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This manual aims to fill the gap that currently exists in the availability of technical and practical information related to the current scaling up of IRS for malaria control and elimination. It brings together the knowledge of a number of senior contributors with decades of field work behind them, and supplements this with peer reviews from an extensive list of distinguished contributors and collaborators. Though comprehensive, this manual is not intended to replace field expertise in IRS. It has been created to enhance existing knowledge and skills, and to assist malaria programme managers, entomologists and vector control and public health officers to design, implement and sustain high quality IRS programmes.
### Abbreviations

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ai</td>
<td>Active ingredient</td>
</tr>
<tr>
<td>AMI</td>
<td>Annual malaria incidence</td>
</tr>
<tr>
<td>API</td>
<td>Annual parasite incidence</td>
</tr>
<tr>
<td>ACT</td>
<td>Artemisin-based combination therapy</td>
</tr>
<tr>
<td>CS</td>
<td>Capsulated suspension</td>
</tr>
<tr>
<td>EC</td>
<td>Emulsifiable concentrate</td>
</tr>
<tr>
<td>EIR</td>
<td>Entomological inoculation rate</td>
</tr>
<tr>
<td>DDT</td>
<td>Dichloro-diphenyl-trichloroethane</td>
</tr>
<tr>
<td>DHS</td>
<td>Demographic and health survey</td>
</tr>
<tr>
<td>GMP</td>
<td>Global Malaria Programme</td>
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<tr>
<td>GMAP</td>
<td>Global Malaria Action Plan</td>
</tr>
<tr>
<td>GPIRM</td>
<td>Global Plan for Insecticide Resistance Management in malaria vectors</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic information system</td>
</tr>
<tr>
<td>GR</td>
<td>Geographical reconnaissance</td>
</tr>
<tr>
<td>ITN</td>
<td>Insecticide treated mosquito net</td>
</tr>
<tr>
<td>IRS</td>
<td>Indoor residual spraying</td>
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<tr>
<td>IEC</td>
<td>Information, education and communication</td>
</tr>
<tr>
<td>IVM</td>
<td>Integrated vector management</td>
</tr>
<tr>
<td>KABP</td>
<td>Knowledge, attitude, behaviour and practice</td>
</tr>
<tr>
<td>LSM</td>
<td>Larval source management</td>
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<tr>
<td>LLIN</td>
<td>Long-lasting insecticidal net</td>
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<tr>
<td>M&amp;E</td>
<td>Monitoring and evaluation</td>
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<tr>
<td>MDG</td>
<td>Millennium Development Goal</td>
</tr>
<tr>
<td>PCR</td>
<td>Polymerase chain reaction</td>
</tr>
<tr>
<td>PDA</td>
<td>Personal digital assistant</td>
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<tr>
<td>PP</td>
<td>Parasite prevalence</td>
</tr>
<tr>
<td>POA</td>
<td>Plan of action</td>
</tr>
<tr>
<td>RBM</td>
<td>Roll Back Malaria Partnership</td>
</tr>
<tr>
<td>RDT</td>
<td>Rapid diagnostic test</td>
</tr>
<tr>
<td>SC</td>
<td>Suspension concentrates/flowable concentrates</td>
</tr>
<tr>
<td>TOT</td>
<td>Training of trainers</td>
</tr>
<tr>
<td>WG</td>
<td>Water dispersible granules</td>
</tr>
<tr>
<td>WP</td>
<td>Wettable powder</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
</tr>
<tr>
<td>WHOPES</td>
<td>WHO Pesticide Evaluation Scheme</td>
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</table>
CHAPTER 1

Indoor Residual Spraying (IRS) Policy and Strategy
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1.1 Introduction

Vector control is the key intervention for global malaria control and elimination efforts. It is critical for the reduction and, ultimately, for the interruption of malaria transmission. Currently, the two most common vector control interventions are long-lasting insecticidal nets (LLINs) and Indoor Residual Spraying (IRS). Together these account for almost 60% of global investment in malaria control (1).

The number of LLINs delivered by manufacturers has increased dramatically in recent years, rising from 5.6 million in 2004 to 145 million in 2010 in sub-Saharan Africa. Nearly 300 million LLINs were delivered to African countries between 2008 and the end of 2010. Meanwhile, the number of people protected by IRS in the WHO African Region increased from 10 million in 2005 to 78 million in 2010. In total, 185 million people were protected by IRS in 2010, representing 6% of the global population at risk (2).

These investments are now demonstrating returns. During the past decade, malaria mortality rates have declined by 25% globally, and by more than 33% in the WHO African Region. But the estimated number of deaths worldwide is still too high for a disease that is entirely preventable and treatable. In 2010 there were an estimated 660,000 deaths (range 490,000–836,000) from malaria. An estimated 81% of cases and 91% of these deaths occurred in the WHO African Region and, globally, 86% of the victims were children under 5 years of age. In the same year an estimated 219 million cases of malaria (range 154–289 million) occurred in 99 countries and territories around the world.

IRS can contribute to the elimination of malaria if rigorously applied. Historically, IRS was largely responsible for the tremendous accomplishments of malaria programmes in Europe, Asia and the Americas that resulted in hundreds of millions of lives being saved between the 1940s and the 1980s. More recently, the scale-up of IRS in Africa has contributed, together with LLINs and improved diagnostic testing and treatment, to remarkable declines in malaria burden and all-cause childhood mortality. IRS is highly effective when properly applied, but it requires national programme capacity, structures, and systems.

The IRS Management Cycle, described in greater detail below, requires detailed and rigorous planning, management and supervision. It also has a significant entomological and epidemiological monitoring component. The basic techniques, i.e. how one plans and implements a spray campaign, have remained more or less the same for decades. However, the strategy around IRS management and the context in which it is deployed has changed tremendously in recent years. These changes include: the role of IRS in the context of universal LLIN coverage; the role of IRS in insecticide resistance management; and the reorientation of many national malaria control programmes towards an integrated vector management (IVM) approach.

Effective IRS operations require:

- adequate political commitment and social acceptance of IRS;
- adequate programme and health system capacity to deliver good-quality, well-timed and high-coverage IRS;
- adequate information on local vectors, especially insecticide susceptibility status and indoor versus outdoor feeding and resting behaviours; and
- adequate and sustainable financial, logistical and human resources.

Use of the manual

The purpose of this manual is to provide up-to-date information on IRS operations, to outline current WHO standards on IRS intervention, and to offer step-by-step guidance on the overall
management of an IRS programme together with practical steps on household spray application. This manual will enable national programmes to:

- develop or refine policies and strategies
- develop or update existing guidelines
- develop or update existing training materials
- review access and coverage of IRS programmes
- review the quality and impact of IRS programmes.

This manual is designed to focus on the management of a safe and effective IRS programme and to help managers and policy makers make the most effective possible use of an IRS strategy within the context of a comprehensive malaria control programme.

The manual is divided into three chapters:

1) IRS policy, strategy and standards for national policy makers and programme managers;
2) IRS management, including stewardship and safe use of insecticides, for both national programme managers and district IRS coordinators;
3) IRS spray application guidelines, primarily for district IRS coordinators, supervisors and team leaders.

To maximize its impact, it is recommended that the manual be translated into other languages relevant to malaria endemic countries.

1.2 Defining IRS

Indoor Residual Spraying (IRS) is the application of a long-lasting, residual insecticide to potential malaria vector resting surfaces such as internal walls, eaves, and ceilings of all houses or structures (including domestic animal shelters) where such malaria vectors might come into contact with the insecticide.

IRS, carried out correctly, is a powerful intervention to rapidly reduce adult mosquito vector density and longevity and, therefore, to reduce malaria transmission. The effectiveness of IRS as a malaria control intervention arises from the fact that many important malaria vectors are endophilic. That is, when searching for blood meals they enter human habitations or animal shelters where they rest on the walls, ceilings and other interior surfaces before and/or after feeding on the inhabitants. When a vector comes into contact with a sprayed surface, it absorbs lethal doses of insecticide, thereby reducing its lifespan. This results in a progressive decline in vector density and longevity, especially among older female mosquitoes, reduces overall vectorial capacity, and contributes to a reduction in malaria transmission. IRS is most effective against indoor feeding (endophagic) and indoor resting (endophilic) vectors.

One significant difference between the use of IRS and the use of treated mosquito nets is the point at which each intervention works to greatest effect. IRS may provide some small amount of individual house protection by repelling and reducing the number of vectors that come into a house. However, the greatest impact of an IRS intervention takes place after feeding when the anopheline mosquito is more likely to rest on a sprayed surface and pick up a lethal dose of insecticide, thus preventing her from going on to transmit the malaria parasite to others in the vicinity. This means that for IRS to be effective, there must be high coverage of all structures that are potential resting places in order to obtain the “mass effect” on the vector population: in other words, being the only sprayed house in the neighbourhood will do little to protect the

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1 Endophilic: tends to rest indoors. Exophilic: tends to rest outdoors.
Endophagic: tends to bite indoors. Exophagic: tends to bite outdoors.
2 “high coverage” is common usage meaning that a high proportion, over 85%, of the structures in a targeted area has been sprayed.
inhabitants. LLINs, however, inhibit feeding before the mosquito can inoculate the person with sporozoites as well as having a degree of lethal effect on the vector. This provides both personal protection and, at high coverage rates, a “mass effect” on the vector population. Therefore, being the only house in the neighbourhood with inhabitants sleeping under a treated net will provide some degree of protection, even if the neighbours are not covered.

1.2.1 IRS in the context of integrated vector management (IVM)

National ministries of health and their partners, including private-sector workplace protection programmes, should plan IRS in the context of a broader malaria control effort. The approach should be adapted to the specific challenges and opportunities presented by their individual ecological situation and within the context of their own national malaria control programmes. IVM provides a framework within which these strategic challenges and opportunities can be addressed.

IVM is defined as “a rational decision-making process for the optimal use of resources for vector control” (3). The approach seeks to improve the efficacy, cost-effectiveness, ecological soundness and sustainability of disease-vector control. IVM is not simply throwing multiple interventions together, nor is it a separate programme. Rather, IVM is a management approach that enables vector control efforts to be adapted, broadened, optimally deployed and sustained.

The Global Strategic Framework for IVM identifies five key elements for successful implementation. These are listed in Table 1 below, with examples of how these can frame the IRS programme strategy.

1.2.2 IRS and insecticide resistance management

Insecticide resistance is emerging as a major challenge to global malaria control efforts, especially in Africa. WHO and its partners have developed a Global Plan for Insecticide Resistance Management (GPIRM) (4) that should form the basis of any national vector control strategy, including the use of IRS. Fundamental to this plan is the building of capacity and systems for basic epidemiological and entomological monitoring, including bioassays for insecticide susceptibility of the local vector populations. This information, together with information on local transmission ecology and epidemiology, e.g. length of transmission season and levels of transmission, will determine the appropriate selection of insecticides in order to mitigate or delay the further development of resistance. This is particularly important for the pyrethroids, the only class of insecticide that can be used on nets. As outlined in the GPIRM, pyrethroids need to be ‘protected’ through judicious use and through rotation amongst the four classes of insecticides that can be used for IRS.

1.2.3 IRS combined with long-lasting insecticidal nets (LLINs)

Generally, the resources available for vector control are not adequate to justify the routine combining of IRS with LLINs. However, there are specific situations in which such combinations may be justified for targeted areas. National malaria programmes may consider using an IRS/LLIN combination for the following purposes.

■ As a response to identified pyrethroid resistance in settings where LLINs remain the dominant vector control method. In such cases, as outlined in the GPIRM, focal IRS with a non-pyrethroid insecticide should be introduced, preferably through annual rotations. Best practice is to do this in all areas of resistance; good practice is to do it at least in the areas of greatest concern.

■ As a means to achieve additional epidemiological impact. Data from both cross-sectional surveys (5) and prospective cohort studies have indicated an additive benefit of combining IRS with
### TABLE 1
Applying IRS within the IVM framework

<table>
<thead>
<tr>
<th>IVM ELEMENT</th>
<th>APPLICATION TO IRS OPERATIONS</th>
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| Advocacy, social mobilization and legislation | - ensure adequate, up-to-date national insecticide and application equipment legislation & regulatory mechanisms to ensure safe and judicious use;  
- if possible, coordinate with the ministry of agriculture on the use of pesticides, especially on those with similar mode of action as those used in IRS, e.g. pyrethroids;  
- reduce taxes and tariffs on commodities used for IRS;  
- ensure that IRS advocacy and communications effectively target policy makers, implementers, communities and other stakeholders. |
| Collaboration within the health sector and with other sectors | - establish partnerships with private-sector IRS operations for joint training, entomological monitoring and insecticide selection;  
- establish technical support linkages with insecticide and application equipment manufacturers and distributors;  
- establish partnerships with the ministry of agriculture and ministry of environment for supervision and pesticide management. |
| Capacity building | - identify the range of skills/competencies and staffing levels necessary for effective IRS operations;  
- ensure adequate human resource capacity by establishing training for spray operators, warehouse managers, and for entomological and epidemiological monitoring;  
- establish requisite infrastructure for IRS including insectaries, entomology labs, warehouses, and waste disposal systems;  
- establish IRS recording and reporting methods and procedures as well as vector control information systems. |
| Evidence-based decision-making | - clarify information needs, IRS indicators and data collection methods;  
- establish entomological and epidemiological monitoring plans to help target and evaluate interventions;  
- select insecticides based on local data regarding vector susceptibility and transmission ecology, especially with regards to the duration of malaria transmission seasons;  
- ensure insecticide selection is based on an insecticide resistance management plan as outlined in the Global Plan for Insecticide Resistance Management (GPIRM);  
- ensure IRS and vector data collection are completed in a timely and rigorous manner;  
- manage and utilize evidence for decisions on IRS implementation and strategy refinement, including annual reassessment of targeted spray areas. |
| Integrated approach | - ensure there is adequate, evidence-based guidance on combining IRS with LLINs and other malaria control interventions;  
- evaluate whether IRS is having an impact on other vector-borne diseases;  
- explore additional complementary malaria vector control measures where they may be appropriate. |

LLINs (6). Additionally, experimental hut studies indicate overall mortality rates of mosquitoes are significantly higher with such combination treatments than with either intervention alone (7). The question for programmes is cost: is the incremental benefit of the combination worth the additional cost of investing in both interventions in the same community?

**As a ‘safety net’ for IRS programmes in highly endemic areas.** Programmes may consider introducing LLINs as an adjunct to IRS in highly endemic areas to guard against a sudden collapse in vector control. While IRS can quickly decrease malaria transmission, it consequently decreases protective immunity in the population, placing individuals at risk if IRS operations were to suddenly stop. A sudden halt to IRS could be due to problems associated with insecticide procurement, labour costs, fuel and transport problems or social instability. In such cases, the sudden interruption of IRS operations may result in a rebound in the vector population and in malaria transmission, leading to a potential upsurge of malaria in the community with significant adult illness and deaths.
As a transition strategy, it is difficult to estimate how many IRS rounds will be needed before an area can transition or “graduate” to a strategy of continued high LLIN use, a robust epidemiological surveillance system and limited focal spraying for remaining pockets of transmission. This “road to elimination” is outlined in a number of WHO manuals (8).

1.2.4 IRS combined with larval source management (LSM)

Larval source management (LSM) for management control is not applicable across many ecological and programme situations and should be approached judiciously with appropriate entomological and epidemiological monitoring capacity and infrastructure in place. Larviciding should be rigorously evaluated to ensure appropriate and good quality products are being used, and that it is being deployed where it can have the maximum impact on transmission. There may, however, be specific situations, where the vector breeding sites are few, fixed and findable, where LSM could be considered as an adjunct to the IRS programme as outlined in the WHO position statement on larviciding (9).

1.3 Objectives and outcomes of IRS

1.3.1 Objectives of IRS

The objectives of IRS are to reduce, and ultimately interrupt, malaria transmission by reducing vector survivorship, density and human-vector contact, in a manner that is safe for human health and not harmful to the environment. Specific objectives are the following.

- **To reduce the vector’s life span** to less than the time it takes for the malaria sporozoites to develop. In this way the vector can no longer transmit malaria parasites from one person to another.
- **To reduce vector density** by immediate killing. In some situations, particularly with *Anopheles funestus*, IRS can lead to the local elimination of important malaria vectors.
- **To reduce human-vector contact** through repellent effect, thereby reducing the number of mosquitoes that enter sprayed rooms.

1.3.2 Outcomes of IRS

IRS, when applied properly, is a powerful malaria vector control intervention, rapidly reducing vector transmission capacity and malaria incidence. IRS provides maximum mass effect on the vector populations at high coverage levels.

1.4 Selection of areas for IRS

The selection of areas for IRS must take into account the relationship between the vector, humans and the environment, as well as the level of disease transmission in the area under consideration.

Applying IRS in a targeted manner is critical, and programme managers will need to make strategic decisions about where IRS should be deployed in relation to transmission ecology, malaria endemicity, cost, and logistics. The possibility of combining the intervention with other vector control measures, especially LLINs, will also have to be considered.

- In low and moderate transmission areas, IRS is used as a primary vector control intervention to reduce the seasonal annual peaks of malaria transmission, to prevent epidemics and to support malaria elimination.
- In high transmission areas, IRS can be used to rapidly bring down malaria transmission to a level that can subsequently be sustained through a high proportion of the population using LLINs.
In areas of significant economic importance, e.g. areas with large development projects such as industries, oil refineries, mines, irrigation and agro-forestry schemes, targeted IRS can be carried out to mitigate the impact of malaria on economic development.

While IRS has been used in some urban situations, under any circumstances it is important to take into account the biting behaviour of the vector and the actual level of malaria transmission relative to the costs of spraying a large number of structures.

Before the era of treated mosquito nets and improved diagnostics and mapping, malaria eradication strategies recommended IRS in all areas with an annual parasite incidence (API) of greater than 5/1000 and parasite prevalence (PP) greater than 1%. As malaria transmission was reduced, IRS became more selective and only targeted areas with an API of more than 2/1000. The current malaria elimination strategy, however, does not provide an absolute API or prevalence threshold above which IRS should be implemented and below which it should be halted. The decision to halt IRS in a particular area and “graduate” to a more surveillance-driven programme is context-specific and depends upon: the malaria situation and the objective of IRS, i.e. whether it is intended to eliminate malaria or reduce transmission; the receptivity and vulnerability of the various transmission foci; the sensitivity of the surveillance system to detect cases; and the flexibility of the control programme to respond to a reintroduction of cases. The API figures provided in Table 2 below can serve only as a general guide, with the final decision on whether to deploy or withdraw IRS dependent on a number of other factors outlined below.

The following determinants should be considered when selecting where to implement IRS:

- entomological
- epidemiological
- ecological
- environmental
- demographic and socio-economic
- health service.

1.4.1 Entomological determinants

The key entomological determinants are:

- vector species
- seasonal density and distribution of the vector(s)
- resting and feeding behaviour of the vector(s)
- insecticide susceptibility status.

A preliminary study must be carried out to identify the primary and secondary (if any) vector species responsible for malaria transmission in a given area. It is important to remember that vector genetic diversity may coincide with important biological characteristics such as insecticide resistance. Seasonal changes in vector density and transmission potential need to be established so that IRS is applied before the peak transmission period that usually occurs before the onset of the rains.

Accurate information regarding the resting and feeding behaviour of the local vectors must be gathered and fully documented before selecting IRS as an intervention.

A basic entomological monitoring plan must be established. Basic entomological indicators and methods of assessment and training materials are available from WHO and can be found on the Global Malaria Programme (GMP) website. In addition to vector identification, feeding and resting behaviors and insecticide susceptibility status, programmes should also monitor the duration and effectiveness of IRS application. Currently this is done through the standard WHO “Cone bioassay”; new colormetric assays that do not require a colony of susceptible mosquitoes are currently under development.
Insecticide resistance is the most critical challenge currently facing global malaria vector control efforts, and is central to the planning and implementation of an effective IRS programme. As outlined in the GPIRM, the insecticide resistance status of the local vectors must be determined before selecting the insecticides to be used in the IRS programme.

IRS is very effective in areas where the vectors have a strong preference for feeding and resting indoors (i.e. are endophagic and endophilic). Some vectors that feed indoors but tend to rest outdoors (exophilic) can also be controlled if they rest, even very briefly, after feeding and before exiting the house. Likewise, there are situations where the human population tends to sleep outdoors at night, but where the vector rests indoors during the day in houses or cattle sheds, and can thus be controlled by IRS. There are however, some situations where the vector is strongly exophagic and exophilic, both feeding and resting outdoors, and rarely comes into contact with an indoor wall surface. In these cases IRS may not be suitable.

