awareness of ongoing initiatives and results. The list should be reviewed every 12–24 months to ensure relevance and to update based on changing priorities of the NMCP.

A3.4 Tasks, activities and timelines

- **Establish an overview of the main tasks and their objectives, as well as related activities and timelines.**

This information is best presented in a simple Gantt chart. The chart should include an indication of the institutions (or individuals) responsible for each activity, as shown in Fig. 7. Specific operational plans for each task can be developed, in conjunction with the decision-making body. Expected outcomes from defined activities can also be documented.

11 See http://www.who.int/en/; accessed March 2017.

FIG. 7
Example of a table outlining tasks, objectives, activities, body responsible and timelines

TASK	OBJECTIVES	ACTIVITY	RESPONSIBLE	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
Capacity building	To enable appropriate insecticide resistance monitoring and management through human and infrastructural capacity enhancement	Recruit necessary personnel to fill identified gap	NMCP	x	x																		
		Conduct training of established and new personnel (followed by ongoing mentorship)	NMCP / partners			x				x				x				x				x	
		Improve laboratory and insectary facilitates and procure necessary equipment	NMCP / research institute	x	x											x	x						
Insecticide resistance monitoring	To conduct annual evaluations of insecticide resistance at all sentinel sites to support evidence-based decision-making	Establish sentinel sites	NMCP	x	x																		
		Carry out field collections of larvae (or bloodfed adults as required)	NMCP	x		x		x		x		x		x		x		x		x		x	
		Rear larvae to adult mosquitoes in field insectary	NMCP	x		x		x		x		x		x		x		x		x		x	
		Conduct morphological species identifications (and using other techniques as required)	NMCP / research institute	x		x		x		x		x		x		x		x		x		x	
		Conduct bioassays with discriminating and intensity concentrations	NMCP	x		x		x		x		x		x		x		x		x		x	
		Conduct synergist-insecticide bioassays	NMCP		x		x		x		x		x		x		x		x		x		x
		Enter data electronically into standard spreadsheet	NMCP		x		x		x		x		x		x		x		x		x		x
Quality assurance and control	To conduct periodic evaluations of vector control interventions at selected sites to support evidence-based decision-making	Develop and implement monitoring and evaluation plan for interventions (residual efficacy, durability)	NMCP / partner			x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Conduct monitoring and evaluation activities	NMCP / partner	x		x		x		x		x		x		x		x		x		x	
		Enter data electronically into standard spreadsheet	NMCP / partner		x		x		x		x		x		x		x		x		x		x
Data management and dissemination	To streamline system for reporting of insecticide resistance monitoring as well as quality monitoring data	Develop standard national spreadsheets for data reporting, and disseminate to partners involved in data collection	NMCP / WHO	x																			
		Establish and maintain national insecticide resistance database	NMCP	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

TASK	OBJECTIVES	ACTIVITY	RESPONSIBLE	YEAR 1				YEAR 2				YEAR 3				YEAR 4				YEAR 5			
Data management and dissemination (cont.)	To streamline system for reporting of insecticide resistance monitoring as well as quality monitoring data	Establish and maintain national database for intervention monitoring information	NMCP	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
		Compile available data on insecticide resistance, interventions implementation and quality, and link with epidemiological information	NMCP				x				x				x				x				x
		Report data to WHO and implementing partners	NMCP				x				x				x				x				x
Insecticide resistance management	To leverage available information to tailor vector control interventions to local situation, and communicate outcomes with partners	Convene the body responsible for insecticide resistance management decision-making	NMCP	x	x	x				x				x				x				x	
		Evaluate data to determine impact of resistance management strategies on a) disease outcomes, and b) resistance profiles of local malaria vectors	NMCP / WHO			x				x				x				x				x	
		Generate recommendations for changes in vector control interventions or their implementation based on decision-making framework	Decision-making body			x				x				x				x				x	
		Update national malaria strategic plan as required	NMCP								x								x				
		Implement changes	NMCP					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Coordination	To strengthen collaboration and communication within the health sector and with other sectors (e.g. agriculture, education)	Convene broad stakeholder meeting to report outcomes	NMCP								x				x				x				x
		Actively engage with national regulatory body to identify ways to optimize registration process for vector control products	NMCP			x	x							x	x							x	x
		Engage with partners involved in development of new vector control tools to encourage and support development and registration as appropriate	NMCP / regulatory body	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Operational research	To address gaps in evidence and knowledge on insecticide resistance and its management	Establish or update research agenda for insecticide resistance management	NMCP / research institute			x	x									x	x						
		Collaborate with research institutes as required to evaluate the impact of insecticide resistance and management strategies	NMCP	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