1.4.2 Epidemiological determinants

The key indicators of malaria endemicity are:

- Parasite prevalence (PP) – gathered through cross-sectional population-based surveys;
- Parasite incidence – usually gathered passively through facility-based records and calculated monthly or annually. Traditionally this has been expressed as the annual parasite incidence (API), and calculated as the number of new parasitologically confirmed cases per thousand population per year (10).

Malaria transmission and epidemiology vary both within and between countries. Different areas may require different interventions or combinations of interventions. IRS can be implemented in all eco-epidemiological settings as long as conditions for effective implementation and maintenance of the programme are met. However, shorter transmission seasons (where insecticides with shorter residual efficacy can be used) and more densely spaced housing (where transportation needs are less) favour IRS. Areas with perennial transmission (where two rounds of spray per year may be required) and widely dispersed housing (where transportation and labour costs will be higher) may favour the use of LLINs. IRS programmes in different epidemiological settings can have different objectives, including the following:

- in unstable and seasonal transmission areas – to eliminate or reduce the seasonal peak, prevent epidemics and, if detected at an early stage, to control epidemics;
- in perennial transmission areas with distinct seasonal increase – to suppress seasonal peaks, and to reduce overall malaria transmission;
- in stable and perennial transmission areas – to reduce transmission rapidly, generally followed by sustained vector control through the use of LLINs.

In all settings, vector control must be combined with diagnostic and treatment services as outlined by WHO in its T3: Test. Treat. Track Initiative (11). Malaria-endemic countries should ensure that every suspected malaria case is tested, that every confirmed case is treated with a quality-assured antimalarial medicine, and that the disease is tracked through timely and accurate surveillance systems to guide policy and operational decisions.

In the “attack phase” of malaria control, as programmes scale up coverage to all malaria risk populations, IRS is conducted in targeted areas, usually for a period of three to five years. In the consolidation phase, maintenance phase, pre-elimination and elimination phases, IRS is used more selectively, based on malaria surveillance, and is targeted towards locations where there are residual malaria foci and towards areas where there is re-establishment or a resurgence of transmission.

In countries where IRS has not been implemented, pilot implementation should generally precede the attack phase (Table 2).
TABLE 2
IRS in phases of malaria control and elimination

<table>
<thead>
<tr>
<th>PHASE</th>
<th>ACTIVITIES</th>
<th>TRANSMISSION</th>
<th>IRS OPERATIONS</th>
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</thead>
<tbody>
<tr>
<td>Preparatory Phase</td>
<td>1. survey (geographical reconnaissance [GR],</td>
<td>API &gt;5/1000</td>
<td>pilot IRS operations in selected</td>
</tr>
<tr>
<td></td>
<td>mapping, epidemiological, entomological)</td>
<td>PP &gt; 1%</td>
<td>areas</td>
</tr>
<tr>
<td></td>
<td>2. planning, organization, legislation, training</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>and public education</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Attack Phase</td>
<td>1. surveillance and repeated surveys with</td>
<td>API &gt;5/1000</td>
<td>total coverage IRS of all malaria</td>
</tr>
<tr>
<td></td>
<td>generalized attack operations in all malaria</td>
<td>PP &gt; 1%</td>
<td>risk areas for 3–5 years</td>
</tr>
<tr>
<td></td>
<td>areas</td>
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</tr>
<tr>
<td></td>
<td>2. evaluation of operations</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3. update GR and mapping</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consolidation Phase</td>
<td>1. surveillance for three years</td>
<td>API &lt;5/1000</td>
<td>targeted IRS operations</td>
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<tr>
<td></td>
<td></td>
<td>PP &lt; 1%</td>
<td></td>
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<tr>
<td></td>
<td>2. update GR and mapping</td>
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<tr>
<td>Maintenance Phase</td>
<td>1. surveillance</td>
<td>sporadic cases</td>
<td>focal IRS operations</td>
</tr>
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<td></td>
<td>2. update GR and mapping</td>
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</table>

1.4.3 Ecological determinants
There are a number of variables, which largely determine the intensity of malaria transmission. These variables, which include topography, altitude, presence of permanent water bodies, temperature, humidity (wet, dry and winter seasons), and rainfall (duration and intensity) have an impact on vector bionomics and transmission dynamics.

1.4.4 Environmental safety determinants
Programmes should only use WHOPES-approved chemicals and application equipment for IRS and these should comply with national and international regulatory and environmental safety standards. Detailed guides for good pesticide management, including procurement, quality control, transport, storage, use and disposal are available from WHO (12).

Agricultural practices, including certification for organic farming, export of pesticide-free crops, or practices such as silk-worm cultivation in Asia, need to be taken into account when selecting areas for IRS.

Consulting and achieving consensus with environmental agencies and agricultural ministries is vital. Many countries, programmes and implementing partners require environmental safety reviews to be carried out to ensure safe pesticide management and delivery of IRS. Programmes must ensure they comply with specific standards and procedures for pesticide storage, delivery, usage, stock control, recording and reporting.

1.4.5 Demographic and socio-economic determinants
When selecting which zones are to be sprayed, population number, density and ease of access need to be taken into account. Poor or non-existent roads, widely dispersed housing, or the presence of physical barriers, such as rivers and mountains can be major obstacles for spray teams trying to reach all settlements.

In order for IRS programmes to be successful, target structures must have suitable surfaces for treatment and the correct insecticide formulations for those surfaces must be selected. Traditional housing made of mud, clay or wood requires different chemicals or formulations from modern houses that are made of brick or concrete and are usually painted. Total spraying of all suitable surfaces is required.
Settled populations that remain in one location for a good part of the year are more accessible than nomadic or mobile populations who migrate seasonally to fields or forests. The movements of people in and out of sprayed areas for the purpose of planting, harvesting, cattle grazing and other seasonal activities, can result in temporary shelters being left unsprayed. These require special repeated follow up (mop up) spraying. “Incomplete Houses” also pose a challenge for IRS as do those that are structurally “open” with few walls.

Social factors, such as the willingness of a community to accept IRS services and to cooperate with a spraying programme, are of critical importance when selecting areas for IRS. Sometimes households are receptive to IRS in the early stages when malaria and intense mosquito biting are perceived as problematic, but are less receptive when transmission has been reduced but not yet eliminated.

Cultural patterns in relation to housing must be considered. In some communities, outdoor sleeping is common in the hot and humid season, a time when mosquitoes are also abundant and active. Individual householders may re-plaster or whitewash walls, or re-thatch ceilings after spraying, thereby reducing vector exposure to the insecticide and making repeat spraying a necessity.

Areas of economic importance, such as irrigation schemes, mines and tourism centres are a priority for IRS. High population density and economic viability mean they are priorities for protection from malaria. In addition, the populations that live in these areas usually comprise a mix of migrant workers from areas with different levels of malaria endemicity and immunity, including malaria-free areas. Such a mix creates situations conducive to epidemics.

IRS is also an appropriate vector control method for the protection of camps for displaced persons or refugees, migrants, military and sometimes construction camps. More information on malaria and vector control for refugee camps is available from WHO (13).

### 1.4.6 Health services determinants

Adequate health service capacity is important for the successful establishment of IRS programmes and it is necessary to assess the status of the following elements:

- health policies to support vector control with IRS;
- health system organization at district, regional and national level to support an IRS programme;
- health financing for annual insecticides, equipment, transport and operational costs;
- human resources capacity in vector control and entomology for planning and managing an IRS programme.

Ideally, IRS programmes are based on national financing and capacity building, with the aim of long-term sustainability. The long term costs of insecticides, spray application equipment, permanent IRS staff including operations managers, field supervisors and seasonal temporary spray operators, as well as an annual operational budget, need to be estimated and planned for. Costs should be estimated both for initial pilot districts and for rapid roll out to cover all risk districts targeted for IRS.

The cost-benefit analysis of IRS is also an important determinate. Programmes must make rational resource allocation decisions for the location and size of IRS operations in relation to other programme activities. Examples of IRS cost components (e.g. equipment, insecticides, labour, and operations) for a number of both large (above 150,000 houses) and small (below 150,000 houses) target areas are available (14).
1.5 When to use IRS

The timing of IRS applications, or “rounds”, is a critical factor for a successful programme. Best practice is to schedule the completion of spray application to coincide with the build-up of vector populations just before the onset of the peak transmission season. This ensures fresh deposits of insecticides during periods of peak mosquito density. It is usually not operationally feasible to conduct more than two rounds of IRS in one year; ideally areas that can be protected with a single round of IRS per year are chosen. With timely, good quality spraying, most recommended insecticides (particularly pyrethroids, a new organophosphate formulation, and DDT) are effective for six months or longer. With these insecticides, in the correct formulations, one round of effective spraying may be adequate to control malaria in most areas.

In summary IRS is appropriate:

- where the majority of the vector population feeds and rests inside houses;
- where the vectors are susceptible to the insecticide in use;
- where people mainly sleep indoors at night;
- where the malaria transmission pattern is such that the population can be protected by one or two rounds of IRS per year;
- where the majority of structures are suitable for spraying;
- where structures are not scattered over a wide area, resulting in high transportation costs.
References and web links


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2.1 Introduction

Timely and good quality delivery of IRS operations depends on strong programme leadership and a well-monitored management system. This includes collection of baseline information, detailed proposal development, thorough planning, rigorous implementation, strict supervision, careful monitoring and evaluation, and reporting. The planning and management cycle must take into account current epidemiological and entomological conditions. These should be reviewed annually and IRS strategy adapted and optimized according to changing conditions.

Successful IRS campaigns require a high level of political commitment, dedicated human, logistic, transport and financial resources, and adequate organizational and planning capacity. In order to deliver IRS effectively, temporary field staff must be recruited, trained, motivated and retained; they also require back-up and supervision. While the spraying itself can be delivered by semi-skilled but dedicated temporary field staff, the programme requires a well-trained core of skilled environmental or public health officers, field entomologists and epidemiologists, supported by programme managers. Timeliness is a key factor in obtaining maximum benefits from IRS, i.e. the spray should be applied in the shortest period of time just prior to the onset of the transmission season.

Community awareness and support are other critical factors that influence the effectiveness of IRS programmes. To ensure that IRS is accepted by the local population, which contributes to obtaining a high level of coverage, community education and communication campaigns must be implemented. Households should be well-informed about the programme and aware of its benefits.

When introducing IRS in a country for the first time, it is best to start with one pilot area and then to expand the intervention out to other districts in each region or province. IRS should be started on a small scale, with measured annual increases allowing programmes to gain experience in developing the necessary operational capacities, infrastructure and systems for an efficient operation.

As there is a shortage of field-experienced IRS coordinators and supervisors, it is advisable when starting a new IRS programme to seek technical assistance from well-established programmes in other countries, or to engage private-sector expertise. As pilot districts scale up, IRS coordinators and supervisors will be able to support more districts in the planning and implementation of IRS.

In countries where IRS operations are ongoing, the focus should be on improving quality before any scale-up of coverage is considered. This should be accomplished through post-spray season reviews, which analyse timing of implementation, coverage, quality, and impact on the disease. The information generated in a post-season review provides essential lessons for adapting and improving planning and management for the next season’s spray operations.

2.2 Gathering baseline information

Baseline epidemiological, entomological and demographic data need to be assembled from desk reviews of health facility surveillance reports and from research studies and survey reports. This information should be regularly updated through rapid field assessments and geographical reconnaissance (GR).

2.2.1 Epidemiological baseline survey

Routine malaria surveillance data from health facilities should be accessed and tabulated by unit, by sub-district and by district based on monthly and annual figures. Annual parasite incidence (API) and malaria mortality rates should be calculated both in total and by age group with slide
positivity rates (or test positivity rates if the programme is using rapid diagnostic tests [RDTs]).
Where feasible, and where sufficient financial and human resources are available, passive facility-based incidence data can be complemented by a community-based malaria prevalence survey.

Collection and analysis of parasitologically-confirmed, facility-based malaria incidence data, complemented by community-based prevalence data when available, enables the district IRS coordinators to stratify their areas of operation by level of intensity of transmission. The epidemiological data should be correlated with the meteorological data, especially rainfall, for the previous two to three years. This will also provide guidance for prioritizing and limiting areas to spray, identifying the best months for spraying and the number and timing of spray cycles required. Thresholds for stratification are set by the individual country based on epidemiology, geography, cost and available budgets. A key consideration is what is logistically practical. The thresholds and stratification are reviewed annually based on the latest data and feedback from the field.

Health facility incidence data and community-based prevalence data will also form the baseline from which the impact of IRS can be monitored and evaluated (1).

2.2.2 Entomological (vector) baseline survey

Entomological surveys provide essential information regarding the presence, distribution, behaviour, and insecticide susceptibility status of vectors in the target areas. The surveys are designed to gather both basic required information as well as additional complementary data.

**Essential information**
The following basic information needs to be regularly updated:

- identification of the anopheline vector species in the targeted areas;
- distribution and seasonality of the vector;
- indoor and outdoor resting habits of the anopheline vector;
- insecticide susceptibility using the WHO Tube Assay or the CDC Bottle Assay (2).

**Additional information**
The following further information can be collected periodically and in collaboration with national research and academic institutions:

- the behaviour of local vector species regarding time of feeding and preference for indoor or outdoor, and human and animal feeding;
- the sleeping habits of the human population in relation to the feeding habits of the vector;
- ecological data on the breeding habits of local vector species;
- baseline vector parameters, including parity rates, human biting rates, human blood indexes, sporozoite rates and entomological inoculation rates (EIR).

Collection methods designed to catch different species of *Anopheles* include: human landing; indoor spray sheets; indoor and outdoor resting; exit traps; CDC light traps (with or without CO₂ augmentation); animal-baited traps; experimental huts; and larval collections (3).

2.2.3 Geographical reconnaissance and mapping of structures/households

Geographical reconnaissance (GR) is defined as “the operation that provides the basis for the choice of field centres and depots, for detailed schedules and itineraries of spraying and surveillance personnel, for the final deployment of transport, and for the numerical control of the completeness of the work accomplished or reported” (4).

Before IRS begins, detailed information on the target areas should be collected. This should include the distribution, location, number, type, size and accessibility of households and struc-
tures to be sprayed. Maps showing roads, location of villages, water points and important geographical features such as lakes, streams and mountains, should be prepared. The number, type and size of dwellings should be identified, mapped and recorded. Each household should be given a reference number to be painted on a door or a wall and should be issued with a malaria house card so that spray operators can determine where and what they have to spray. This also enables spray team leaders to better supervise the work. The average surface area of unit structures/houses must be calculated to estimate the total number of square metres of surface to be sprayed and the amount of insecticide needed.

Detailed GR may not be financially or practically possible before the first spray rounds. However, a full GR should be conducted during the first round and updated during subsequent rounds. The scope of GR will vary from country to country and programme to programme, depending on the available resources.

The tools and technology for GR and data management through geographical information systems (GIS) are evolving rapidly. Hand-held electronic instruments such as smart phones and personal data assistants (PDAs), as well as freely available basic satellite imagery of many targeted areas and powerful portable computing equipment all greatly increase the potential contribution GR can make. However, the fundamental principles, and the need for accurate and up-to-date basic information remains the same.

To help with the detailed recording of structures during GR, households can be rapidly georeferenced, mapped and recorded in the field using integrated handheld PDAs fitted with a global positioning system (GPS). This data can then be added to base maps to provide detailed GR information of target IRS areas, thereby assisting in many aspects of operations.

**Delineation of malaria risk areas to be sprayed**

The areas to be sprayed should be identified during an initial assessment. They should then be delineated with clear identification numbers and will form the basis of the GR within the boundaries. Topographical maps, available from government offices, which show administrative boundaries, roads, villages, water sources and other useful features will greatly facilitate the GR.

As national malaria control programmes progress, more and more areas within districts and countries should move from being high-transmission to being low-transmission, and finally become areas free of malaria. Clear boundaries need to be established between malaria-free zones and areas of low transmission, and between low transmission zones and high transmission zones. The methodology for the demarcation of malaria transmission zones is still evolving; the use of GIS and WHO Health Mapper is improving this process.

Barrier IRS with a width of one to two kilometres between malaria-free zones and low to high malaria transmission areas can be used to prevent re-invasion of areas where malaria has been eliminated (Figure 1).

**Mapping**

Maps provide a spatial view, which significantly helps operational planning and guides the spray teams to the structures to be sprayed each day.
Detailed, printed topographical maps can often be obtained from the surveyor general’s department or from local government planning departments. Field teams can develop hand-drawn sketch maps during the GR. Today, satellite imagery can be downloaded from free services such as Google Earth or Google Maps, with more detailed maps and images available from other on-line services.

With the aid of a compass, patterns of the structures or houses to be sprayed, together with their access routes, can be marked on a spot map and locations for field camps can be identified (Figure 2).

**Geographic information systems (GIS)**

Base maps can be obtained using computer software such as the WHO Health Mapper, suitable for use by district and provincial malaria management teams. This mapping database can be updated with information on the location of households by entering household numbers, together with their details, on a hand-held GPS or on a PDA.

WHO Health Mapper, a core geographic health database, contains country-specific information that is important for developing IRS operational plans. This includes:

- administrative boundaries (national, sub-national)
- location of villages (including village names and codes)
- location and type of health infrastructure
- location and type of schools and other public infrastructures
- location and type of safe water points
- population by administrative level (to village level where available)
- roads, rivers, forests, elevation
- indicator data such as population subgroups (gender, sex, risk group), time, location, source.

In many countries, the geographic database has been developed in collaboration with ministries of health, integrating several datasets from a variety of sources in the country. This is a work in progress and in many countries the databases may still be incomplete.

Before undertaking a GR, it is necessary to check what core geographic data may already be available in the WHO Health Mapper, available on the WHO public health mapping and GIS resource site at [http://healthmapper.software.informer.com/](http://healthmapper.software.informer.com/).

GIS in a given country may already be well-established in other government and non-governmental agencies working in health, agriculture, environment, public works, etc. The malaria control programme can collaborate with these institutions to prepare malaria risk maps (both spatial and temporal) using available malaria data. This type of database and mapping are excellent resources to support effective targeting of IRS.

The GR and house census can be carried out using either traditional paper questionnaires and/or topographical maps, or using PDAs. When used in the field by interviewers, PDAs can store and present information collected from survey questionnaires. They are advantageous due to the fact that they can be pre-programmed to navigate through questionnaire skip patterns and to adjust question wording for specific situations. With PDAs, survey results can be cleaned and

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**FIGURE 2**

Spot map for IRS planning

downloaded quickly after fieldwork is carried out. Many PDAs also now come with GPS receivers (either embedded or as add-on devices) for automatically integrating geocodes with survey data. In addition, PDAs with embedded GPS receivers can be useful for fully automating the process of survey sample design and mapping households for household listings. Household characteristics, such as previous spray history, the number of bedrooms sprayed and the number of unsprayed structures can be easily recorded.

An integrated approach to the collection, storage, analysis and mapping of relevant malaria data allows relatively easy, accurate and quick assessment, planning, monitoring, and reporting of a number of malaria control and elimination interventions (Figure 3).

FIGURE 3
Integrated approach to malaria information systems

House geo-referencing for IRS using handheld PDAs and GPS
Geo-referencing and mapping of household structures using handheld PDA and GPS can be used in the overall planning of IRS activities and to assist in monitoring spraying operations and follow-ups as shown in Figure 4 below.

2.2.4 Population census
The starting point for the IRS population census is to look at the latest national population census document, inter-census surveys and demographic health surveys (DHS). These provide the basic information required, including:

- the names of administrative areas (e.g. province, region, state, district, ward, parish, village) broken down to the lowest levels;
- the names of major urban centres;
- population numbers by administrative areas and by rural and urban distribution;
- population structure by age groups (less or more than 5 years, male or female);
- population distribution and density;
average household size (number of people per household);
number of rooms per household or dwelling;
type of household and materials used for construction;
name of head of household.

The IRS teams should update the population data when they conduct house-to-house GR census prior to the spray campaign.

2.2.5 Estimating number, size and type of structures or houses

In order to plan an IRS campaign it is essential to know:

- the number of houses or structures;
- the average number of rooms per household (e.g. sitting room, bedroom, kitchen, dining room, bathroom, toilet);
- the average size of one room (in square meters of sprayable surface area);
- the average number of persons per household;
- the type of materials used for construction of walls and ceilings (e.g. mud, thatch, brick, bamboo, corrugated iron).

IRS district coordinators should compile this information using the latest census data, local government records and health-sector data, as well as data from other major community-based programmes such as expanded programmes on immunization. They should establish an initial estimate of the number of structures or houses that require spraying, the number of spray rounds to be carried out in a year, and the details and location of areas that can be placed under active...
surveillance with target spraying in response to outbreaks. The determinants for targeting which areas should be sprayed are discussed in detail in Section 1.4. PDAs can also be used to record spray round information.

**Estimating sprayable surface area**

The average sprayable surface area of the target houses must be obtained before insecticide quantification and procurement. This is usually accomplished using a representative sample of 5–10% of the total houses. The surface and type of all the structures (main houses, animal shelters and other buildings) should be measured (inside walls, ceiling, doors and windows - inside and outside). The proportion of the different type of houses (traditional or modern) and average sprayable surfaces are estimated. From this information the quantity of insecticide needed can be estimated.

Most spray target areas contain two basic types of structures: traditional and modern (or formal). This classification is very useful in estimating the formulation of insecticide to be used in IRS operations and in determining the logistical requirements of the programme.

- A traditional or rural house/structure is constructed from materials readily available in the surrounding area (e.g. mud, thatch, sticks, and rough lumber). These dwellings frequently have very few internal partitions and their internal walls are seldom finished with plaster or paint.
- A modern or urban house or structure is frequently constructed from finished lumber, cinder block or brick with multiple internal walls that have been plastered with a smooth finish or painted.

‘Sprayable surface’ is defined as the inside surfaces of all structures or houses that should be sprayed. This includes eaves not exposed to rain, ceilings, under-floor areas in raised housing, and the inside walls of latrines. Other structures in the village, outside the household compounds and where there are no sleeping areas, such as schools (except boarding school dormitories) and shops, should not be sprayed, as these will attract very few malaria vectors. Annex A1.1 shows an example of a sprayable surface record form for baseline estimation of insecticide quantification needs.

### 2.3 Selection of insecticides

Selection of insecticides for IRS is guided by: the characteristics of the insecticides; the susceptibility status of the local vectors; the epidemiology of the disease, especially the duration of the transmission season; the environmental situation; and other factors relevant to the effectiveness of the IRS programme.

#### 2.3.1 Type of action of insecticides

Different insecticides may have different effects on the particular species of mosquito through one or more of three types of action:

- repellent
- irritant
- killing.

In order to maximize the effect on vector survivorship and malaria transmission, insecticides with a high level of killing effect are preferred to those with a high level of repellent and irritant effect.
2.3.2 Characteristics of good residual insecticides

The following factors should be considered when selecting insecticides for IRS.

- **Efficacy:** for IRS to be effective, female anopheline mosquito vectors must be susceptible to the insecticide selected. Insecticides may lose their efficacy if the target insects develop resistance. Susceptibility studies should be conducted on samples of the target insect population collected from the area. If resistance is observed, another insecticide, to which cross-resistance is unlikely, must be selected (6).

- **Residual effect:** the most important quality of a residual insecticide is its long-acting effect on a given surface and high toxicity to vector mosquitoes. The toxicity should remain effective for a period long enough to cover the malaria transmission season.

- **Correct formulation:** optimum effectiveness of IRS can be achieved by spraying the right formulation on the right type of surface. For instance, wettable powders (WP) and water dispersible granules (WG) are best suited to very porous surfaces such as mud walls, while suspension concentrates (SC) or emulsifiable concentrates (EC) are more effective on finished cement, finished wood or lumber, or painted surfaces, especially those where oil-based paints have been applied.

- **Robustness (stability):** the insecticide selected should be stable during transportation and storage, at room temperature, and with minimum ventilation. It should mix evenly or dissolve in the selected solvent and it should be harmless to the spray equipment.

- **Safety:** insecticides are inherently hazardous. However, when handled and applied according to label recommendations, WHOPES-approved insecticides carry a low risk and will provide the desired results. When properly applied the insecticides used for IRS should pose no danger to spray workers, householders, domestic and wild animals or the environment. Steps to mitigate accidental contamination and spills should be implemented prior to commencing spray operations.

- **Acceptability:** some insecticide groups and formulations have been found less acceptable by householders due to their peculiar smell or because they leave unsightly deposits on the sprayed surfaces. Acceptability may vary by location.

- **Cost:** programmes should monitor costs according to standard cost categories, i.e. operations, labour, equipment, personal protective equipment, insecticide, and administration. Costs can then be calculated per unit structure sprayed or per population protected.

2.3.3 Classes and compounds of insecticides

Insecticides used in public health are usually contact insecticides and considered either residual or non-residual. Residual contact insecticides are stable, organic chemicals which, when applied, remain toxic for a given period (usually several months) to insects alighting on or walking over that surface. By contrast, a non-residual insecticide may be used for space spraying where it is quickly degraded and does not persist in the environment.

**Classification**

Insecticides approved for indoor residual spraying fall into four major classes:

- **carbamates (C):** bendiocarb, propoxur
- **organochlorines (OC):** DDT
- **organophosphates (OP):** malathion, fenitrothion, pirimiphos-methyl
- **pyrethroids (PY):** alphacypermethrin, deltamethrin, lambda-cyhalothrin, etofenprox, bifenthrin, cyfluthrin
These insecticides are chosen based on safety for humans and their residual efficacy when applied to a dwelling surface. The minimum residual period required of the currently available residual insecticides is two to six months. They are available in various formulations to increase their longevity on different surfaces.

**Compounds**

Under the major classes of chemicals there are different compounds sold by different manufacturers using different trade names. These trade names should not be confused with the type of active ingredient (a.i.). For instance, the a.i. of Fendona® is alphacypermethrin and the a.i. of K-Othrine® is deltamethrin. The use of trade names is to be avoided since a product may be registered under different trade names in different countries, and therefore be unfamiliar to programme managers.

The most important criterion to be considered is the active ingredient; it is essential to check if the compound meets WHO specifications and if the manufacturer has submitted the product for evaluation with the WHO Pesticide Evaluation Scheme (WHOPES). A complete list of WHOPES-approved insecticides is provided in section 2.3.4 and can be found on-line at [http://www.who.int/whopes/Insecticides_IRS_Malaria_09.pdf](http://www.who.int/whopes/Insecticides_IRS_Malaria_09.pdf).

**Concentration**

The concentration of the products is displayed as a.i./kilogram or a.i./litre.

**Formulation for type of sprayable surface**

IRS insecticides are applied as formulations adapted to the type of surface to be sprayed. A formulation is a mixture of one a.i. with an inert ingredient that has no pesticide action. All residual insecticides are toxic to most insects in very small doses and thus, for their efficient application, some dispersion medium is necessary.

Residual insecticides for spray application are generally formulated as:

- wettable or water-dispersible powder (WP)
- emulsifiable concentrate (EC)
- suspension concentrate (=flowable concentrate) (SC)
- water dispersible granule (WG)
- capsule suspension (CS).

The major characteristics of the different formulations and their impact on IRS are described in Table 3 below.

WP formulations are the most commonly used insecticides for IRS in rural areas on porous surfaces (such as mud and thatch walls) in traditional buildings. EC formulations and SC formulations are used on modern buildings for spraying impervious and painted surfaces because they do not cause spots and stains.

WP, WG and CS formulations have longer residual effect, except on non-absorbent surfaces where the effectiveness and persistence of all three kinds of formulations are the same. Recently introduced capsule suspensions are showing longer residual activity especially on porous surfaces.

**Types of sprayable surfaces**

The persistence of an insecticide sprayed on a surface varies with the type of insecticide, its formulation and the type of surface. Most insecticides last longer on wood and thatch than on mud. Mud surfaces, cement blocks, concrete and brick absorb the insecticide, and certain types of mud may also break it down chemically. The residual efficacy of insecticides on absorbent
surfaces is 10–20% less than on non-absorbent surfaces. Therefore, it is important to ensure the right concentration of the recommended dosage is sprayed on non-absorbent surfaces.

Application Rates

The application rate is the amount of a.i., expressed in grams, per square metre (g/m²) of the insecticide applied to a unit of surface area. The correct application is one of the most important issues in IRS programmes. Monitoring systems must be established to ensure that the correct application rates are adhered to at all times. Training programmes for spray operators should always focus on proper application techniques.

Number of Spray Rounds

The implementation of spray operations of all sprayable houses in an area over a period of time is called a ‘spray round’. The repetition of spray rounds at regular intervals is the ‘spraying cycle’. The frequency of the spraying cycle will depend on the malaria transmission patterns of the area and the residual effect of the insecticide formulation chosen. Spray rounds should ideally be completed in less than two months and just before the transmission season. In endemic areas with perennial transmission, two rounds of spraying in six month cycles may be recommended to ensure that there is adequate year-round coverage with residual insecticides. If the transmission pattern exhibits bimodal peaks, spraying rounds should target the peaks. In areas with one seasonal transmission, one spray round, in yearly cycles before the period of transmission, should be enough to have an impact on malaria transmission.

### TABLE 3
Different Insecticide formulations

<table>
<thead>
<tr>
<th>FORMULATION</th>
<th>DESCRIPTION</th>
<th>ADVANTAGES</th>
<th>DISADVANTAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wettable powder (WP) and water-dispersible Granule (WG)</td>
<td>The a.i. is added to an inert powder containing a wetting and dispersing agent. Forms a suspension in water.</td>
<td>Effective on porous surfaces (mud bricks/ concrete walls); Easy to transport, store and use; Relatively inexpensive.</td>
<td>Ineffective on plastic sheeting, canvas tents, oil based paint; Spray tank needs occasional agitation/ shaking; Risk of exposure to dusts and spills during mixture.</td>
</tr>
<tr>
<td>Emulsifiable concentrate (EC)</td>
<td>The a.i. is dissolved in an oil-based solvent and emulsifiers. When mixed with water it forms a milky, white oil-in water emulsion composed of finely suspended droplets carrying the insecticide.</td>
<td>Easy to mix with water; Few visible deposits; More effective on cement, wood or lumber; Effective on oil based painted surfaces; High concentration of a.i. in each container.</td>
<td>Strong smell; Absorbed by porous surface; High dermal absorption increases risk for operators; Flammable.</td>
</tr>
<tr>
<td>Suspension concentrate/flowable concentrate (SC)</td>
<td>Contains tiny particles of a.i. suspended in a liquid (usually water). Forms crystalline particles, but smaller than those formed with WP and WG.</td>
<td>Safer for operators; Less visible residues than WP; Effective on cement, wood or lumber and on oil based paints.</td>
<td>Less effective on porous surface than WP.</td>
</tr>
<tr>
<td>Capsule suspension (CS)</td>
<td>The a.i. is encapsulated in microscopic polymer capsules. Suspended in water for spraying.</td>
<td>Capsules release the insecticide slowly after spraying, extending compound’s residual life.</td>
<td>Constant agitation is needed.</td>
</tr>
</tbody>
</table>
2.3.4 WHO recommended insecticides for IRS

Public health insecticides are under continuous review by WHOPES, with 12 currently approved for use in indoor residual spraying. These have been used safely and effectively in many countries around the world to control malaria vectors. Table 4 presents a list of WHOPES recommended insecticides for IRS as of August 2012. Updates to this are available at http://www.who.int/whopes/quality/en/.

<table>
<thead>
<tr>
<th>INSECTICIDE COMPOUNDS &amp; FORMULATIONS</th>
<th>CLASS GROUP</th>
<th>DOSAGE (g a.i./m²)</th>
<th>MODE OF ACTION</th>
<th>DURATION OF EFFECTIVE ACTION (MONTHS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DDT WP c</td>
<td>OC</td>
<td>1–2</td>
<td>Contact</td>
<td>&gt;6</td>
</tr>
<tr>
<td>Malathion WP</td>
<td>OP</td>
<td>2</td>
<td>Contact</td>
<td>2–3</td>
</tr>
<tr>
<td>Fenitrothion WP</td>
<td>OP</td>
<td>2</td>
<td>Contact &amp; airborne</td>
<td>3–6</td>
</tr>
<tr>
<td>Pirimiphos-methyl WP &amp; EC</td>
<td>OP</td>
<td>1–2</td>
<td>Contact &amp; airborne</td>
<td>2–3</td>
</tr>
<tr>
<td>Bendiocarb WP</td>
<td>C</td>
<td>0.1–0.4</td>
<td>Contact &amp; airborne</td>
<td>2–6</td>
</tr>
<tr>
<td>Propoxur WP</td>
<td>C</td>
<td>1–2</td>
<td>Contact &amp; airborne</td>
<td>3–6</td>
</tr>
<tr>
<td>Alpha-cypermethrin WP &amp; SC</td>
<td>PY</td>
<td>0.02–0.03</td>
<td>Contact</td>
<td>4–6</td>
</tr>
<tr>
<td>Bifenthrin WP</td>
<td>PY</td>
<td>0.025–0.050</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Cyfluthrin WP</td>
<td>PY</td>
<td>0.02–0.05</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Deltamethrin WP</td>
<td>PY</td>
<td>0.020–0.025</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Etofenprox WP, WG</td>
<td>PY</td>
<td>0.1–0.3</td>
<td>Contact</td>
<td>3–6</td>
</tr>
<tr>
<td>Lambda-cyhalothrin WP, CS</td>
<td>PY</td>
<td>0.02–0.03</td>
<td>Contact</td>
<td>3–6</td>
</tr>
</tbody>
</table>

Use of DDT (Dichlorodiphenyltrichloroethane) in IRS

The use of DDT is strictly governed by the protocols of the Stockholm Convention on Persistent Organic Pollutants of 2001 and the specific recommendations by the WHO that allow DDT production and use strictly for public health purposes related to disease vector control. As stated in the WHO Position Statement on the use of DDT in Malaria Vector Control:

**Concerns about the safety of DDT**

DDT has a low acute toxicity on skin contact, but if swallowed it is more toxic and must be kept out of the reach of children. Because of the chemical stability of DDT, it accumulates in the environment through food chains and in tissues of exposed organisms, including people living in treated houses. This has given rise to concern in relation to possible long-term toxicity. The risks that DDT poses to human health are re-evaluated by WHO whenever there is significant new scientific information. In 2000, the Joint FAO/WHO Meeting on Pesticide Residues undertook a comprehensive re-evaluation of DDT and its primary metabolites including storage of DDT and its metabolites in human body fat; the presence of residues in human milk and the potential carcinogenicity; and biochemical and toxicological information including hormone-modulating effects. While a wide range of effects were reported in laboratory animals, epidemiological data did not support these findings in humans.
New information published since 2000 was evaluated by a WHO Expert Consultation held in December 2010 (7). This information included new epidemiological studies, up-to-date reported levels in human milk, and new information on exposures to DDT occurring as a result of IRS. A detailed exposure assessment was undertaken, including potential exposure to both residents in IRS-treated homes as well as to spray operators. The WHO Expert Consultation concluded that in general, levels of exposure reported in studies were below levels of concern for human health. In order to ensure that all exposures are below levels of concern, best application practices must be strictly followed to protect both residents and workers. Based on the most recent information, WHO has no reason to change its current recommendations on the safety of DDT for disease vector control. However, WHO’s position on the safety and use of DDT will be revised if new information on the potential hazards of DDT becomes available justifying such a revision (8).

When considering the use of DDT, programmes should take into account the additional reporting requirements to the Stockholm Convention, additional environmental assessment procedures that may be required (such as the need in some programmes for a public comment period), and additional procedures for disposing of empty containers and other contaminated waste. DDT has the longest residual effect (6 to 12 months) compared to other classes of insecticide and thus may reduce the number of applications required in perennial transmission areas. In terms of insecticide resistance, there is cross-resistance with pyrethroids in some situations, but in other situations the vector may be resistant to pyrethroids and to carbamates, but still susceptible to DDT. As with all insecticides, there needs to be careful monitoring of insecticide susceptibility and a robust plan for insecticide resistance management as outlined in the Global Plan for Insecticide Resistance Management (GPIRM) (6). In addition, there needs to be good stock management through stringent accounting, secure storage and close supervision to prevent illicit diversion and use, especially for agriculture.

### 2.3.5 Estimating insecticide requirements

To estimate the amount of insecticide required for an IRS spray round the following information is needed:

- **N**: the number of houses to be sprayed (expressed as the percentage of modern and traditional structures);
- **S**: the average sprayable surface per house in m² (modern and traditional structures);
- **C**: the concentration of the active ingredient in the formulation (% a.i.);
- **Y**: the target dosage expressed in g/m² (application rate) of insecticide to be used on each type of structure according to WHO recommendation (Table 4).

Once this information is gathered, \( Q \), the total quantity of insecticide needed (kg) is calculated as shown below:

\[
Q = \frac{S \times Y \times 100}{C} \times N = XXX,XXX \text{ g}
\]

**Note**: when the full quantity of insecticide needed is calculated it should then be increased by 10% to overcome any possible shortage.
Example 1a: Determine the amount of insecticide formulation required to treat 11,607 formal structures with an average sprayable surface area of 300 m$^2$. The insecticide formulation selected is lambda-cyhalothrin 10% WP. The dose to be applied (application rate) is 0.025 g of a.i. per m$^2$.

$$Q = \frac{300 \times 0.025 \times 100}{10} \times 11,607 = 870,525 \text{ g}$$

870.5 kg of insecticide formulation are required to spray 11,607 structures/houses; + 10% buffer stock = 87 kg

The total amount of lambda-cyhalothrin required: 958.5 kg

Example 1b: Determine the amount of insecticide formulation required to treat 6,250 traditional structures with an average sprayable surface area of 125 m$^2$. The insecticide formulation selected is DDT 75% WP. The dose to be applied (application rate) is 2.0 g of a.i. per m$^2$.

$$Q = \frac{125 \times 2.0 \times 100}{75} \times N = 2,083,333 \text{ g}$$

2083.3 kg of insecticide formulation are required to spray 6,250 structures/houses; + 10% buffer stock = 208 kg

Total amount of DDT required: 2291.3 kg

2.3.6 Management of insecticides

Insecticide (pesticide) management is the regulatory control, proper handling, supply, transport, storage, application and disposal of insecticide products to minimize adverse environmental effects and human exposure. Additional guidelines and best practices are available through WHO and FAO as well as from manufacturers of the particular insecticide.

National insecticide registration

Recommendations for WHOPES approved insecticides are based on tests and assessments on their efficacy and safety. However, national regulatory authorities, ministries of public health, and environmental authorities may require additional assessments and procedures. Guidelines and additional information on national pesticide registration are available from WHO (9).

The national registration process is usually as follows.

- The agent or company wishing to register a compound completes specified forms supplied by the national authority for the registration of agricultural pesticides or public health insecticides for use in indoor residual spraying for malaria control.
- Information must be provided regarding the a.i., proposed use, formulation characteristics, toxicity, and handling issues.
- The application must be accompanied by documentation of all trials for efficacy and safety, including where and how they were conducted.
- The documents are reviewed by the registration authority and submitted to the ministry of health and the national environmental agency for review and comment.
- If there are no problems and the documentation is complete, a registration number is assigned.
- Compounds using the same a.i. as previously registered compounds may be registered more quickly.
Depending on national capacity in entomological research, field trials may be requested in the local country context. However, the assessment may rely primarily upon reviews and trials carried out in other countries and on the recommendations of WHOPES.

All insecticides must have labels in local languages and sample labels are required before registration.

WHOPES provides detailed guidance for sound management of public health pesticides throughout their life-cycle, including issues related to the registration, distribution and sale, use and application, and disposal of pesticide waste, as well as to training and awareness raising and to enforcement of pesticide regulations (10).

**National environmental assessment for insecticide application**

Before procuring or using insecticides for malaria control, many countries and programmes require an environmental assessment. This may include:

- the health and environmental registration status of the insecticides;
- the rationale for selection and conditions of use for the insecticide(s);
- the availability and effectiveness of other alternative pesticides or nonchemical control methods;
- the extent to which the proposed insecticide use is part of an integrated disease control programme;
- the availability of the appropriate application and safety equipment;
- any acute or long-term toxicological hazards, either human or environmental, associated with the proposed use, and measures available to minimize such hazards;
- the provisions made for training coordinators, supervisors and spray operators on safe handling and use of insecticides;
- provisions made for monitoring the safe handling, use and effectiveness of the insecticides;
- the public health and environmental regulatory institutions’ ability to regulate and control the distribution, storage, use, and disposal of the pesticide.

**Environmental risk**

Environmental risks include contamination that could adversely affect humans, domestic animals and aquatic organisms. This risk can be mitigated through ensuring:

- secure and safe storage of insecticide with adequate inventory and stock control procedures;
- intensive supervision of spray teams and spray operators to ensure proper insecticide handling and use;
- audits of used insecticide sachets and containers;
- the use of standard sprayers and effective maintenance;
- re-cycling of waste water used for washing equipment;
- the appropriate incineration of empty sachets.