NMCP, national malaria control programme

A3.5 Human resources

- **Detail the overall human resources required to implement the formulated IRMMP.**
- **Identify the existing human resources available and any gaps in numbers of personnel or the requisite skill sets.**
- **Present the proposed source for filling identified gaps, including sources of funding for recruitment of posts, additional training, etc.**

A3.6 Budget and potential sources of funding

- **Include an overall budget for implementation of the proposed IRMMP for the strategic period defined.**[12]

Budgets should include a summary of all requirements, in which will be given in more detail in the annual workplans (see Section B). As shown in Fig. 9, the budget should cover the cost of establishment of sentinel sites, insectary facilities and bioassay laboratories, plus molecular biology laboratories, where appropriate, and the annual costs of:

- conducting laboratory and fieldwork including, for example, the costs of consumables, transport and overheads;
- staffing;
- engaging external institutions to conduct aspects of testing, where appropriate; and
- meetings of the decision-making bodies.

Existing human resources should be deployed to meet the priority needs identified whilst additional resource mobilization is being undertaken. If there is a malaria resource mobilization strategy or plan, this should be referenced. In the absence of such a strategy or plan, consideration should be given to developing one. Advocacy to ensure continued high-level national political commitment and partner commitment should be prioritized.

12 Usually as aligned with the national malaria strategic plan.

FIG. 8

Example of a table to identify human resource requirements and gaps

SPECIFICATIONS			CURRENT PERSONNEL	REQUIRED PERSONNEL		
ADMINISTRATIVE LEVEL	ROLE	MINIMUM QUALIFICATION [a]	TOTAL FOR CURRENT INSECTICIDE RESISTANCE MONITORING AND MANAGEMENT ACTIVITIES, IN FTE	TOTAL REQUIRED FOR IRMMP IMPLEMENTATION, IN FTE	CAPACITY GAP	ESTIMATED COST TO FILL CAPACITY GAP
National	Senior public health entomologist/ senior supervisor	Tertiary postgraduate				
National	Insectary manager/ manager	Tertiary postgraduate				
National	Insectary technician	Tertiary graduate				
National	Laboratory technician	Tertiary graduate				
National	Epidemiologist	Tertiary postgraduate				
National	Statistician	Tertiary postgraduate				
National	Database manager/ GIS specialist	Tertiary postgraduate				
Subnational	Public health entomologist/ supervisor	Tertiary postgraduate				
Subnational	Field personnel/ Environmental health technician	Secondary graduate				
Subnational	Insectary technician	Secondary graduate				
Subnational	Laboratory technician	Secondary graduate				
Subnational	Data entry clerk	Secondary graduate				

FTE, full-time equivalent; GIS, geographic information system; IRMMP, insecticide resistance monitoring and management plan

Notes: [a] Tertiary postgraduate (e.g. PhD or MSc), tertiary graduate (e.g. BSc), secondary graduate (e.g. high school).

Additional rows or columns can be added to the table as required.

FIG. 9
Example of a template for summarizing a multi-year budget

BUDGET LINE	YEAR 1	YEAR 2	YEAR 3	YEAR 4	YEAR 5	TOTAL
Insectary						
Laboratory						
Field						
Data management and dissemination						
Personnel						
Meetings						
Office						
Additional cost for response to resistance						
External testing						
Technical support						

A3.7 Risks and mitigating measures

- **Identify the risks to effective and successful implementation of the national IRMMP, and measures to address these.**

Risks may include lack of sufficient financial, human and logistical resources; limited availability or stock-outs of key laboratory equipment, consumables and reagents; and lack of awareness of or support for the IRMMP from senior management or national and international development partners. The plan must include clear priorities to guide resource allocation. It should also outline measures to mitigate the identified constraints and risks as well as the associated budget for implementing these measures.

A3.8 Annexes

Additional useful information or tools may be included in the annex, such as:

- standard operating procedures for insecticide resistance monitoring;
- field specimen collection record; and
- insecticide susceptibility report form.