**Packaging and storing insecticides**

**Packaging**

Insecticides should be carefully handled. It is important that spray charges (or the quantity of the insecticide needed in one sprayer of 8 or 10 litre capacity) are pre-packed to facilitate easier transportation, handling and efficient filling of the sprayers. The programme should use the WHO (10) and RBM (11) guidelines for procurement of public health insecticides. Measured amounts of insecticides should be pre-packaged in sachets or plastic bottles corresponding to the operational capacity of the sprayer, i.e. 8 or 10 litres of water. For wettable powders, water soluble sachets that can be placed directly in the spray tank are preferred.
Packaging should be sufficiently robust to withstand any difficult transportation, handling, storage and climate conditions to which they may be exposed. Insecticide containers should be clearly labelled. They should also be rigid, leak-proof, weather-, tamper- and rat-resistant. If containers are damaged, the insecticide should be re-packaged with clear labelling. Plastic bags and bottles, shipping boxes and other insecticide containers should be disposed of safely after use by means of appropriate incinerators.

**Storage**

Insecticides must be kept in a safe storeroom with a current inventory and stock control number and audit system. The storeroom should be free from moisture and heat (direct sunlight) and well ventilated. The containers should be placed above ground level and not directly on the floor. Insecticides must be kept in the original packaging and containers and only transferred into sprayers as needed. Insecticides should be kept away from food, animal feed, children and unauthorized persons. Detailed organization and management of stock can be found in the Food and Agriculture Organization of the United Nations’ *Pesticide storage and stock control manual* (12).

**Insecticide Safety Procedures**

Insecticides, like drugs, have inherent potential hazards. However, if they are handled and applied according to label specifications, they will be safe and effective. Safety instructions must be followed at all times to avoid potential problems for operators, house residents, pets and domestic animals and the environment. Safety procedures and best handling practices are described in more detail in Chapter 3, but include:

Reducing risk to household residents by ensuring they:

- remove as much of their household contents as possible, specifically water, food, cooking utensils and toys;
- move furniture away from the walls to allow easy access for spraying of walls and cover it with a plastic tarp or sheeting. All pictures, wall hangings, and posters should be removed. Items that cannot be removed should be well covered with a plastic sheet and placed in the centre of the room;
- relocate, cage or leash pets and domestic animals away from the house until sprayed surfaces have dried and the dead insects have been swept up and removed from the floor. They should be kept outside until for at least one hour after spraying is complete. This will avoid the temporary skin and eye irritations that may occur with some of the chemicals.

Chronic exposure risk for spray operators is minimized by the wearing and regular washing and changing of protective clothing when handling insecticides and during all spray operations. Spray operators may also require periodic medical examinations, depending on the insecticide they are applying. Some countries, for example, may require weekly monitoring of acetylcholinesterase (AChE) among spray personnel using organophosphates such as fenitrothion.

The WHO Expert Committee on Vector Biology and Control has considered worker safety when applying carbamates and organophosphates and gives the following information (13):

- carbamates – no testing required;
- pirimiphos-methyl and malathion – safe enough to be applied operationally without requiring routine cholinesterase monitoring, provided protective clothing is regularly cleaned and a high standard of personal hygiene is maintained;
- fenitrothion – at the limit of acceptable toxicity for conventional indoor application. Its relatively narrow safety margin calls for strict precautionary measures and regular cholinesterase monitoring of exposed people throughout the spraying operation;
propoxur – no cholinesterase monitoring required (it is a carbamate) but conclusions on use are similar to those with fenitrothion, i.e. it is at the limit of acceptable toxicity with narrow safety margins, and strict precautionary measures must be followed.

**Safety precautions**

Exposure to insecticides may occur during the following stages of the spraying process:

- opening of the package
- mixing of insecticide
- loading of the sprayer
- maintaining the equipment
- spraying, especially in high, overhead places
- through spillage
- during disposal.

The following safety precautions should be taken:

- read the label carefully and understand the directions for preparing and applying the insecticides, as well as the precautions listed;
- follow the directions and precautions exactly;
- know the first-aid measures and antidotes for the insecticides being used;
- use protective clothing while handling and spraying insecticides;
- mix insecticides in a well-ventilated area, preferably outdoors;
- make sure that the spray equipment does not leak and check all joints regularly;
- avoid skin contact;
- use dedicated equipment for measuring, mixing and transferring pesticides;
- use pre-packed insecticides with the appropriate quantity of water in the sprayer;
- ensure the sprayer is depressurized before opening the lid;
- do not eat, drink, smoke or use mobile phones while handling and spraying insecticides;
- wash hands and face with soap and water after spraying and before eating, smoking or drinking;
- shower or bathe at the end of every work day and change into clean clothes;
- wash overalls and other protective clothing at the end of each work day in soap and water and keep them apart from the rest of the family’s clothes;
- change clothes immediately if they become contaminated with insecticides;
- keep two sets of protective clothing in different colouring to avoid using the same uniform as the previous day. In this way it is always possible to use one set while the other is being washed;
- do not clear blocked spray nozzles by blowing with the mouth;
- inform the supervisor immediately if feeling unwell.

Further information can be obtained from US Environmental Protection Agency (14).

**Empty sachet disposal**

All empty sachets and containers should be collected by the team supervisors and taken to the central storage area for proper disposal by qualified staff. Burning in a conventional open fire will not destroy any residual insecticides and may generate environmentally toxic emissions (15).

Good inventory control is essential to ensure that each empty sachet or container has been collected and not diverted for unauthorized use.
**Disposal of expired stock of insecticides**

Insecticides should not be allowed to expire. This can be avoided through proper planning and accurate estimation of needs. Should expiry occur, the means of safe disposal should be decided by the national authorities (ministry of health, ministry of agriculture, ministry of the environment) according to the available disposal facilities in the country and in compliance with international conventions related to international transportation of pesticides.

Expired insecticides can sometimes be extended beyond their expiration date in consultation with the manufacturer and quality control centres. If this is not possible, large quantities of insecticides are best disposed of by incineration in specially designed incinerators that are able to reach a temperature of 1200 °C. If such equipment is not available in-country, expired insecticides should be returned to the supplier or passed on to a specialist disposal agent selected by the national authorities.

**2.3.7 Insecticide procurement and quality control**

Insecticides should only be procured if they conform to WHOPES specifications as previously outlined and, if they are registered in the country of use. WHO has recently published guidelines for procurement of public health pesticides (10).

Quality control for all insecticide procurement is important in terms of: the concentration of a.i.; the level of impurities; and, especially in the case of wettable powders, the quality of the suspension when mixed in a sprayer, which may vary from one procurement to the next.

Insecticides packaged in a water soluble sachet significantly decreases human and environmental exposure to the insecticide and should be encouraged in procurements.

One of the conditions for the supply of pesticides should be that all products offered must conform to WHOPES specifications. Conforming to these specifications will ensure high quality insecticides are provided to programmes and help exclude suppliers who cannot guarantee the quality and performance of their products. Unwillingness to guarantee conformity and compliance to these specifications should result in rejection of a supplier.

**Procurement tender specifications and labelling**

Tender documents should be prepared on the basis of legal provisions on the procurement of goods and services in the country, including those specific to pesticides. The format of the tender document will vary from country to country but usually consists of three sections:

- **Section 1** provides information on the procurement procedure, including instructions to tenderers, conditions of tenders and technical specifications and requirements of the products being procured.
- **Section 2** contains the schedule of requirements, such as time, quantity and place of delivery.
- **Section 3** describes the contract for procurement. Instructions to tenderers inform them about the procurement process and the actions they must take to comply with the requirements. The instructions are based on the legal requirements for procurement of goods and include: the scope of the tender; procedures for tender submission, opening, and evaluation; and award of a contract. The principles of sound public procurement must be followed by providing potential suppliers with accurate technical information and specifications for the products to be procured.

Open tenders are often advertised in newspapers, international journals or on the internet, to promote competition and allow procurement entities to obtain pesticides at the best possible price.

The tender documents include the technical specifications and other requirements that define the commercial and logistic framework for procurement. They include:
pesticide specifications (without specifying trade names);
- technical specifications and documentation to be submitted in support of compliance requirements for outer packaging and shipping. This includes compliance with norms, dimensions, volumes, stacking requirements, materials, crush resistance padding and external marking;
- quantities and delivery schedules, required delivery terms (e.g.: ‘free carrier’, nearest terminal sea- or airport) and ordering procedures;
- applicable terms and conditions that will form the basis for selection;
- the deadline for submission of bids, which should not be so short as to restrict competition;
- timetables for orders and delivery (bidders should be alerted to any anticipated delays, for example if the pesticides have still not been authorized for use in the destination country);
- procedures for awarding tenders;
- any special conditions in adjudicating tenders, such as preference for products recommended by WHOPES;
- request for a statement of the supplier’s administrative and legal status and its link with the product; and
- a standardized proposal form, stating delivery times, expected delivery date, gross weight of the order, personnel involved with contact details, and a quotation for the total amount, including any discounts.

Other information in the document should include the name and address of the procurement entity and the place of delivery of the goods. Some countries also require tender specifications to include registration or authorization for importation of the pesticide or LLINs in the country of use.

Tender documents can also contain other administrative requirements, such as insurance requirements, percentage of advance payment, payment schedule, interest for payment delays, and bond for satisfactory completion of contract.

**Labelling**
Labelling must conform to the requirements of national registration authorities regarding insecticide labelling for public health use.

**Quality control: checking product on delivery**
Preferably before shipment, but failing this, upon delivery, random samples for quality control should be taken by the national drugs and insecticides regulatory authority from the different batches of consignment. These samples should be sent to independent analytical laboratories to ensure that the product conforms to the required specifications. Such testing should be paid for by the supplier. The testing should not be limited to the amount of a.i., but to all physical and chemical properties of the product as detailed in the specifications.

WHO provides guidance to national health authorities and offers assistance through designated WHO collaborating centres on quality control of insecticides. WHO procedures for quality control for public health pesticides are available at [http://www.who.int/whopes/quality/en/](http://www.who.int/whopes/quality/en/).

**2.3.8 Insecticide use: annual reporting**
WHO encourages all countries using insecticides for IRS to submit annual reports on the class, compound, formulation and concentration used (see Annex A1.3 for an example of annual reporting on insecticides used). This allows WHO to monitor and plan support for countries in terms of insecticide specifications and use. It also enables both individual countries and WHO to advise industry of changes in the size and needs of the market, and of the priorities for research and development.
WHO-UNEP guidance on DDT use and reporting

All countries that are signatories to the Stockholm Convention on Persistent Organic Pollutants, and that either produce or use DDT for IRS for the control of malaria or other vector-borne diseases, are required to report on its use every three years.

There is a standard format for such reporting by each country as described in paragraph 4 of Part II of Annex B of the Stockholm Convention on Persistent Organic Pollutants (Section A) combined with a questionnaire for reporting other information relevant for the evaluation of the continued need for DDT for disease vector control, sections B, C and D. The Stockholm Convention text is available at http://chm.pops.int/Convention/ConventionText/tabid/2232/Default.aspx.

WHO supports national malaria control programmes on the effective and safe use of public health insecticides including DDT for IRS in malaria control as outlined in the position statement on the use of DDT (8). UNEP and WHO give support to national environmental agencies to monitor the regulation and use of DDT and other public health insecticides for IRS in malaria control.

2.3.9 Managing insecticide resistance

Insecticide resistance monitoring

Insecticide resistance is when the anopheline vectors are no longer killed by the standard dose of insecticides used for IRS or when they manage to avoid coming into contact with the insecticide sprayed on inside house walls.

Before finalizing the choice of an insecticide for IRS, it is essential to test the susceptibility of the target vector populations to a range of insecticides. This should include the insecticide whose use is being considered as well as possible alternatives. WHO recommended standardized test systems should be used (16).

An initial baseline survey should be followed by longitudinal monitoring at sites in different eco-epidemiological areas. Maximum effort is required to ensure the testing is standardized and supervised to ensure comparability of data from different sites.

Sentinel sites for monitoring insecticide susceptibility should include both areas that are sprayed as well as comparable areas that are not. As detailed in the testing guidance literature, the WHO Tube Assay and the CDC Bottle Assay should be the primary methods by which resistance to insecticides is initially detected and identified. Molecular and biochemical assays have an important role in providing additional information on mechanisms, but should not be a substitute for these standardized bioassay methods.

The two main type of insecticide resistance mechanisms are:

- Metabolic resistance, which is mediated by a change in the enzyme systems that normally detoxify foreign materials (including insecticides) in the insect. Resistance can occur when increased levels or modified activities of an enzyme system cause it to detoxify the insecticide much more rapidly than usual, thus preventing the insecticide from reaching its intended site of action;

- Target-site resistance, which occurs when the molecule that the insecticide normally attacks (typically within the nervous system) is modified, such that the insecticide no longer binds effectively to it, and the resistant insect is therefore unaffected, or less affected, by the insecticide.

Cross-resistance can restrict the choice of alternative insecticides. Cross-resistance often occurs between insecticide classes that have the same mode of action for killing vectors. For example, if a resistance gene creates a change in a target site in a vector, it is likely to affect any other insecticides that attack that same target site, thus conferring cross-resistance. Similarly, an alteration to an enzyme that affects susceptibility to one insecticide may result in cross-resistance to another.
Resistance genes can spread rapidly in malaria vector populations over large areas. Data also suggest that resistance can evolve swiftly, occurring at low frequency for many years without being detected and then increasing rapidly to very high levels, to a stage at which it becomes less likely or even impossible to reverse the trend.

Once IRS operations have started, it is important to regularly monitor the susceptibility of the target vector populations by conducting at least one survey every year with a sufficient number of representative sentinel sites in the areas targeted for IRS. As outlined in the GPIRM, programmes should ideally plan rotation schemes, even pre-emptively, before resistance is detected. Programmes should complete any required national pesticide registration, carry out environmental impact assessments, and implement pesticide management plans for potential alternate insecticides, so that when the time comes, the rotation can be made quickly and efficiently.

Resistance Management

The strategy for resistance management is based on current WHO guidance found in the GPIRM. This guidance may be adapted and revised as more evidence and research results become available. Updates of these recommendations are available on the WHO GMP website at http://www.who.int/malaria/en/.

Specific resistance management strategies for each geographic area should be based on current national programme vector control interventions, the status of resistance and the epidemiological context. For IRS, the recommendations focus on pre-emptive use of rotations. For LLINs, the options are more limited, and strategies will require consideration on a case-by-case basis. As described in the GPIRM, the response should focus on areas where resistance is of greatest concern. Whenever possible, countries should introduce focal IRS with non-pyrethroids in addition to LLINs in resistance “hot spots”.

If resistance is detected, even before any control failure that could be potentially linked to this is observed, the best solution is to shift rapidly to a suitable alternative insecticide. The choice of alternative should take into account information concerning the resistance mechanism identified. Insecticide choice may need to be extremely area specific, even down to district level. A change of insecticide will have potential logistical and financial implications and should only be made after careful review.

Strategies for delaying/avoiding the onset of resistance

As detailed in the GPIRM, a resistance management strategy includes: preservation of insecticides susceptibility; slowing down the evolution of resistance; and prolonging the effectiveness of current vector control interventions. The best way to delay resistance is to spray insecticides only when and where they are really needed. It is important to determine the origin of selection pressure: whether it is due to public health use alone or also related to use in agriculture, domestic pest control, or a combination of all three. If resistance pressure appears to be resulting from agriculture or from domestic pest control (including private pest control operators) steps need to be taken to coordinate with the ministry of agriculture and national regulatory authorities.

There are several options for preventing or slowing down the evolution of resistance. The following broad principles should be kept in mind when addressing resistance issues:

- avoid indiscriminate use of insecticides by planning targeted interventions with care and deliberation;
- avoid use of the same insecticide against both adults and larvae;
- avoid use of same class or related insecticides for IRS and LLINs in the same area;
- avoid excessive or unnecessary IRS operations;
- change the insecticide(s) being used before resistance reaches a high level.
Tactics for managing resistance include the following.

- **Rotations of insecticides**: Two, or preferably more, insecticides with different modes of action are rotated from one year to the next.

- **Combination of interventions**: Two or more insecticide-based vector control interventions are used in a house (e.g. pyrethroids on nets and an insecticide of a different class on the walls), so that the same insect is likely, but not guaranteed, to come into contact with the second insecticide if it survives exposure to the first.

- **Mosaic spraying**: One compound is used in one geographic area and a different compound in neighbouring areas, the two being in different insecticide classes; further research is required on the use of mosaics.

- **Mixtures**: Two or more compounds of different insecticide classes are mixed to make a single product or formulation, so that the mosquito is guaranteed to come into contact with the two classes at the same time. Mixtures are not currently available for malaria vector control, but will become the future of IRM once they are available.

These approaches can have different effects on populations of resistant mosquitoes: they can delay the emergence of resistance by removing selection pressure (e.g. rotation) or kill resistant vectors by exposing them to multiple insecticides (e.g. mixtures).

The most practical approach to resistance management is judicious use and high quality IRS spray application, using different classes of insecticide for IRS and LLINs, and rotating the class of insecticide used for IRS.

Most pyrethroids share common resistance mechanisms. New data is emerging indicating that there may be differences in some of the metabolic mechanisms within the pyrethroid class. For now, however, it should be assumed that changing from one pyrethroid to another will not have any significant benefit in terms of preventing or managing resistance. If cross resistance between DDT and pyrethroids is found, this implies a kdr resistance mechanism. In this case, an organophosphate or carbamate could be considered as an alternative.

### 2.4 IRS application equipment: hand-operated compression air sprayers

WHO guidelines are available for hand-operated compression sprayers that are used for IRS application (17):

The sprayer, with fittings assembled, must have no sharp edges or projections that might injure workers during normal operation. Wooden parts should not be used in the construction of any part of the sprayer. The materials of construction, including filler cover, must be corrosion-, pressure- and UV-resistant. The weight of the complete sprayer, when filled to the manufacturer’s maximum recommended capacity for operation, should not exceed 25 kg.

#### 2.4.1 Function, components and design

A hand-compression sprayer basically consists of a tank for holding a liquid insecticide formulation, which can be pressurized by means of a hand pump attached to it. The compressed air forces the liquid out of the tank via a hose with a cut-off valve, a lance and a nozzle. Specifications for tanks are available through WHO (18).

**Tank assembly**

The tank itself is usually made of stainless steel. Most tanks have four openings on top: a large one for filling, fitted with a removable cover; and openings for the air pump, discharge system and pressure gauge.
The tank cover consists of: (i) a rubber gasket; (ii) a handle; (iii) a pressure-release valve, operated by hand or by giving the handle a quarter turn; (iv) a chain to prevent the cover from being lost.

An air pressure gauge is used to measure pressure in the tank.

The shoulder strap must be wide enough to prevent it from cutting into the shoulder of the person using the sprayer. It is fastened to the tank with steel buckles. On large tanks it is adjustable.

When the tank is not in use, the spray lance is held in a bracket and nozzle cup, which protects the nozzle from damage.

Air pump assembly

A piston-type compression sprayer consists of a plunger operated inside a cylinder. The plunger forces air through a check valve at the base of the cylinder. The plunger seal may be made of leather, rubber or plastic, and must be resistant to the chemicals used in insecticide formulations.

Discharge assembly

The main parts are: (i) the dip tube, mounted in the tank with an O-ring gasket; if the gasket is damaged, air may leak from the tank; (ii) a flexible hose of a material resistant to chemicals used in pesticide formulations; (iii) a filter with housing which filters out particles too large to pass through the nozzle opening (this can be taken out for cleaning or replacement); (iv) a cut-off valve that permits the person using the sprayer to close the system; (v) a lance, or extension tube, 40–60cm in length (some models are telescopic); (vi) a nozzle assembly, comprising a nozzle tip, filter, body and cap (the tip may be of stainless steel, ceramic or plastic).

A swan neck nozzle can be used for spraying underneath floorboards, heavy furniture, and other areas where a normal straight lance will not reach.

Nozzles

The nozzle is one the most important components of the sprayer. It should deliver a precise amount of spray suspension per minute at a certain pressure in the tank, and maintain a uniform spray pattern and swath width. The selection of the nozzle depends on how the insecticide is to be sprayed. The 8002E or 8001E stainless steel nozzles are the standards for flat fan nozzles recommended by WHO for IRS.

The 8002E nozzles produce a spray pattern with an angle of 80° and a flow rate of 0.2 US gallons per minute or 757 ml per minute at a standard tank pressure of 45 psi (or 315 kPa). The 8001E nozzles produce a spray pattern with an angle of 80° and a flow rate of 0.1 US gallons per minute or 378 ml per minute at a standard tank pressure of 45 psi.