SECTION B: ANNUAL WORKPLAN FOR NATIONAL INSECTICIDE RESISTANCE MONITORING AND MANAGEMENT PLAN IMPLEMENTATION

The annual workplan for IRMMP implementation should be a short document that includes a clear definition of the main tasks and associated activities, along with timelines for their implementation for the year. An overview of insecticide resistance monitoring can be included. The overall budget to complete activities defined for the year should be provided. Suggested content is outlined below for annual plans and budgets for implementation of the overall national IRMMP.

B1. Annual tasks, activities and timelines

- **Identify the timelines for the proposed activities, as well as the institutions (or individuals) responsible for the specific actions to be undertaken in the current year.**

Use of a more detailed Gantt chart can help to visualize the workplan activities, resources required, timelines and contingencies, as shown in Fig. 10.

FIG. 10
Example of a spreadsheet of annual workplan activities

ACTIVITY	RESPONSIBLE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Recruit necessary personnel to fill identified gap	NMCP	x	x	x	x	x	x						
Conduct training of established and new personnel (followed by ongoing mentorship)	NMCP / partners							x					
Improve laboratory and insectary facilitates and procure necessary equipment	NMCP / research institute	x	x	x	x	x	x						
Establish sentinel sites	NMCP	x	x	x	x	x	x						
Carry out field collections of larvae (or bloodfed adults as required)	NMCP	x						x					
Rear larvae to adult mosquitoes in field insectary	NMCP	x						x					
Conduct morphological species identifications (and using other techniques as required)	NMCP / research institute	x						x					
Conduct bioassays with discriminating and intensity concentrations	NMCP	x						x					
Conduct synergist-insecticide bioassays	NMCP		x					x					
Enter data electronically into standard spreadsheet	NMCP		x					x					
Develop and implement monitoring and evaluation plan for interventions (residual efficacy, durability)	NMCP / partner							x	x	x	x	x	x
Conduct monitoring and evaluation activities	NMCP / partner												x

ACTIVITY	RESPONSIBLE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Enter data electronically into standard spreadsheet	NMCP / partner												x
Develop standard national spreadsheets for data reporting, and disseminate to partners involved in data collection	NMCP / WHO	x	x										
Establish and maintain national insecticide resistance database	NMCP	x	x	x	x	x	x	x	x	x	x	x	x
Establish and maintain national database for intervention monitoring information	NMCP							x	x	x	x	x	x
Compile available data on insecticide resistance, interventions implementation and quality, and link with epidemiological information	NMCP												x
Report data to WHO and implementing partners	NMCP												x
Convene insecticide decision-making body for resistance management decision-making	NMCP		x					x					x
Evaluate data to determine impact of resistance management strategies on a) disease outcomes, and b) resistance profiles of local malaria vectors	NMCP / WHO												x
Generate recommendations for changes in vector control interventions or their implementation based on decision-making framework	Decision-making body		x					x					x
Update national malaria strategic plan as required	NMCP												x
Implement changes	NMCP												x
Convene broad stakeholder meeting to report outcomes	NMCP												x
Actively engage with national regulatory body to identify ways to optimize registration process for vector control products	NMCP							x	x	x	x	x	x
Engage with partners involved in development of new vector control tools to encourage and support development and registration as appropriate	NMCP / regulatory body	x	x	x	x	x	x	x	x	x	x	x	x
Establish or update research agenda for insecticide resistance management	NMCP / research institute							x	x	x	x	x	x
Collaborate with research institutes as required to evaluate the impact of insecticide resistance and management strategies	NMCP	x	x	x	x	x	x	x	x	x	x	x	x

NMCP, national malaria control programme; WHO, World Health Organization

B1.1 Insecticide resistance monitoring

The IRMMP annual workplan should include a tabular summary of the proposed collection locations, specifications and timing of testing for the 12-month period (as shown in Fig. 11), because this can vary between years, depending on the interventions being used or planned for use. The insecticides to be tested should be listed in order of importance, to guide prioritization in the event that collections yield an insufficient number of mosquitoes to allow full testing.

FIG. 11
Example of a table of locations, test and assay types, priorities and frequencies for insecticide susceptibility tests

LOCALITY NAME	TEST TYPE[a]	ASSAY TYPE[b]	INSECTICIDE AND CONCENTRATION TO BE TESTED, ORDERED BY PRIORITY	MONTH TO BE TESTED (ADD X)											
				JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC

Notes: [a] For example, WHO susceptibility test or CDC bottle bioassay; [b] For example, discriminating concentration or intensity concentration.