With the 8002E nozzle, a spraying speed of 2.5 seconds per vertical metre on a wall will produce the correct application of 40 ml/m². On non-absorbent surfaces early run-off of insecticide solution will normally occur and target deposit will not be achieved. The 8001E nozzle could be

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**FIGURE 5**

Cutaway diagram of a compression sprayer

Source: WHOPES
used on these surfaces. However, spray concentration may need to be adjusted. With a spraying speed of 2.5 seconds, the application rate will be 20ml/m² (half the rate when compared to the 8002E nozzle) and therefore the concentration of the insecticide should be doubled to give the same deposit rate. For both (8002E and 8001E) the nozzle should be kept at 45 cm from the surface being sprayed.

Plastic or brass nozzles are not recommended, as wettable powders considerably shorten their operational life expectancy and they will not maintain their designated spray rating throughout the duration of the malaria season.

**Nozzle Flow Regulators (Constant Flow Valves)**

To avoid a decrease in flow rate, and to ensure an even discharge as pressure drops from 55 to 35 psi, it is recommended that flow regulators are included in the nozzle tip.

### 2.4.2 Hand compression sprayers and spare or replacement parts

The number of sprayers required depends on the number of spray operators needed to complete the IRS cycle in the allotted timeframe. This will depend on the total number of houses to be sprayed, the average number of houses that can be sprayed daily, and the timetable of the spraying campaign. Sprayers should always carry sufficient spare parts for the equipment, and nozzles should be checked for wear at the beginning of every round and replaced as necessary. The best way to assess whether a nozzle needs to be changed is for it to be checked for one minute; if the outflow is more than 10% of the normal 757ml/min, then it is time to change the nozzle. Ideally, nozzles should be changed after spraying every 200–300 houses. Spray deposition patterns can be easily checked by spraying coloured water against a contrasting surface. The nozzle should be changed if the resulting spray does not produce a uniform pattern or if the volume sprayed is 10% more than the nozzle rating.

In addition to spare nozzles, programmes should stock other spare parts, especially gaskets, springs and lances, which can be prone to wear and damage. Spare part kits are available from the manufacturers. Spare parts and a system for sprayer maintenance and repair must be included in the annual procurement and planning.

Further details of how to check the sprayer and fill the tank ready for use in the field are given in Chapter 3, section 3.1.3.

### 2.4.3 Personal protection equipment for spray operators

Spray teams must be provided with adequate materials and these must be procured and delivered with sufficient lead-time to equip teams when they start training and preparing for field operations.

Core requirements for spray operators are:

- insecticides
- 8–10 litre compression sprayers
- sufficient spare parts
- protective clothing.

Additional requirements, depending on the situation, may include:

- tents
- camp beds or sleeping mats
- mosquito nets
- cooking utensils
- lighting.
Programme coordinators must develop and implement an inventory and stock control programme that includes a maintenance plan or replacement schedules for field equipment (sprayers, vehicles, and personal protection equipment).

Protective clothing includes:
- broad rim hat (protects head, face and neck from spray droplets);
- full face shields or goggles (protect eyes against spray fall-out);
- face mask/respirator (protects nose and mouth from airborne particles of the spray fall-out and serves to avoid inhalation);
- face shield (protects face from the spray fall-out and splashes);
- long sleeved overalls (keep overalls outside of boots);
- rubber gloves (protect the hands);
- boots (protect the feet);
- raincoat (protects spray operator when it is raining).

The spray operator should also be provided with the following:
- map of area showing the houses or structures to be sprayed;
- notebook and records;
- bag/satchel for carrying insecticide bottles or sachets;
- muslin cloth for sieving dirty water;
- plastic sheeting.

### 2.4.4 Inventory and maintenance of the equipment

A weekly, or at minimum monthly, inventory of equipment should be conducted during spraying. The final inventory at the end of the spray round should indicate any necessary repairs, replacements or other requirements. Developing and implementing routine daily and weekly cleaning, together with monthly maintenance schedules during spraying, will maximize the life expectancy and performance of sprayers. This is achieved by checking the flow rate of the nozzles as described above. Efforts should be made to provide adequate facilities and equipment for field maintenance and repair of compression sprayers. Sprayers and insecticides are expensive items. Routine cleaning and checking of equipment will prolong the life of the sprayers and ensure the economical use of insecticides.

In order to maintain and repair compression sprayers during and after each spray round, the programme needs to ensure it has identified equipment technicians and provided them with workshops and appropriate tools at designated centres. One member of each district spray team should be given extra training on equipment maintenance and should be responsible for troubleshooting. Training material for equipment maintenance is available in the overall IRS training package available through the WHO, or directly from the manufacturers. The same designated person should also prepare an inventory of sprayers and spare parts that will be needed for future IRS campaigns. At provincial level, sprayers are kept in a central location and are repaired by a technician. Alternatively, a technician will visit the sprayer storage facilities at district and, in some cases, sub-district level.
2.5 Organization and delivery of IRS campaigns

2.5.1 Performance targets

A ‘sprayable surface’ is defined as the inside surfaces of all structures or houses that should be sprayed. This includes eaves not exposed to rain, ceilings, under-floor areas in raised housing, and the inside walls of latrines. Other structures in the village outside the household compounds, and where there are no sleeping areas, such as schools (except boarding school dormitories) and shop houses, should not be sprayed, as these will attract very few malaria vectors.

The minimum spray team operational performance target is 80% of houses, structures or units targeted in any spray round; the ideal is 100%.

2.5.2 Management cycle

An effective IRS programme is based on a well-defined management cycle of operations which is linked to:

- the seasonality of malaria transmission
- the annual health planning and financial budgeting cycles.

The IRS management cycle (Figure 7) is an effective framework that outlines activities at different stages of the planning and delivery of the spray campaign. It also provides guidance for IRS coordinators and programme managers in the timely management of IRS operations.

**FIGURE 7**
IRS management cycle

Source: WHO
2.5.3 Phases of an IRS campaign

The four phases of an IRS campaign are:
- baseline appraisal for new programmes/post-season review for on-going operations;
- pre-season planning, procurement and preparation;
- season-implementation of IRS spraying;
- end of season recording, reporting and evaluation.

Phase-I: baseline (new programmes)/post season review (on-going programmes)
- baseline or annual epidemiological, entomological, demographical and operational situation- al analysis, including review and surveys of malaria burden and trends, vector ecology, popula- tion at risk, and coverage of IRS where available;
- annual update of geographic reconnaissance of target districts, including population at risk, and target household structures or units to be sprayed;
- operational assessment of insecticides, sprayers, transport. Review arrangements for stock control, storage and repairs.

Phase-II: pre-season planning, procurement and preparation
- inventory and estimate of annual needs for insecticides, equipment, spray teams, transport, fuel and funds;
- procurement of necessary equipment and insecticides;
- planning and preparation for schedule of spraying;
- organization and logistics for the spray teams, transport, commodities, and delivery;
- environmental impact assessment and pesticide management plans;
- plan IRS publicity, IEC and community mobilization;
- begin recruitment and cascade training of coordinators, supervisors and spray teams.

Phase-III: season-implementation of IRS spraying
- distribution of insecticides, sprayers, personal protection equipment and supplies;
- collection of baseline entomological data from both IRS targeted and comparable control sites;
- IRS implementation including supervision and reporting;
- conduct quality control of spraying using either WHO cone bioassay test or colormetric assay within one week of the start of the campaign.

Phase-IV: end of season recording, reporting and evaluation
- annual review of entomological monitoring and epidemiological surveillance;
- annual review of IRS performance, documentation and reporting.

2.5.4 Plan of action for operations

The management cycle of operations should be supported by a detailed plan of action (POA). The POA should have strong political support with the required financial and human resource investment to ensure timely procurement of commodities and the establishment of systems and structures, such as a multi-sector national IRS committee. Policies for requirements such as pesticide registration and compliance with environmental regulations, as well as labour policies for hiring temporary workers, need to be in place. It is essential that there are sufficient personnel with an adequate skills mix to implement effective annual or six monthly campaigns and achieve planned objectives.
IRS implementation requires good coordination and tracking with clear timelines. Securing finances and procuring commodities must be planned at least 6–12 months in advance. Spraying should be completed just before the onset of transmission, usually coinciding with the rainy season. Once the rains begin, roads may become impassable for spray teams and householders may be reluctant to place their belongings outside in preparation for the spray. The POA should include:

- defining the districts, towns, villages, houses and structures to be sprayed;
- estimating the amount of insecticide, equipment, transport, labour costs and other requirements;
- establishing spraying schedules, both for individual areas and for completion of the whole spraying round. The timing of the spraying should ensure that the residual life of the insecticide being used is at least as long as the transmission season (i.e. that IRS is not applied too early and thereby fails to provide coverage for the whole transmission season);
- clearly indicating the average number of houses or sprayable surface areas to be treated by spray operator (daily output of spray operator) and number of work week days;
- calculating financial expenditure and securing financing for operations;
- procuring all materials needed: e.g. insecticides, personal protection equipment, sprayers;
- calculating the number of spray operators, team leaders, and supervisors;
- recruiting and training of spray teams;
- assessing the status of transport and fuel, and developing mitigation plans for breakdowns and shortages;
- establishing finance and accounting systems for field operations, including systems for worker payments, e.g. bank accounts and mobile banking;
- arranging for spray team transport as well as transport for coordinators for their supervision duties;
- preparing district and sub-district malaria camps for storage and base operations;
- preparing clear terms of reference, salary structures and working conditions, codes of conduct and reporting structures for all staff involved in the spraying programme;
- preparing supervision schedules and supervision checklists including those relating to pesticide management and environmental compliance;
- preparing a plan for the collection, accounting and disposal of empty insecticide sachets and containers;
- informing, educating and mobilizing local authorities and communities;
- preparing reporting systems and appropriate reporting forms;
- tracking progress towards achieving the activities and objectives.

Throughout the planning process, technical goals need to be within the scope of the finances and human resources that are available. There are numerous examples of programme failure due to underestimates of insecticide quantification or of personnel and fuel costs, or where the expected staffing support from partners did not materialize.

The POA should be developed in consultation with experts from the ministry of health (e.g. in the areas of epidemiology, entomology, human resources, finance, and logistics) and other ministries, such as agriculture and the environment, as well as national pesticide regulatory authorities, partner NGOs and private sector entities. There must be open communication between the IRS staff, the rest of the health system and the community. A timeline for implementation of IRS is available in Annex A1.4 and an RBM IRS Toolkit is also available at http://www.rbm.who.int/toolbox/tool_IRStoolkit.html.
2.5.5 Financial Planning for IRS

The annual cycle of IRS operations requires preparation of financial plans or proposals based on estimated needs of insecticides, equipment, human resources, logistics, travel, per diem for coordinators and supervisors, etc. These estimates are based on the number of spray rounds per year, the number of houses, rooms or structures to be sprayed and the planned duration of the spray campaign.

2.5.6 Costing, budgeting and financing

Every IRS operation must have a budget for:

- baseline and routine entomological monitoring;
- mapping and geocoding of target areas;
- insecticide and equipment, including sprayers and personal protection gear;
- supplies such as tools, spares and replacement parts;
- transportation (vehicle rental, fuel, insurance, drivers);
- warehousing, camp or staging areas and maintenance repair facilities, including lease and site management costs;
- staff salaries, per diems and benefits;
- partnership collaboration, including advisory committees and entomological monitoring networks;
- managerial costs;
- contingency funds.

As outlined in the framework for integrated vector management (IVM), programmes should aim to optimize resources for vector control including, where possible, collaborating with other ministries, with civil society and with the private sector to enable an efficient and cost-effective IRS operation. The plan should include identifying sources of funds and in-kind contributions (such as warehousing and transport), whether from central government, from local government budgets, or from other sources.

A contingency fund, generally estimated as 10% of overall budget, should be available in the event of there being more targeted structures than initially estimated, or of price increases in fuel, salaries, or insecticides. An example of capital and operational budgets for IRS can be found in Annex A1.5.

2.5.7 Checklist for tracking POA implementation

IRS implementation requires careful tracking with clear deadlines for completion of activities before the start of the malaria transmission season. A checklist will help ensure that all areas of the programme are in place or have been duly considered.

2.5.8 Timing and duration of spray rounds and cycles

The timing of spray rounds is critical and depends on the seasonality of vector populations and malaria transmission. These are related to weather, especially rainfall, humidity and temperature. Spraying cycles can be designed to control one major peak transmission in low to moderate transmission areas or for year round transmission in high transmission areas.

**Spray round**

Effective spray round implementation should be:

**Total:** all the dwellings are sprayed;
**Complete:** all sprayable surfaces are covered;

**Sufficient:** uniform application of the required dose to all sprayable surfaces;

**Regular:** spraying should be at regular intervals so as to ensure that an effective residue is in place during the whole malaria transmission season.

### Spray cycles

The spray cycle is the time between consecutive spray rounds. If the malaria season lasts only three months and the insecticide used persists for three months or more, then spraying should only be done once a year. In areas where malaria transmission occurs throughout the year, at least two spray rounds may be needed to cover the whole transmission period. However, DDT and new Capsule Suspension (CS) insecticide formulations have been shown, in some areas, to last more than ten months. In areas with perennial transmission, where there is high LLIN coverage, it may not be necessary to apply two rounds per year. If a single spray round is carried out, it should target the major peak transmission period.

Ideally, spray operations should be completed in less than two months with a weekly work routine of 5–6 days on and 1–2 days off. Programmes need to ensure adequate numbers of spray operators to complete the spray round within the stipulated time.

The seasonality of onset of the rains (and malaria transmission season) often varies from one part of the country to another. Monthly malaria surveillance data should be analysed and areas stratified to ensure that the critical areas are sprayed before the onset of the rains.

### 2.5.9 Programme organization

In most country settings, the national malaria control programme should direct and coordinate provincial or state IRS operations. A vector control officer should be designated as the IRS focal person at each level. Central or provincial technical support in entomology and epidemiology should be made available during the planning, monitoring and evaluation of district IRS operations. The national and provincial IRS focal points should be supported by a national vector control or IRS vector control technical advisory committee and a network of research and academic institutions with a central entomology laboratory.

Responsibility for planning and decision-making and other aspects of malaria control depends on the administrative structures of the central and local governments. Responsibility for implementation may be localized at the district level, regionalized and completely vested in the ministry of health, or may be shared, at the district level, with local government structures such as local councils, municipalities and town boards.

#### Organizational chart

In order to calculate the human resources needed, an organization chart should be developed. The organization will depend on the size of the area to be sprayed, the distance between target houses, the difficulty of the terrain, and the target timeframe for completion of the spray round. See Annex A1.7 for examples of IRS operations organizational charts.

#### IRS multi-sectoral task force

Indoor residual spraying is a labour-intensive field operation. In order to ensure that sectoral coordination concerns are addressed a task force needs to be assembled. This will comprise high-level policy makers across sectors such as ministries of local government, agriculture, environment, transport, communications, education, finance and labour. This task force should ideally meet quarterly during the preparatory periods and monthly during the two-month spray period.
Vector control technical advisory committee

An advisory committee should be established, made up of members of the national vector control unit, and with the national IRS coordinator in the malaria department to provide support on policy, technical and programmatic issues. They will also provide guidance on selection of districts for IRS and of insecticides and equipment, on monitoring of coverage rates and will provide support for spray round reviews and programme evaluations. The advisory committee should also include representatives from other sectors such as ministries of environment and agriculture, as well as representatives of the private sector (who may support IRS as part of their workplace protection programme). The committee should meet regularly during the preparatory planning period for each spray round in order to ensure timely preparation of estimates of insecticides and financing. It should then meet as frequently as necessary during the spray round to ensure timing and quality are maintained.

Provincial or state and district malaria control officers, as well as IRS coordinators, should be invited to meetings to review the planning and implementation progress as well as to identify and propose solutions for problems that arise in the field.

The structure and organization of campaigns may vary from centralized programmes with operations managed at the national level, to decentralized programmes where operations are managed at the provincial or district levels. There have been some programmes, e.g. in Ethiopia, where IRS has been successfully managed at the community level by health extension workers, with two workers per village of 5000 people. The main role of these health extension workers has been to lead health promotion and preventive activities. After being trained in IRS and provided with insecticide and with personal protective and spray equipment, the health extension workers then recruited, trained, and led spraying in their catchment areas.

The IRS structure may be part of the national ministry of health system or may be part of local government, such as district, town or municipal councils. In all situations it is important to develop organograms illustrating the location of staff according to duties and as a way of visually linking duties to individuals. The IRS structure is summarized in Table 5 below.

Responsibility at national level

The national malaria control programme manager coordinates the overall programme implementation with responsibilities delegated to a national vector control or IRS coordinator working with the national entomologist. As outlined above, the national coordinator is usually supported by a national vector control or advisory committee, and by a national research institution with a central entomology laboratory.

Duties at national level include:

- preparing national IRS proposals, planning, coordination, formulation of policy;
- setting standards and preparation of operational guidelines;
- providing IRS technical advisory services and providing feedback for remedial action where appropriate;
- maintaining a database on epidemiological, entomological, demographic and operational information with integrated GIS;
- managing of resources for IRS by defining specifications and procuring insecticides, sprayers, transport;
- securing staffing and financing;
- managing the finance and accounting systems for operational field costs (note in some countries this is managed at the local government level);
- organizing distribution of supplies, including insecticides;
- monitoring and coordinating all IRS activities carried out by the provinces/states and related agencies and providing feedback for remedial action;
### TABLE 5
IRS operations structure and systems

<table>
<thead>
<tr>
<th>LEVEL OF HEALTH SYSTEM</th>
<th>RESPONSIBLE OFFICER</th>
<th>TASKS</th>
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| National               | National IRS coordinator (1)  
                         | National Entomologist (1)  
                         | Data Manager (1)  
                         | Financial Manager (1)  
                         | Logistician (1)  |
|                        |                     | • overall quality control;  
                         |                     | • IRS policy;  
                         |                     | • IRS proposal and plans;  
                         |                     | • IRS guidelines;  
                         |                     | • monitoring and evaluation;  
                         |                     | • budgeting and securing finance;  
                         |                     | • managing finance and accounting systems;  
                         |                     | • estimation of commodities and transport needs;  
                         |                     | • managing central stores and stock control;  
                         |                     | • training provincial and district coordinators;  
                         |                     | • central procurement and quality control;  
                         |                     | • support for vector sentinel sites (vector ecology, bioassay, susceptibility studies);  
                         |                     | • operational research. |
| Provincial             | Provincial IRS coordinator (1)  
                         | Provincial Entomologist (1)  |
|                        |                     | • plans of action;  
                         |                     | • developing and evaluating information education and communication materials (IEC);  
                         |                     | • coordination and supervision;  
                         |                     | • monitoring and evaluation;  
                         |                     | • cascade training district supervisors;  
                         |                     | • equipment repairs. |
| District               | District IRS coordinator (1)  
                         | District IRS operations coordinator (1)  
                         | Entomology technician (1)  
                         | Data manager and data entry officers  
                         | District IRS logistician and equipment technician (1)  
                         | District finance and payroll officer (1)  |
|                        |                     | • plans of action;  
                         |                     | • monitoring and evaluation of field operations;  
                         |                     | • budgeting and securing finance;  
                         |                     | • managing finance and accounting activities;  
                         |                     | • estimation of commodities and transport;  
                         |                     | • stores and stock control;  
                         |                     | • equipment inventory and repairs;  
                         |                     | • selection and recruitment of field team;  
                         |                     | • field training of team leaders and spray operators;  
                         |                     | • supervision;  
                         |                     | • reporting;  
                         |                     | • running vector sentinel sites (vector ecology, bioassay, susceptibility studies). |

- ensuring IRS multi-sectoral cooperation;  
- identifying IRS training needs and organizing training of trainers (TOT) sessions;  
- planning IRS operational research (when required) and collaborating with research institutes and universities.  

**Responsibility at provincial/state level**

The provincial malaria control officer and an IRS officer coordinate the implementation of the IRS programme in all the districts and help to put policies and guidelines from the national level into practice.
Duties at provincial level include:

- planning and management of IRS operations in target districts;
- providing estimates for operational requirements of insecticides, equipment, human resources and finance at provincial level;
- providing support and training to district coordinators;
- providing scheduled supervision of IRS district coordinators;
- taking responsibility for tracking implementation in each of the districts;
- reporting on coverage and quality of IRS in districts;
- supporting district entomological monitoring (vector types and susceptibility).

Responsibility at district level

The district health officer, district malaria coordinator or district IRS coordinator is in charge of the implementation of all IRS operations and activities within the district. At operational level, IRS activities are managed through the sub-district field coordinators and malaria spray team group leaders.

Duties at district level include:

- implementing day-to-day running of IRS operations;
- recruiting and managing IRS control personnel;
- coordinating and/or conducting annual training;
- costing, budgeting and financial reporting;
- managing payroll, local rentals and other operational costs;
- estimating overall operational requirements of IRS in the district;
- monitoring and evaluation of the quality of interventions;
- updating geographical reconnaissance information;
- ensuring security and safe use of insecticides, equipment and transport;
- implementing information, education and communication activities.

Ministry of environment and ministry of agriculture representatives should ideally be included on the district supervision teams, especially in countries using DDT, to make sure the insecticides are managed properly and that all rules and regulations on safe use and disposal are followed.

Supervision

District IRS coordinators should directly supervise operations at ground level. Provincial coordinators should oversee monthly operational review meetings and give appropriate guidance to the district coordinators. Spray operations are logistically and technically demanding and it may be necessary for provincial and national coordinators to maintain strong vertical tracking and close supervision to ensure quality implementation of IRS programmes.

Organizing spray teams

In order to achieve greater than 80% spray round coverage in a timely annual implementation (usually less than two months), programmes must include an adequate number of IRS teams, each of sufficient size and with appropriate field supervision and district coordination, as outlined below.

At the planning stage, the number of spray teams required should be calculated based on: the time available to conduct spray operations; the total number of housing structures or units to be sprayed; and the number that can be completed by one operator in one day, taking into account the travel distance between structures and the actual size of the sprayable surface per structure. Spray teams may be allocated specific areas to spray in each district. This is done to ensure that every village is covered and that teams do not have unmanageably large areas to spray, which
could lead to spray operators being so dispersed that supervision and re-supply becomes a problem. Detailed spraying schedules showing planned movements, activities of spray teams, the site of malaria camps, and areas for IRS should be mapped out. It is important that community, leaders and local authorities are consulted when preparing these schedules. In some cases, the target spraying areas will be close enough to the homes of spray operators, such that they can carry out their work during the day and return to the central depot, clean and store their equipment, and return to their homes at night.

**Number size and composition of spray teams**

The number of spray teams per district ranges between five and ten, depending on how many structures need to be sprayed during a six-to-eight week spray campaign. A *single spray team* is one unit and the number of spray teams required depends on the areas that have to be covered. The composition of a team is as follows:

- **one team leader** whose function is to record and report on the households and housing rooms/units to be sprayed and on those missed for follow up mop-up spraying;
- **five to ten spray operators** (with smaller teams highly preferable in cases where the personnel are less experienced and require greater supervision or where the areas to be covered are spread over a wide geographic area), each with their own compression sprayer and an adequate supply of insecticide charges for the day;
- **one ‘warner’** or community mobilizer. This is a role undertaken by a paid casual worker who communicates with local leaders and who also informs the householders that the spray is about to take place so that they can make the necessary preparations;
- **one driver** with a vehicle capable of safely and comfortably transporting the spray team, their equipment and approximately 250 litres of water;
- **one group leader/supervisor** to coordinate 3–5 spray teams.

In cases where households are both easy to access and near to each other, one spray operator should be able to spray between eight and ten (up to fifteen in some locations) households a day. This may fall to as low as five per day in areas where houses are scattered and separated by long walking distances or where there are very large houses.

The number of houses in each district divided by the number of working days in the two- or three-months spray round timeframe equals the number of houses to be sprayed in each working day. This number, divided by the number of houses that can be treated per spray operator per day, gives the required number of spray operators for that district. Assuming a five and a half day working week (with Saturday afternoon and Sunday off), there will be 48.5 work days in two months, assuming there are no holidays during this period.

The number of spray operators required for a two month spray cycle should include a 5% cushion to allow for absences and unforeseen events.

District and sub-district coordinators, in consultation with community leaders and local authorities, are required to recruit spray operators and train them to handle insecticides safely and to accurately apply insecticides under local conditions.

Spray team leaders and squad/group leaders or supervisors must check that the amount of insecticide sprayed on walls is sufficient and completed according to recommended standards. Spray teams should be instructed to implement total coverage of all units and rooms. This entails searching out and spraying every single sprayable structure.

Spray operators are often casual workers or individuals who are employed from a community district for just two to three months. This period covers both training and implementation of the spray operation. The contracts for these operators may be done through the ministry of health or any local authority. In some situations an implementing partner (such as a bi-lateral donor,
an NGO or a private sector company) takes responsibility for IRS. Spray operators should be at least 18 years old, be physically fit and healthy, have no obvious disabilities that would limit his or her mobility, be able to read and write the national language (so they can read the label and follow emergency procedures if needed), and be able to operate the sprayer. The operator should be a responsible person who can work under minimum supervision and be able, where possible, to read and write. Women who are breastfeeding or are pregnant are not able to work as spray operators. In addition, any woman who becomes pregnant during the campaign should be reassigned to duties other than spraying.

Spray team members have a duty to always act in a professional manner towards each other and maintain good relations with the local community members. For this reason spray operators are drawn from their own communities and vetted by the community members. Their behavior and demeanor should be beyond reproach. A “code of conduct” for spray operators and team leaders is included in Annex A1.6 (19).

**Daily routine of spray teams**

The daily routine of a spray team includes the following.

- The spray team leader checks the spray team every morning to verify that they are all wearing clean protective clothing, and to provide them with a briefing of where they will be spraying that day.
- Each spray operator prepares his/her hand compression sprayer for review and inspection by the spray team leader. In addition, the spray team leader ensures that the spray operator has all the necessary personal protection equipment and that it is in good working order.
- The spray team leader checks the amount of insecticide in numbered sachets that each spray operator requires for the day and ensures that he or she has all the necessary information and recording forms for the day’s work.
- The spray team then proceeds to work using the transport assigned.
- Upon arrival in a targeted village, the spray team leader allocates a number of houses to each spray operator.
- The spray team leader arranges sleeping accommodation with the community leader if the team are required to stay overnight in the village. In some areas, teams will establish malaria field camps and will be provided with camping equipment.
- At the completion of the day’s work, the spray team leader ensures that each spray operator properly and safely disposes of any remaining insecticide in his or her sprayer following the progressive rinse method, and that he or she thoroughly cleans his or her sprayer at a designated wash point.
- The spray team leader will run the evening de-briefing and check on insecticide use, on the return of empty sachets and on the handing in of daily recording forms.

**Occupational protection and safety for IRS spray teams**

Spray operators are required to wear protective clothing when handling insecticides and during all spray operations. Absorption of insecticide occurs mainly through the skin, lungs and mouth. Specific protection clothing must be worn in accordance with the safety instructions on the product label (see Section 2.4.3).

Upon completion of the day’s activity, all protective clothing, including boots, should be washed. If overalls are accidentally contaminated, they should be removed immediately and washed as soon as possible.
Supervising spray teams and spray operations
IRS requires guidance and support from all involved senior officials at district, provincial and national levels, especially the IRS coordinator. This support and supervision should be provided routinely and consistently throughout the period of the spray round. Inspections should be carried out using standard forms and checklists to ensure uniformity and accuracy.

Spray operators and teams should be constantly monitored to ensure that team tasks are on schedule, that there is a high quality of spraying of individual housing units, and that coverage is high.

**Purpose of supervision**
The overall purpose of supervision is to ensure that high quality IRS is delivered and that high coverage is achieved. Specifically, supervision aims to:

- ensure that the planned work schedule is strictly adhered to;
- take corrective measures on the spot, especially where technical deficiencies are concerned;
- stimulate, encourage and advise on effective functioning of the field work;
- ensure that strict discipline is maintained;
- assess, evaluate and acknowledge the work output of individuals;
- make recommendations, report and follow up.

**Supervisory tools**
These include forms, reports, records, graphs, and charts to monitor operations. See Annex A1.13 for a sample supervision checklist.

**Training for IRS coordinators and spray teams**
A successful IRS spraying campaign depends on the application of an adequate and uniform dosage of insecticide on all possible resting places of the adult female mosquito. This requires appropriate training of spray operators, team leaders and group team leaders or supervisors, as well as sub-district and district coordinators.

**Institutional training for IRS coordinators**
Formal IRS training of trainer (TOT) courses for district, provincial and national IRS coordinators should be conducted by the ministry of health and implementing partners as short practical courses and workshops. Generic IRS training materials are available through WHO, RBM and the US President’s Malaria Initiative.¹

This training should include the following topics:

- understanding what IRS is; why, where and when it is used;
- the role of baseline entomological surveys;
- conducting GR and census of spray areas and houses or structures;
- insecticides used for IRS and related safety precautions;
- spray application equipment, its maintenance and inventory;
- developing an IRS plan of action;
- conducting a house spray;
- tracking, supervising and implementing spray rounds;
- reporting on progress and performance of an IRS campaign;
- principles and requirements of safe and appropriate pesticide management.

Field training for IRS supervisors and spray operators

Field training of all spray operators immediately before the beginning of each spray round must be provided. The technical skills of spray operators, team leaders and group leaders or supervisors must be updated regularly. Malaria programmes should establish field training centres strategically placed in the districts for this purpose.

The annual practical training of spray operators should focus on developing the necessary skills for adequate spraying, especially spray timing, spray pattern, deposition overlap, and personal and environmental safety.

The training course should be subdivided into several sections and should take place over five to seven days. No time limit should be set on how long each individual section takes to complete, as this will vary according to the trainees’ readiness and skills. However, three to five days should be dedicated to the practical portion of the training.

The purpose of training should be to ensure all personnel involved in IRS understand their tasks and responsibilities and are made aware of their responsibility to their colleagues, the environment and the community. They undergo training to enable them grasp the concepts of:

- what IRS is and why, where and when it is used;
- the insecticides and their safety precautions;
- the use of spray equipment, its handling, care, transportation and storage;
- dismantling and reassembling a sprayer;
- preparing the sprayer;
- sprayer pressurization and calibration;
- preparing a house for spraying;
- sequence of spraying in a house;
- practice spraying with water i.e. nozzle distance, agitation, speed or rhythm of spraying, sequence of swaths, and achieving and maintaining correct pressure;
- how to complete the house cards and required daily reporting forms;
- how to explain the objectives of the IRS programme to householders and how to answer any questions asked.

Training wall

The periodic practical training of spray operators includes, among other activities, spraying of a training wall with water. The IRS training wall helps operators to focus on two areas: teaching them how to maintain the exact distance from the nozzle tip to the surface being sprayed; and how to spray at the correct rate and keep up the speed of application over the surface. To accomplish this:

1. The trainer marks an area 3m high and 6.35 m long, divided into 9 bands, the first one 75 cm wide and the remainder 70cm wide. Note that the spray nozzle will provide a spray swath or spray pattern 75 cm wide if kept at distance of 45 cm from the wall.
2. To practise keeping the nozzle 45 cm from the wall, a wooden or plastic extension is fitted to the lance. The length from the nozzle tip should be 45 cm.
3. The spray operator stands directly in front of the wall, with right arm extended and body inclined towards the surface while raising or lowering the right arm so that the end of the stick remains in contact with the surface.
4. The spray operator should start at the top corner of the wall and spray at a uniform rate, moving downwards to the bottom. He/she takes one step to the right and continues spraying. The next swath should overlap with the previous one by about 5cm. The operator should spray down to the bottom.
5. At the end of each swath, the spray operator stops the flow of insecticide steps one metre to the right.
6. The spray operator continues in this way until the entire area of 19 square metres is covered. Each swath of 3 m in height should be covered in about 7 seconds, or 9 swaths in one minute to cover the whole area.

**Spray training practice**

During the training, spray operators should try working under real conditions in order to practise spraying different parts of a structure such as wall space, above and below heavy furniture, ceilings etc.

**Training of team leaders and supervisors**

The first-line group leaders should be trained to carry out the same tasks as the spray operators. In addition, they should be trained to carry out GR, record keeping, reporting, public relations and sessions on basic health messaging related to malaria and IRS. This will enable them to provide supervision.

### 2.5.10 Equipment and logistics for spray teams

IRS spray teams require that sufficient materials and supplies be procured and delivered in time for training and preparation for field operations. Core requirements are insecticides, hand compression sprayers with adequate spare parts, and protective clothing for spray operators. Other equipment for spray teams may include tents, camp beds, sleeping mats, mosquito nets, cooking utensils and lighting.

IRS coordinators must develop and implement a stock inventory with a maintenance plan or replacement schedules for field equipment (hand compression sprayers, vehicles and personal protective equipment). See also Section 2.4: IRS application equipment.

### 2.5.11 Transport

IRS operations require vehicles for moving equipment, materials and personnel over different areas of a district during the period of the spray round. Given the difficulties of accessing many areas during the rainy season, it is best that spraying rounds are completed before this begins.

Spray teams have to be moved between malaria field camps and between different locations during spraying operations in order to cover all households. The minimum requirement is one to two 3-5 ton trucks per district to service five to ten spray teams. When areas to be covered are small and the number of teams is small, a 4x4 pickup may be assigned to one spray team to carry the operators, spray equipment and materials. Supervisors and district coordinators should be provided with motorcycles. Provincial and national coordinators should be provided with 4x4 pickup vehicles.

### 2.5.12 Communication equipment

To improve management, supervision, tracking and reporting of spray teams, the use of VHF radio-communication or a cell phone system for district coordinators, supervisors and group leaders should be considered.

### 2.5.13 IRS field camps

As each district will have five to ten spray teams that move around different areas over the two to three months of the operation, it is important to set up temporary field camps at strategic locations. Some of these field camps may also become permanent storage, equipment repair and training facilities for districts and provinces.
2.6 Information, education, communication (IEC) and community mobilization

The public needs to be kept well informed to ensure full support and cooperation with any IRS activities. IRS programmes should always have an effective advocacy and public health promotion component to ensure widespread acceptance and support at household and community level. This requires an ongoing dialogue between those coordinating IRS programmes and community and local government leaders, together with other sectors such as local government, agriculture, and education. Professional guidance should ideally be sought from health educators, health promoters and social scientists to develop information, education and communication (IEC) strategies and to conduct IEC campaigns before the start of each spray round. Focus group sessions should be held to define how IRS is justified to the public, to anticipate areas of concern, and to develop key messages.

2.6.1 IRS advocacy

IRS constitutes a public health service that is provided at regular intervals to every household. It is labour intensive and, when properly implemented, lends credibility to health services and to government. As such, it has political and policy-setting potential, which can be maximized through periodic IRS campaign launches and IRS campaign closing ceremonies held in strategic locations and featuring national and international celebrities.

2.6.2 IEC campaigns

IEC campaigns should be carried out before spraying operations are launched countrywide or in specific districts in order to: raise awareness around IRS; facilitate community mobilization; ensure acceptance of IRS; and encourage participation in IRS operations at the family and household level.

IEC campaigns use simple messages that are consistently reinforced through different media. Educational materials such as pamphlets, posters and cartoons need to be produced and widely distributed. Where possible, these should be supported by radio and TV spots.

Meetings organized by community leaders to explain the procedures and benefits of IRS programmes should be one of the tools used in health education and should include:

- how insecticide application impacts on malaria, including the duration of activity on the sprayed surfaces;
- the fact that spraying does not harm walls, ceilings and furniture;
- the fact that spray operators are responsible people who will take care of people’s property;
- the need for the participation of householders in preparing their houses for spraying and complying with instructions;
- the fact that insecticides used are not hazardous to humans, dogs, chickens, cats or other domestic animals especially if the precautions outlined by the spray operator are followed;
- instructions to house owners not to re-plaster or wash sprayed walls for a few months after spraying and until the peak malaria season is over.

2.6.3 Community participation

For a spraying programme to be successful, people must be informed of the benefits of protection against malaria-carrying mosquitoes that is afforded by residual house spraying. The higher the percentage of houses completely sprayed with residual insecticides, the better the protection afforded to the entire community.
Target groups for community mobilization include:

- traditional leaders
- political leaders
- religious leaders
- civil society leaders
- women’s group leaders
- youth leaders
- school children

Every effort must be made to enlist the cooperation of each household. This requires obtaining community leaders’ and householders’ agreement before initiating an IRS programme in a locality/village. There should be opportunities for community members to debate issues, seek advice and arrive at a consensus of opinions and approaches. Community meetings should emphasize the procedures of an effective programme. Ideally local spray operators should be employed or a local community leader or resident should accompany spray teams to secure full householder cooperation.

Household and community cooperation with spray teams is needed to:

- assist in ensuring water is made available for mixing insecticides;
- assist in clearing and covering household furniture before spraying;
- allow evaluation procedures to take place and, if required, assist with the set up and management of mosquito window traps or CDC light traps;
- take an active role in the execution of IRS to make sure it is done on time and ensuring all household structures are treated by the spray operator.

### 2.7 Reporting on progress and performance

Efficient and accurate reporting is a critical element of any IRS program. It is critical for gauging the effectiveness and efficiency of the programme and is vital to its sustainability.

Accurate recording during the planning and implementation of an IRS campaign will generate information on management effectiveness and performance in terms of coverage and impact. The main activities related to this are:

- daily recording and weekly and monthly reporting on structures and populations covered, amount of insecticide used, problems encountered in implementation and proposed solutions. Note that some programmes implement daily summaries by telephone from the team leader to the district manager to report key indicators and spray operator daily output;
- review of IRS spray operations, calculation of structure and population coverage;
- monthly assays on the quality of IRS at sentinel sites or villages;
- regular entomological monitoring at sentinel sites or villages, including vector composition and density, and feeding and resting behaviours;
- insecticide susceptibility monitoring, on an annual basis at least;
- planning and financing of subsequent IRS spray rounds;
- updating GR and mapping records.

In order to facilitate efficient recording and reporting of information, clear and simple data collection forms, entry forms, analysis tables as well as report templates, should be developed. Handheld PDAs and computers with spreadsheet, database and mapping software can be used to speed up manual data recording, storage, analysis and reporting. This will contribute to rapid, efficient and effective management.
2.7.1 IRS programme performance

Malaria programme managers, IRS coordinators, group team leaders and field supervisors must track the performance of IRS interventions in order to assess their progress in relation to targets. These targets are primarily coverage of the targeted rooms or structures, households and populations at risk from malaria. Epidemiological impact should be monitored through Health Management Information Systems (HMIS) or sentinel facilities.

The main outputs of IRS are:

- the number of rooms and structures sprayed and unsprayed as compared to target number;
- the number of people protected through structures or houses sprayed.

The objective of an IRS spray round is to achieve a minimum of 80% coverage of targeted structures, houses and population at risk.

2.7.2 Methods of programme performance measurement

Entomological baseline surveys on vector density, distribution, biting and resting behaviours, and susceptibility, must be conducted before IRS begins (see Section 2.2). This supplements the situation analysis through rapid review and collation of existing information from past programme records, other surveys and research studies.

Routine reporting relating to IRS access and coverage should be undertaken, with reporting forms completed daily, weekly and monthly by spray operators. During spray operations, these reports are used to track and report on structure, house and population coverage indicators. Daily supervision of spray operators by team leaders and supervisors should be conducted to ensure they comply with standard operating procedures.

Provincial and district coordinators should conduct random sample surveys of one in 10 households to cross-check the validity of reported coverage, the quality of spraying, and household perception.

WHO cone bioassays (preferably using susceptible anophelines from insectaries) should be used to measure the quality of application of spray. If this is not possible, field-collected susceptible anophelines can be used. Colormetric Assays, which do not depend on live mosquitoes for a bioassay, are under development. These will be able to quickly quantify in the field the amount of insecticide on the wall surface. When they become available, these Colormetric Assays should enable programmes to increase the speed and ease of quality assurance of IRS programmes.

Insecticide susceptibility testing should be conducted annually, to verify that the insecticide being used is still effective.

Field entomology teams are required to assess operational effectiveness in different areas and to manage sentinel sites in different ecological zones. These sites enable the teams to monitor and detect changes in trends in vector composition, density, behaviour and susceptibility.

IRS coordinators should seek support to establish central and field insectaries. They should also collaborate nationally and internationally with research or academic institutions and with insecticide resistance networks to support the above areas of performance measurement.

2.7.3 Routine operational performance indicators and performance targets

Once a spraying operation has been carried out, checks must be made to ensure that the spraying coverage is complete, that no structures have been missed, and that all sprayable surfaces within those structures have been covered. Every effort must be made to ensure good supervision of the spraying operation and that an efficient recording and reporting system is in place.
Coverage

The percentage of houses and rooms sprayed in relation to the targeted number of houses or rooms should be regularly calculated. Coverage below the pre-defined target indicates operational shortcomings and appropriate action should be taken to overcome constraints and achieve high coverage. The proportion of houses re-plastered or missed (or closed) during spraying needs to be recorded and followed with mop-up operations.