Additional rows or columns can be added to the table as required.

B2. Annual budget

- **Outline the annual budget required for implementation of all monitoring activities, such as insectary maintenance, laboratory equipment and consumables, field equipment and activities, and data management and dissemination.**
- **Include anticipated annual cost for any proposed or potential change in vector control strategies for the purposes of insecticide resistance management (e.g. the use of a different insecticide class for IRS).**
- **List training, meetings and additional technical support needed and costs.**

An annual budget template can be established, such as that shown in Fig. 12.

FIG. 12

Example of an annual budget template

ITEM DESCRIPTION			UNITS	UNIT COST	TOTAL
Insectary	Building	Building maintenance			
	Colony rearing equipment	Larval rearing trays			
		Adult mosquito cages			
	Consumables	Water			
		Larval food			
		Blood-meal source (e.g. animal or artificial)			
		Sugar/honey			
		Filter papers			
		Mosquito netting material			
		Cotton wool			
		Pipettes			
		Paper cups			
		Petri dishes			
		Data forms			
	SUBTOTAL				
Laboratory	Building	Building maintenance			
	Fixed equipment	Stereo / compound microscopes			
		Equipment for DNA extraction			
		PCR machines			
		Equipment for gel electrophoresis and imagery system			
		Freezers			
		Centrifuges			
	Other equipment	Insecticide susceptibility test kits			
		Hand-held magnifying glass			
		Forceps			
		Pipettes			
	Consumables	Substrates (detail each)			
		Insecticidal papers			
		Silica gel			
		Specimen tubes			
		Pipette tips			
		Latex gloves			
		Data forms			
		DNA extraction reagents			
		Other biochemistry / molecular work consumables			
	SUBTOTAL				

ITEM DESCRIPTION			UNITS	UNIT COST	TOTAL
Field collections	Transport	Vehicle lease / maintenance			
		Fuel			
		Driver			
	Mosquito collection equipment	Larval dippers / adult aspirators			
		Larval collection vials / adult cages			
		Torches + batteries			
		Forceps			
		Buckets			
		Rubber boots			
		Cool boxes			
	Data-collection tools	Global positioning system units			
		Handheld data entry device			
	Communication	Mobile phones			
		Airtime			
	Consumables	Specimen tubes			
		Silica gel			
		Emergence cups			
		Data forms			
	SUBTOTAL				
Data management and dissemination	Office information technology hardware	Desktop			
		Printer			
	Office information technology software	Data processing software			
		Mapping software			
	National insecticide resistance database	IR database establishment			
		IR database maintenance			
	SUBTOTAL				
Human resources	Senior public health entomologist / senior supervisor	Salary, benefits and overheads			
	Public health entomologist / supervisor	Salary, benefits and overheads			
	Insectary manager / Laboratory manager	Salary, benefits and overheads			
	Insectary technician	Salary, benefits and overheads			
	Laboratory technicians	Salary, benefits and overheads			
	Field personnel / Environmental health technicians	Salary, benefits and overheads			
		Per diems for fieldwork			
	Data entry clerks	Salary, benefits and overheads			
	Epidemiologist	Salary, benefits and overheads			
	Statistician	Salary, benefits and overheads			

ITEM DESCRIPTION			UNITS	UNIT COST	TOTAL
Human resources	Database manager / GIS specialist	Salary, benefits and overheads			
	Training courses	Field collection techniques and mosquito identification			
		Insectary management and mosquito rearing			
		Laboratory management, insecticide susceptibility testing, resistance mechanisms testing			
		Insecticide resistance management (including sound management of public health pesticides)			
		Other as needed (e.g. data management, GIS, programme management)			
	SUBTOTAL				
Meetings	Meetings of decision-making body	First meeting, quarter 2			
		Second meeting, quarter 4			
	SUBTOTAL				
Office	Overheads	Administration feeds, maintenance, electricity, water			
	Stationery	Paper, pens, photocopying			
	Communication	Internet, phone			
	SUBTOTAL				
Additional cost for response to resistance	Commodities	Alternative or additional formulation			
	Implementation	Training			
		Equipment			
	SUBTOTAL				
External testing	Specimen assessments by external institution	Testing services			
	SUBTOTAL				
Technical support	Specialist assistance	Consultants			
	SUBTOTAL				
TOTAL					