**TABLE 6**  
Core IRS operational performance indicators

<table>
<thead>
<tr>
<th>NO.</th>
<th>INDICATOR NAME</th>
<th>METHOD</th>
<th>FREQUENCY</th>
<th>APPLIED TO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Number of structures/houses to be sprayed and not sprayed (Number of structures/houses sprayed)</td>
<td>Malaria programme IRS reporting system</td>
<td>Daily and weekly</td>
<td>Structures/houses</td>
</tr>
<tr>
<td>2</td>
<td>Proportion of structures/houses sprayed in relation to those not sprayed (proportion of structures/houses sprayed in relation to those targeted for spraying)</td>
<td>Malaria programme IRS reporting system</td>
<td>Daily, weekly and end of spray round</td>
<td>District, province/region, country, global</td>
</tr>
<tr>
<td>3</td>
<td>Proportion of structures/houses not sprayed in relation to those targeted for spraying</td>
<td>Malaria programme IRS reporting system</td>
<td>Daily, weekly and end of spray round annually</td>
<td>District, province/region, country, global</td>
</tr>
<tr>
<td>4</td>
<td>Number of people living in structures / houses which have been sprayed</td>
<td>Malaria programme IRS reporting system</td>
<td>Daily and weekly</td>
<td>Structures/houses</td>
</tr>
<tr>
<td>5</td>
<td>Proportion of population at risk of malaria protected by IRS</td>
<td>Malaria programme IRS reporting system</td>
<td>Annual</td>
<td>District, province, country, global</td>
</tr>
<tr>
<td>6</td>
<td>Proportion of districts at risk of malaria covered by IRS</td>
<td>Malaria programme information system</td>
<td>Annual</td>
<td>Region, province country</td>
</tr>
</tbody>
</table>

Calculating coverage

The number of houses or structures that have been sprayed or left unsprayed will be derived from daily and weekly spray operations reporting.

- The coverage is calculated by dividing the total number of houses or structures actually sprayed during a round by the total number of houses or structures that were targeted or found.

Malaria IRS house cards

A household record card should be given to each household during the GR and census, and should be updated during every spray round. It should include the house location and identification number, the name of the head of household, the number of residents, the number of rooms, the date of spray, the insecticide used, and the names of the spray operator and team leader together with their signatures. See Annex A1.2 for an example of an IRS house spray card.

Routine reporting forms

Standard reporting forms should be used by spray operators, team leaders and district coordinators to report, supervise and monitor IRS operations. Daily spray cards are submitted at the end of the day to the spray team leader who records and checks the performance of his six to ten spray operators. A weekly summary record is maintained by IRS sub-district coordinators who track two to five spray teams and measure their weekly progress in relation to the total planned targets for the spray rounds. The district coordinators prepare monthly reports on the districts’ spray operations. See Annex A1.8, A1.9 and A1.10 for sample forms.
The daily spray operator’s reporting form should contain:

- name and ID number of the spray operator and team leader
- location identification, family name, address, geo-code
- number of residents
- number of mosquito nets available
- number of rooms/units sprayed and unsprayed
- if unsprayed, for what reason, e.g. locked or refused
- name of insecticide used
- number of charges/sachets used
- number of sachets returned empty.

The team leader’s daily summary spray reporting form should contain:

- team leader’s name and ID number
- names and ID numbers of the spray operators in his/her team
- total number of houses sprayed and unsprayed by each spray operator
- number of residents in the houses sprayed
- total number of houses with nets available
- total number of rooms/units sprayed and unsprayed
- total amount of insecticide used by the spray operators
- total number of charges/sachets used by the spray operators
- total number of sachets returned empty by the spray operators.

The district coordinator’s monthly spray reporting form should contain:

- district coordinator’s name and ID number
- total number of spray operators and team leaders in the district
- total number of houses sprayed and unsprayed in the district
- total number of people in sprayed and unsprayed houses in the district
- total number of houses with nets available
- total number of rooms/units sprayed and unsprayed in the district
- total amount of insecticide used in the district
- total number of charges/sachets used in the district
- total number of sachets returned empty in the district.

2.7.4 Evaluation of coverage quality and impact

IRS household survey

District coordinators should conduct household surveys as part of their evaluation of operational coverage at the end of the spray round. These household surveys, when compared with the routine reports of the spray campaign, provide a figure for the actual coverage. These surveys can also be conducted as ‘representative’ sample surveys and combined with periodic malaria indicator surveys and other health surveys, and with other broader demographic surveys such as Demographic and Household Surveys (DHSS) or Multi-Indicator Cluster Surveys (MICS), as long as all samples are drawn from areas that were targeted for IRS.

Entomological performance indicators

Entomological monitoring is a key component of IRS programmes providing essential information on the presence of vectors, insecticide susceptibility status, quality of the spraying, and the impact of IRS on the vector population.
Vector dynamics

Vector Species
It is essential to know which vector species are present in the target area. Mosquitoes can be sampled from at least one or two sentinel sites per district. Full-time entomological technicians and mosquito collectors or field workers should make collections prior to the beginning of spraying and, if possible, on a monthly basis during the transmission season. These collections will provide a measure of the impact of the intervention on the vector.

All mosquito specimens should be separated by location and identified using standard morphological keys. When sibling species are present, for example both An arabiensis and An gambiae s.s., approximately 10% of female anophelines collected should be separated in numbered vials with silica gel desiccant. These should be sent to national or regional entomological reference laboratories for polymerase chain reaction (PCR) processing to confirm morphological identification. Captures resulting in small numbers (fewer than 20 individuals) should be sent in total for confirmation. Note that when conducting susceptibility tests, all specimens must be identified to the species level and not just to the species complex level (i.e. senso lato).

Vector density
Many methods exist for sampling mosquito populations to determine adult density. These include indoor knockdown collections using pyrethrum sprays, and direct collection from baited traps, light traps and exit traps. Collectors should take into consideration the specific inherent biases for each collection method. The concurrent use of several different collection methods may overcome some of these biases and allow sampling of populations to result in collections of vectors that have different behavioural characteristics and occupy different habitats.

Vector Resting
Knockdown collections using pyrethrum-spray sheet methods and aspirator collections of mosquitoes are useful for sampling indoor-resting mosquito species during daytime hours. Some mosquitoes may leave houses after feeding or be forced out of houses during the night by the irritant effects of some insecticides or by smoke from cooking. These mosquitoes can be trapped as they leave the houses via exit window traps. Such collections provide information about indoor-resting behaviour and may help measure the effectiveness of IRS.

Human-vector contact
Human-vector contact can be measured directly through human landing collections (HLC) or indirectly, by determining the human blood index (HBI) from a representative sample of adult resting mosquitoes.

Vector survivorship
Mosquito survivorship can be estimated through dissection of the ovaries, and in one technique, calculating the parity rate through the presence of uncoiled tracheolar skeins in the ovary or the presence of an ovariole sac or dilation.

Sporozoite rate
The detection of sporozoites of human origin in mosquito salivary glands is important in determining vector status. This is determined either through salivary gland dissection or the ELISA CS test. The sporozoite rate can be used to estimate the Entomological Inoculation Rate described below.
**Entomological Inoculation Rate (EIR)**

The entomological inoculation rate (EIR) is the product of the sporozoite rate and the human-biting rate and is an important estimate of transmission pressure. In areas where there are several vector species and large differences in biting rates and human blood indices between villages, the EIR is the most appropriate way in which to establish the relationship between the entomological and parasitological variables. The EIR can be used to determine the entomological impact of an intervention.

**Wall Bioassays**

The quality of IRS applications, insecticide dosage and persistence on treated surfaces is qualitatively measured by WHO cone bioassay using susceptible strains maintained in a central laboratory. The WHO cone bioassay test (distinct from susceptibility test) checks the effectiveness of residual insecticide deposits over time, following spraying, and helps determine subsequent spray rounds and schedules. Bioassays of sprayed surfaces are also a means of monitoring the efficacy of spray operations. The cones are kept on the sprayed surface with mosquitoes for 30 minutes and the 24-hour mortality of the mosquitoes is recorded during this period. Tests should be conducted on five to ten homes per week using three cones per home.

More robust quantitative insecticide test kits are under development to measure the amount of insecticide present on the treated walls. These use colorimetric assays to determine the amount of insecticide on the wall surface, and do not require a susceptible strain of live mosquitoes.

**Insecticide resistance**

As detailed in the GPIRM, resistance monitoring and management is an integral part of every IRS operation.

Test procedures and materials are available from WHO. It must be noted that detection of insecticide resistance does not automatically equate with control failure, but that preventive action should be implemented immediately.

**Epidemiological performance indicators**

Monitoring the epidemiological impact of an IRS programme may be complicated by inadequate diagnostic and reporting systems, the impact of concurrent interventions such as LLINs and improved diagnostics and treatment, or variability due to population movement or weather-related changes in the mosquito population. Nevertheless, programmes should endeavour to collect information on malaria trends in the community as they relate to the IRS implementation.

First of all, epidemiological data should be based on parasitologically confirmed cases, and not on the highly inaccurate “fever” cases or clinically diagnosed “malaria”.

There are two basic sources of epidemiological information: facility-based parasite incidence data; and cross-sectional parasite prevalence and anaemia data gained through population-based surveys. Each has its strengths and weaknesses.

Facility-based incidence data is central to the WHO T3 Initiative: Test, Treat and Track (20). Malaria-endemic countries should ensure that every suspected malaria case is tested, that every confirmed case is treated with a quality-assured antimalarial, and that the disease is tracked through timely and accurate surveillance systems to guide policy and operational decisions. The initiative is built upon the 2012 revised Disease Surveillance for Malaria Control: an operational manual (9). Details on the tools, procedures, people and structures needed to build an effective epidemiological surveillance system during the control phase are provided in this manual.

While surveillance data are subject to incomplete reporting and bias, this source of information has the advantage of continuous collection from every district in a country; for most districts, such data are the only readily available source of information on malaria that can be used.
by programme managers. When surveillance systems are working well, they show consistent seasonal variation in the numbers of cases, coinciding with the pattern of malaria transmission. They also show reductions in morbidity and mortality in response to interventions and can alert managers to unexpected increases. Thus, although results should be interpreted with care, they are a critical source of information for programme management and should not be ignored. Continued efforts to improve reporting systems and use of these data will help to improve the quality of malaria surveillance and the operation of malaria control programmes.

A second source of epidemiological information is through periodic cross sectional household surveys that may include an indicator for anaemia as well as parasite prevalence. If conducted, such malaria indicator surveys should be carried out at the peak of the transmission period and conducted in the same month in subsequent years. Population-based malaria indicator surveys can be expensive and must be planned with care to yield useful results (21).

Social performance indicators

When resources allow, the attitude of the community towards IRS can be assessed through community knowledge, attitude, behaviour and practice (KABP) surveys. Such surveys are not required to run an IRS programme, and should be reserved for situations where there appears to be a community-related problem with an IRS programme. The information to be collected during routine spraying may include community acceptance, reasons for not accepting the spraying, locking rooms or re-plastering sprayed rooms. This information can also be collected as part of malaria and other household surveys and can help guide the development of educational messages to improve programme performance.

2.8 Review of annual operations

2.8.1 IRS programme operational review

IRS operational reviews should be undertaken at the end of each spray round to determine whether all aspects of the operation have been carried out according to the POA.

There should also be a more comprehensive annual meeting held one or two months after the spray round has been completed to review the overall IRS operation, to ensure programme targets and objectives have been achieved, and to outline adjustments and improvements for the next year’s operation. Reports and presentations should be prepared by districts and provincial IRS coordinators. The national IRS coordinators and IRS vector control committee members should review the performance of provinces and districts and provide feedback.

Annual IRS reports should be prepared at all levels by IRS coordinators at the end of the spray cycle.

The following areas should be reported on.

- **Coverage**: the percentage of total number of structures sprayed in relation to overall target structures; the refusal rate, the reasons for refusal and how to address this in the future.
- **Timing**: was the insecticide applied at the appropriate time in relation to the onset of malaria transmission?
- **Equipment**: the performance of the spraying equipment under operational conditions.
- **Expenses**: resource utilization (salaries, per diems, spray equipment, insecticides, transport costs).

These reports will provide valuable information for the planning and budgeting of future IRS interventions.
2.8.2 IRS programme strategic review

Following any IRS programme an evaluation of outcomes and impact (from routine health systems data) should be produced. This should document results in terms of improved quality of delivery and coverage targets and changes in malaria incidence or prevalence. This will also establish the need for training and research activities.

Periodic programme evaluations bring together all operational information collected as a basis for planning, and allow assessment of the broader programme components such as cost, policy, management structure and organization, effectiveness and efficiency of the intervention, as well as the programme’s performance and sustainability. These evaluations should ideally be carried out after the completion of two to four spray rounds and will help identify trends, and strengths and weaknesses that could be instrumental in making decisions about future expansion of interventions or reduction of target areas and objectives.

Operational research provides answers to questions tied to specific situations or problems that may require more rigorous examination than the straightforward tracking of indicators. Research priorities should be developed based on the operational challenges faced during the implementation of the IRS programme, i.e. changes in vector composition and behaviour, and changes in programme organization and structure.
References and web links


CHAPTER 3

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3.1 Conducting a house spray

Once the necessary planning, procurement and training has been completed in preparation for IRS, actual house spraying can begin. This phase of the IRS operations involves: informing the community so that they may be ready for the spray teams when they arrive (moving household items, making water for mixing available); preparing insecticides; spraying target structures; and recording which structures are sprayed and which are not. Adequate supervision is important to ensure each step is performed efficiently and to the highest standards.

3.1.1 Communicating with the villages and households

Prior to spraying, team leaders must contact community leaders to inform them of the planned spray operations and of the fact that IRS team members will be visiting the villages to provide more detailed information and to conduct the spray. The day before the actual spraying (or as near to the planned spraying date as possible), a member of the IRS team known as the ‘warner’ or ‘sensitizer’, travels to the target location and informs community leaders and householders of the purpose of spraying, the details of the spraying schedule, and what residents are expected to do in preparation. In this way, members of the community understand what they need to do to facilitate the operations and can prepare their homes and other structures in advance of the spraying. The information provided must be as simple as possible and the use of technical words must be minimized.

Spray operators should always maintain a positive approach when communicating with village leaders and householders. As observed in the Code of Conduct (1) (see Annex 1, Figure A1.6), the spray teams are “the face” of the national malaria control programme and of the ministry of health and, as such they have a duty to always act in a professional manner and to maintain good relations with the villagers.

On the day of spraying itself, it is important that the spray operators reinforce to householders the objectives of the IRS programme and that they outline to them the benefits, safety precautions and potential post-spraying side-effects. The residents should be given information on how long the insecticide is expected to remain effective on their walls, about the importance of not re-plastering, painting or washing the walls during that period, and should be instructed to continue using treated mosquito nets if these are available. They should also be reminded of the importance of waiting outside after spraying is complete, until the insecticide is dry, to reduce the risk of skin and eye irritations. This usually takes about one hour. In some circumstances where there is high humidity drying may be delayed and householders may be requested to remain outside longer, up to two hours.

The spray operators should also: reassure the occupants of the effectiveness and safety of the insecticide being used and tell them where to seek advice and assistance if they experience any problems with side-effects; reassure residents and community leaders that the insecticides applied will not damage walls, ceilings and furniture and; reassure householders that operators will not spray places used for food storage (e.g. rice, yams or corn).

Specifically, spray operators should ensure that householders willingly agree to:

- allow spray teams to enter their households;
- collect and make available at least 15 litres of clean water for mixing of insecticides in the sprayer and for any other use;
- notify the spray team if there are sick residents, newborn infants, or any cultural issues that would prevent a room or house from being sprayed;
- prepare houses for spraying by covering or moving portable items (foodstuffs and other consumables, cooking utensils, light furniture, bedding and clothing) outside;
- move those items that cannot be taken out of the dwelling to the centre of the room and cover them with a plastic sheet;
- move themselves and their families outside and remain outside for one hour or more while the insecticide dries;
- sweep out any household pests (cockroaches, beetles, etc.) that are killed in the house by the spraying and bury, burn, or dispose of these in a pit latrine;
- prevent chickens and other domestic fowls from eating the dead insects;
- refrain from re-plastering, re-painting or washing the sprayed surfaces for at least six months. This is important in order to allow the residual effect of the insecticide to continue killing mosquitoes.

3.1.2 Preparing rooms and households

To prepare for spraying, householders must remove as many of their household contents as possible, especially water containers, food, cooking utensils and toys. All pictures, wall hangings, and posters should be removed. Items that cannot be removed should be completely covered with plastic sheeting and placed in the centre of the room to allow easy access to the walls. Caged or leashed pets and domestic animals should be relocated away from the house until sprayed surfaces have dried and dead insects have been swept up and removed from the floor.

3.1.3 Preparing the spray charge

Just as there are a series of steps for the householder to prepare the structures for spraying, there is a standard series of procedures for the spray operator to prepare the insecticide mixture (the “charge”) to spray. The following nine steps should be followed to ensure safe and proper application.

Step 1: Wearing protective clothing and gear

The first step is for the spray operator to put on protective clothing and gear. Spray operators must be aware that they are at occupational risk when using insecticides. It is their responsibility to ensure they use the following protective clothing:

- broad rim hat or plastic helmet (to protect head, face and neck from spray droplets);
- full face shield or goggles (to protect eyes against spray fall-out and splashes);
- face mask/respirator (to protect nose and mouth from airborne particles of the spray fall-out and to avoid inhalation);
- long sleeved overalls;
- mutton cloth or light cloaks (to protect the neck)
- rubber gloves (to protect the hands);
- boots (to protect the feet);
- raincoat (to protect spray operator when it is raining; not to be used during spraying).

The spray operator should also check other support items including:

- notebook and records
- bag/satchel for carrying charges
- muslin cloth or metal strainer for sieving dirty water
- plastic sheeting.
Step 2: Checking the sprayer

Before starting a spray operation, the equipment must be checked. Faulty sprayers may result in poor application, over or under-application, and personal or environmental contamination.

Examine the sprayer to ensure that all component parts are present, assembled correctly and are in good condition.

a) sprayer tank
b) shoulder strap
c) inner seal lid
d) pump (handle)
e) pressure gauge
f) lance
g) in-line strainer (is the strainer inside valve handle clean?)
h) hose
i) nozzle (see note below)
j) trigger on/off valve
k) footrest
l) trigger assembly
m) shut-off valve (open) if one is present.

Note: Check that the correct type of nozzle (flat fan nozzle with 80º swath and 0.76 l/min flow rate at 40 psi) is fitted and is not damaged or worn. 8001E is usually used on non-absorbent surfaces where early run-off would normally result in under-dosing (i.e. target deposit not being achieved). 8002E is usually used for other surfaces. See section 2.4.1 for more detailed explanation.

Note: The sprayer should be fitted with a control flow valve (CFV). The recommended valve operates at either 2 or 1.5 bar and gives a constant output at the nozzle until the tank pressure is below the stated pressure of the CFV. Spraying will then stop, indicating that the operator must re-pressurize the tank.

The CFV must be fitted between the tank outlet and the nozzle. Usually, it is fitted next to the nozzle.

- Fit the valve by first removing the nozzle tip and cap. Fit a washer, if not present, into the end of the CFV that is screwed to the end of the lance. Then, with another washer if necessary, screw back the nozzle body, tip and cap onto the CFV.

- Alternatively, for other lances, fit the valve by first removing the nozzle body. Fit a washer, if not present, into the end of the CFV that is screwed to the end of the lance. Then, with another washer if necessary, screw back the nozzle body, tip and cap onto the CFV.
Step 3: Mixing the insecticide
Spray operators must follow the instructions on the product label to ensure safe and correct mixing, handling, and application of insecticides. The insecticides should be mixed outdoors or in a well-ventilated area.

Whilst in the field, keep the insecticide sachets or containers in the sachet holders or in drums or cartons free from moisture, heat, and direct sunlight.

In order to mix the product, the following items are required:

- product pre-measured and factory-packed in sachets or plastic bottles (one chemical charge for filling one spray pump);
- functioning sprayer;
- appropriate protective clothing;
- bucket with clean water.

If the standard spraying procedure is adopted, the spray liquid will be applied at a rate of 40 ml per m$^2$ or 1 litre per 25 m$^2$. This amount of suspension normally stays on the surface without run-off.

In general, insecticides now come in pre-measured sachets for ease of use.

Step 4: Preparing the sprayer

- **To close tank:** insert the cover vertically into the tank, lift it and fit it into the tank opening; turn the handle across the width of the opening.
- **To open tank:** push down the air-release valve by turning the handle on the cover; the cover will become loose once the air pressure is released and the tank reaches atmospheric pressure.