DNA, deoxyribonucleic acid; GIS, geographic information system; IR, insecticide resistance; PCR, polymerase chain reaction

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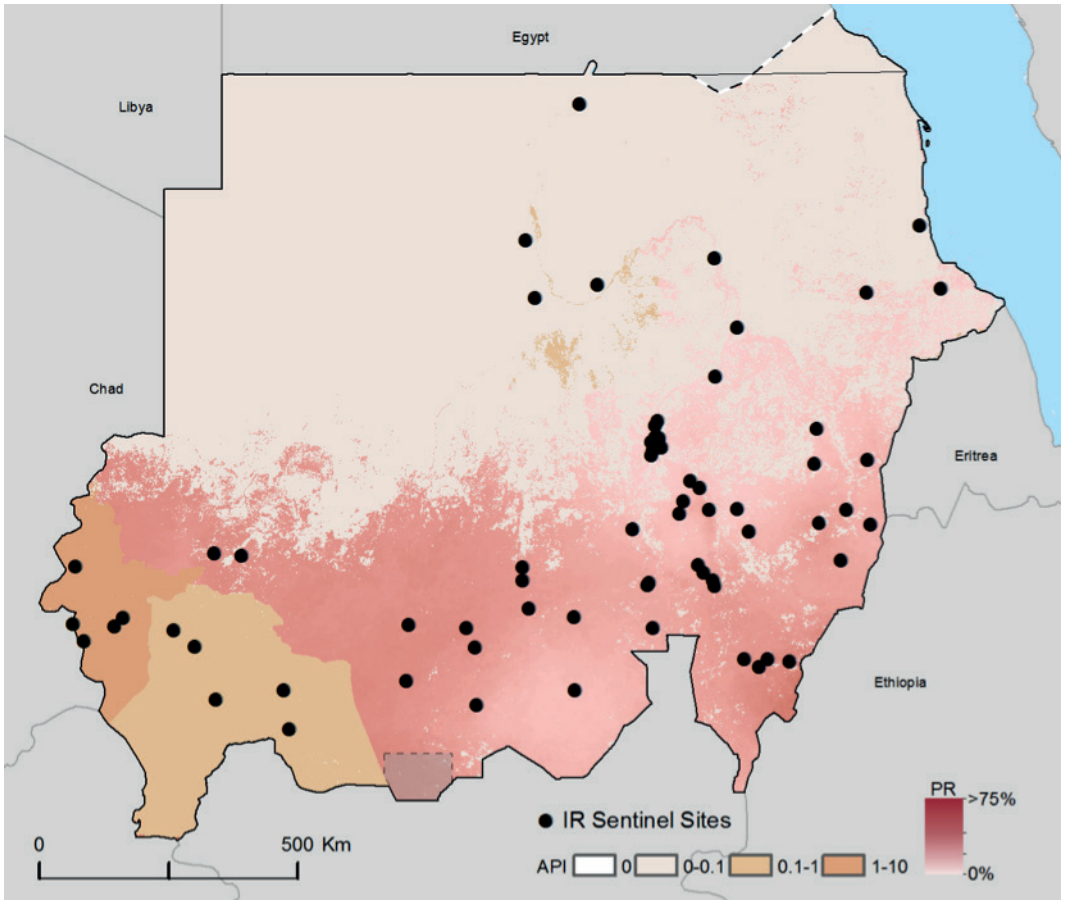
ANNEX 1. EXAMPLE OF INSECTICIDE SUSCEPTIBILITY SENTINEL SITES IN SUDAN

FIG. A.1

Geographical location of sentinel sites for insecticide resistance (IR) monitoring in Sudan. Sentinel site locations are overlaid on a map of spatial distribution of annual parasite incidence (API) or combined *Plasmodium falciparum* and *P. vivax* malaria prevalence (PR) within the limits of stable transmission.



Criteria used for sentinel site selection in Sudan:

1. Level of malaria endemicity
2. Quantity and type of insecticides used for both public health and agricultural pest control
3. Existence of agricultural schemes and type of irrigation activities practised
4. Human settlement (urban or rural)
5. Availability and abundance of mosquito larval habitats
6. Abundance (or fluctuation) of malaria vectors
7. Accessibility

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