Step 5: Filling the spray tank

Spray operators should identify a suitable flat, level and hard surface on which to place the sprayer and half-fill the tank with clean water. The pre-packed insecticide from sachets or plastic containers should be added directly into the spray tank, the sprayer lid should be closed tightly and the contents mixed by agitating the sprayer. The tank must then be filled with the required total amount of water. The tank usually has a mark indicating the total water level and for most standard sprayers this is 10 litres.

Step 6: Shaking the spray tank

The suspension needs to be well mixed by shaking the tank before beginning to spray and by shaking again at regular intervals during spraying. Shaking is done by grasping the sprayer by the pump shaft and the bottom end of the tank. The tank should not be held by the strap, nor should it be swung forward and backward while on the shoulder. Formulations that meet WHOPES specifications should remain in suspension with minimum shaking.

Step 7: Pressurizing the tank

Spray operators should take the following steps to pressurize the tank:

- use the pressure gauge (manometer) to monitor the pressure in the compression sprayer;
- put one foot on the footrest and unlock the pump plunger. Pull the plunger all the way up with both hands and then push it downwards using full, even strokes;
- pump strokes should be even and regular from top to bottom (short irregular strokes make more work and less pressure input per stroke);
- keep pumping the sprayer until it registers a pressure of about 380 kPa (55 psi). The upper and lower operating pressure limits are 380kPa (55 psi) and 245kPa (35 psi), giving an average pressure during spraying of about 280kPa (45 psi);
While some sprayers may be fitted with “constant flow valves”, most are not, so it is important to repressurize as necessary to keep the pressure between 35 and 55 psi throughout the entire charge. As the water level decreases in the sprayer, more strokes will be required to return it to its required pressure;

- if the pressure is too high, the flow rate may increase, causing run off from the nozzle and potentially increasing the flow rate of the sprayer, which may increase spray bounce off and contribute to early damage of the nozzle aperture;
- if the pressure is too low, the operator may try to compensate by reducing the spray angle, which can result in reduced spray coverage or under application;
- check the pressure by looking at the pressure gauge (manometer), which usually shows the ‘operational pressure range’ by a colour band. Pressure should not be checked by
  - amount of fluid discharged
  - appearance or width of fan shaped spray
  - time of last pumping;
- always release pressure when sprayer is not in use e.g.
  - when stopped for long breaks such as lunch
  - when sprayer is being transported.

It will usually be necessary to re-pressurize and re-shake the sprayer once or twice before it is empty.

**Step 8: Checking the nozzle**

Spray operators should inspect the nozzle daily for blockages or signs of wear. Blockages can be removed by cleaning with water or by using a soft probe such as a brush or grass stalk. Sharp instruments should be avoided and operators should NEVER put the nozzle between the lips and blow.

**Step 9: Carrying and handling the sprayer**

- **Carrying position when not spraying:** sprayer should be placed on the back of the left shoulder in an upright position with the strap in front and the hose collected under the sprayer lid handle.
- **Carrying position when spraying:** sprayer should be placed on the front, hanging under the left shoulder with the upper part of the sprayer forward. The sprayer is held with the left hand on top. This allows for:
  - pressure gauge to be monitored regularly
  - quick unloading for placing on the ground for re-pressurizing
  - easy handling in narrow passages and rooms.

*Spray operators should always check and adjust the strap for comfortable carrying and handling.*

### 3.1.4 Applying Insecticide

The insecticide suspension has to be sprayed evenly and at the recommended application rate over all sprayable surfaces. The amount of insecticide that is sprayed on a surface is determined by a number of different factors.

Factors that are influenced by the spray operator during the spraying, and that need to be highlighted during training are:

- the distance from the nozzle tip to the surface being sprayed (should be kept at 45cm);
- the speed of movement of the nozzle over the surface;
- the air pressure in the sprayer (should be maintained at 245–380kPa (35–55psi) or (2.5–3.8 bar).
Factors that are not directly influenced by the spray operator, but that require attention during preparation for actual spraying are:

- the concentration of insecticide in the suspension
- the nozzle tip aperture size.

### 3.1.5 Insecticide spray procedure

The quality of spraying affects the residual effectiveness of the insecticides.

**General:** In households with multiple rooms, spraying should commence in the innermost rooms and work outwards.

**Total coverage:** Spray teams and spray operators must find and spray every single sprayable structure in the target area.

**Complete spraying:** All sprayable surfaces within a structure must be sprayed and no sprayable areas should be left out, missed or forgotten. Sprayable structures include all buildings, large or small, in which people may sleep or gather at night.

**Sprayable structures** include houses, kitchens, health centres (with overnight patients), hospitals, hotels and rest houses, fishing huts, and huts in the field. Animal shelters (cattle sheds in some countries) with roofs can be sprayed but open pens and corrals should not be sprayed.

Schools, shop houses, churches, health centres and other buildings should not be sprayed unless people regularly sleep in them overnight. Latrines are generally not sprayed. The underside of tin/metal roofing should not be sprayed as these can reach high temperatures during the day, which may significantly reduce the duration of effectiveness of the insecticide. However, the undersides of thatch roofing may be sprayed.

**Sprayable surfaces are:** all inside walls, the insides of roofs and under eaves, under exposed doors, verandas, rafters and beams. Sprayable surfaces also include the undersides of beds, tables, chairs, shelves, and the backs of cupboards and wardrobes.

**Correct dosage:** The right amount of insecticide should be deposited on the targeted spray surfaces. The following 10 steps should be followed by spray operators to ensure good practice during spraying:

**Step 1: Inspecting the room**
- on arrival, greet the householders and explain the purpose of the visit;
- request permission to enter the rooms, being led by a member of the family;
- enter the room and conduct a general inspection;
- ensure that the room has been cleared or heavy furniture has been moved to the centre of the room and covered with plastic sheeting;
- check that wall hangings and other items on walls have been removed;
- if the structure has more than one room, make sure that there is no one in the other rooms;
- check that all food and water containers have been removed.

**Step 2: Carrying the sprayer correctly**

Once the inspection is finished:
- lift sprayer using the shoulder strap;
- position strap on the shoulder and tank under the armpit so that the pressure gauge is visible;
- adjust shoulder strap to appropriate length;
- support the hose and lance in one hand;
- enter the room to be sprayed and face the door.
Step 3: Maintaining correct distance and angle for spray pattern or swath

Keeping the correct distance and angle of spraying is critical in depositing the correct concentration of insecticide on the sprayed surfaces. Spray operators should:

- stand in front of the spray surface area;
- maintain a body position of an average of one metre from the surface to be sprayed;
- maintain a distance of 45cm (or 1.5 feet) between the spray nozzle and surface to be sprayed (see Figure 11). This provides a spray pattern of swath which covers 75 cm at operational pressure of 245–380kPa (35–55psi or 2.5–3.8 bar);
- be aware that due to reduced deposit at the edges of the spray pattern, a 5cm overlap needs to be maintained in order to achieve an even coverage of adjacent spray patterns of swaths;
- always begin spraying at the top of the swath, moving down and then up from the left hand side towards the right hand side of the area to be sprayed;
- maintain a smooth comfortable action with the hand and elbow. The arm should be extended fully at the top and bottom with elbow bent in the middle to maintain a 45 cm distance from the nozzle to wall;
- ensure that:
  - in the upper position the spray pump lance moves vertically upwards;
  - in the middle position the spray lance remains horizontal;
  - in the lower position the spray lance moves downwards vertically through the middle position.

The first swath is from top to bottom. After the first swath, the spray operator should take a step sideways to get to the middle of the next swath and cover the second swath from bottom to top. The correct footwork should be maintained together with the hand spray speed to generate the correct rhythm.

The correct timing for spraying a two metre swath is five seconds, i.e. each linear metre covered should take 2.5 seconds. Timing may be aided by mentally counting “one thousand and one, one thousand and two, one thousand and three etc”. Adjust the mental counting procedure according to the local language.

To maintain the proper distance between the nozzle and the sprayed surface while spraying vertically (i.e. a wall or the back surface of large furniture), it is necessary to slowly bend the elbow towards the waist as the nozzle approaches the midpoint. At this point, the elbow should be bent at a 90° angle. The arms must be extended as the spraying progresses. This process must be followed throughout the entire spraying process.

A uniform speed of spraying is required to provide the correct target dosage.

If the arm moves too quickly, less spray will be applied, with the result that the amount of insecticide deposited will be lower than the recommended concentration. This will reduce insecticidal activity and greatly impact on the efficacy of the operation. It might also contribute to the emergence of vector resistance if inadequate concentrations are repeatedly applied. On the other
hand, if the spray speed is too slow there will be an overdose of insecticide, resulting in wastage and unnecessary extra costs.

**Step 4: Spraying doors and windows**

Total coverage cannot be achieved without spraying the sides of all doors and windows of the targeted structures.

- when doors and windows open inwards, both sides need to be sprayed;
- when doors open outwards, the interior surface needs to be sprayed;
- the doorframe must be sprayed, beginning from the left or right bottom corner;
- the portion of the wall covered by the door (behind the door) must be sprayed;
- once sprayed, the door should be opened to allow adequate lighting into the room for the rest of the spray operation.

**Step 5: Spraying the wall (vertical spraying)**

Starting from the edge of doorframe, spray operators should spray the walls as described above moving in a clockwise direction (Figure 11). The operators must:

- make sure the overall swath is 75cm if the nozzle is 45 cm from the wall;
- maintain an overlap of 5cm for successive swaths;
- maintain the rhythm of no more than five seconds for every two vertical metres;
- agitate the sprayer at regular intervals whilst checking pressure gauge;
- ensure that pressure does not drop below 35psi (245kPa) (re-pressurization will be required below this level) One pump stroke generally adds 1 psi to the tank pressure.

**Step 6: Spraying the ceiling**

Spraying of inner roof and ceilings requires horizontal spraying. Spray operators should:

- spray the ceiling or underside of the roof after the walls have been sprayed;
- for distance and timing of spraying, follow the method outlined above for spraying of walls;
- use a lance extension tube where necessary;
- ensure pressure is at 55psi or 4 bars before spraying the roof;
- stay in front of the spray swathe (in front of the nozzle) to minimize exposure to insecticide that may drift down, each time maintaining a distance of 45cm from the surface;
- spray horizontally from the furthest point inside the room until arriving back at the start point;
- move up to the next swath and spray round the room;
- **avoid exposure to spray fall out** by staying in front of the spray swathe;
- on completion, exit room and close the door;
- spray door from outside.

**Step 7: Spraying eaves and openings**

The house eaves and areas around openings such as doors and windows need special attention. Spray operators should:

- start spraying the inside of the eaves, beginning from above the door from the outside;
- move round the house spraying the outside eaves, taking care to avoid insecticide fall out;
- make sure that there is an overlap between the wall and the roof;
- upon completion of the eaves, spray around the window openings and air vents.
Step 8: Spraying difficult to reach surfaces and other structures

It is important that insecticide coverage reaches all potential mosquito resting sites. Obstacles such as chairs, tables and cupboards against walls can impede progress and cause interruption of spray timing and pattern. It may be necessary for the spray operator to adopt different postures while maintaining basic distance and speed, e.g., bending knees to reach under beds.

The underside of floorboards of houses that are elevated or raised above the ground on stilts or posts provide ideal resting sites for many Anopheles vectors. These areas must also be sprayed; an extension lance may be necessary for tall houses. In the Asia-Pacific region, flexible swan neck extensions are necessary for spraying the underside of floor boards. These can be used to spray the edges. The swan neck can be also used in situations where it is difficult to spray e.g., under the bed and where there are cupboards, furniture, floorboards, etc.

After completing the spraying of the rooms, operators must spray the walls of other outside structures such as toilets (pit latrines) and bathrooms, poultry runs, and animal sheds. Poultry and animals should be taken out and secured outside for one day. The inside of granaries or any rooms where agricultural products are stored should NOT be sprayed.

Step 9: Post-spraying communication

Spray operators should give the following post-spraying information and education to householders:

- Advise residents to stay outside until the sprayed walls and other surfaces have dried, which usually takes about one hour;
- Advise residents that there is likely to be residual odour but this should not be cause for alarm;
- Instruct residents to sweep the floor before allowing in children or pets, and to dispose of dead insects and other material immediately by burying or burning;
- Inform the residents of any future spray plans involving their neighbourhood.

Step 10: House spray record keeping

Houses visited by spray teams and which have been totally sprayed can be marked with paint or chalk with the team number and date on the front wall. House spray cards can also be updated by writing the house number, spray operator number, the team number and the date. Locked houses, rooms and households whose inhabitants have refused IRS, should be marked with an R; e.g., 16 (R) T1, 21/04/12

- 16 – spray operator number
- (R) – refused
- T1 – team number
- dd/mm/yy – complete date

Information such as locked rooms, refusals and the number of spray charge(s) used should also be recorded in the daily spray operator record form or book. Houses and structures that have not been sprayed can be followed up with mop-up spraying if they are identified and recorded at the time of the initial attempt.

3.1.6 Spray data recording and reporting

The spray operator should ensure that household information is filled in accurately before leaving the site. This information must be presented to the team leader at the end of each working day using the daily reporting form. It is the responsibility of the team leader to summarize this information at the end of each working day. The information is necessary for programme management and supervision and it will be cross-checked with the information provided by district supervisors.
**Malaria house spray cards**

An IRS household record card is kept accessible in each household. The house spray card acts as a census record of the number of people and rooms or structures per household or dwelling and provides a record of insecticide spraying for each numbered house. Annex A1.2 shows an example of the card.

**Routine reporting forms**

Spray operators, spray team leaders and IRS district coordinators should use standard reporting forms to report, supervise and monitor IRS implementation. A daily reporting form (see Annex A1.8) is completed by the spray operator for each house and submitted at the end of the day to the spray team leader who records and checks the performance of the individual spray operators. A weekly reporting form (see Annex A1.9) should be maintained by IRS district supervisors and districts IRS coordinators. Each coordinator tracks around four to ten spray teams and measures the weekly progress in relation to the total planned target for the spray round. A monthly reporting form (see Annex A1.10) is used by IRS district coordinators to monitor progress on IRS spraying coverage for the spray round in the district in relation to the total planned target.

### 3.1.7 Post-Spraying Procedures

When spraying has finished for the day, and before removing any protective clothing, the following procedures should be followed:

- all the empty chemical containers/sachets should be returned and counted, and unused chemicals should be returned to the camp guard/supervisor;
- the day’s spray report should be submitted to the supervisor;
- any final surplus spray solution from the final cleaning through the progressive rinse method should not be thrown away but should be kept and re-used the next day;
- sprayers must be cleaned daily inside and out using the progressive rinse method of saving and recycling water used for cleaning the sprayers and re-using it the next day. The spray mixture should not be left in sprayer overnight as suspension will start caking and block the filters and hose. The chemicals may also damage the components of the sprayer and reduce their life span (e.g. seals or valves will stick and disintegrate);
- sprayers should be checked for any faults that may have developed and these should be reported to the team leader;
- all cleaning and washing of the sprayer should be done away from water sources;
- cleaned sprayers should be put in an inverted position to drain off any water;
- sprayers are returned to storage making sure they are kept dry. If possible, they are stored in an inverted position with the cover assembly loose.

After doing all the above, spray operators should:

- remove protective clothing and gear;
- wash their whole body thoroughly using soap, and paying particular attention to exposed areas such as hands and face;
- wash used protective clothing in detergent (separately from household washing);
- dispose of washing water and rinse water safely, using a toilet or bathroom with a soakpit or soakway.
3.2 Spray equipment inventory and maintenance

3.2.1 Inventory

A monthly inventory of spray equipment should be maintained during the spraying period. The final inventory at the end of the spray round should indicate repairs and replacement needs. Sprayers and insecticides are expensive items: insecticide must be used economically and sprayers should be handled and maintained carefully. Developing and implementing routine daily cleaning, and weekly and monthly maintenance schedules during the spraying period will help maximize the life expectancy and performance of sprayers. Standardizing hand compression spray pumps and operator calibration procedures will also contribute to prolonging the life of the sprayers. All spray supervisors, team leaders and spray operators should be able to dismantle and reassemble the sprayer without assistance. Efforts should be made to provide adequate facilities and equipment for field preventive maintenance and for repairing hand compression sprayers.

3.2.2 Calibrating the sprayer nozzle

Spray operators must calibrate the nozzle with water in the tank using the following procedure:

- operate the sprayer to ensure working pressure is reached (3 bar or 45 psi);
- open the trigger or on/off valve for one minute, collect the discharge and measure the amount in a measuring jug;
- repeat three times and calculate the average discharge per minute. The correct discharge of a 8002E nozzle at 3 bar or 45 psi pressure is 760 ml per minute. The correct discharge of a 8001E nozzle at 3 bar or 43.5 psi pressure is 380 ml per minute.

The addition of a constant flow valve set on the lance will ensure that the flow rate does not decrease as the pressure in the tank falls. If the discharge rate is greater than 840 ml per minute then the nozzle-tip must be replaced. Nozzle tips are considered worn if the flow rate exceeds the rate of a new tip by 10%. Therefore, based on a pressure of 45 psi/30 sec, we can say that 380 ml is normal for a 8001E nozzle, more than 380 ml means worn but serviceable, but that if the flow rate is more than 418 ml the nozzle should be discarded and replaced.

Note: 3 bar = 300 kpa = 43.5 psi

3.2.3 Maintenance and cleaning of the sprayer

The sprayer must be cleaned at the end of every day’s spraying. Routine maintenance, cleaning and checking of sprayer equipment is critical to any spray programme. Well-maintained sprayers are less likely to have costly breakdowns. Maintenance also:

- prolongs the life-span of the sprayer;
- ensures more efficient application – avoids applying more insecticide than necessary and avoids leakage; well-maintained sprayers will prevent contamination of the spray operator, other people, animals and the environment;
- saves time: a major fault or breakdown can be inconvenient if spares are not readily available.

Maintenance should not only be carried out when something in the sprayer breaks or when some obvious fault is noticed, but must be a regular activity.

- cleaning should always be carried out at the end of the day;
- empty the tank of spray mix;
- fill the tank to approximately a quarter of its volume with water until the water becomes clear;
• close the lid, pressurize and agitate the sprayer; Spray some of the water through the nozzle to ensure the hose lance and nozzle are cleaned: discharge water in a container or dispose of appropriately;
• release the pressure;
• empty the rest of the water using recommended methods;
• repeat the process at least twice with clean water;
• save and recycle water used for cleaning sprayers the next day through progressive rinse method (see below);
• at the end of the season, dispose of all waste water in an evaporation pit or other approved method;
• clean nozzle components in bucket of water. Do not blow into nozzle;
• clean the outside of the sprayer including the straps. Keep cloths or sponges that are to be used ONLY for this purpose;
• remove lid and store sprayer hung upside down for drainage.

Annex A1.11 and A1.12 provide checklists for monitoring effective cleaning and maintenance of sprayers in the field.

The progressive rinse method

The progressive rinse method is used to rinse and clean spray pumps. The method entails washing the spray pump using a series of plastic containers, which are alternatively either empty or filled with clean water i.e. barrel 1 empty, barrel 2 filled, barrel 3 empty, etc. The rinse water is saved and used the next day for making up spray solution. Rinse water MUST not be disposed of into the environment. The steps to carry out a progressive rinse are as follows:

• At the end of the day, spray teams return to their staging areas, sprayers are depressurized and left-over insecticide is poured into the first container (No. 1; empty);
• The operator then adds one to two litres to the sprayer from the second container (No. 2; filled with clean water);
• The sprayer is then closed and pressurized to approximately 25 psi (2 bar), shaken so all inside surfaces are rinsed and the contents sprayed into the third container (No. 3; empty);
• Once the sprayer is empty, it is depressurized and the remaining contents are also poured into container No. 3;
• The operator repeats the process at the next two stations – containers No. 4 (full) & 5 (empty) and containers No. 6 (full) and 7 (empty);
• The other parts of the pump i.e. nozzles, filters and lances, can be washed with clean water in a dish or bucket. However, the waste water resulting from this should then be added to the other rinse water.

Upon completion of these stages, the sprayers have gone through a triple rinse procedure that produces clean rinse water. At this point, the sprayers are considered cleaned. The rinse water generated in this fashion, however, is kept in the rinse containers and is NEVER disposed of in the environment. The next day, about one to two litres of the rinse water is poured into each sprayer and once at the target area, each sprayer can be filled to its capacity with clean water, and charged with pesticide for the day’s operations.

3.2.4 Troubleshooting on the hand compression sprayers

The following are the most commonly found sprayer faults.

1. Control valve does not shut off: Clean O-ring and seating surface on control valve. Replace O-ring if worn.
2. **Leaks where wand joins control valve**: Clean O-ring in lance and sealing surfaces. Replace O-ring if worn.

3. **Tank does not pressurize when handle pumped**: Lubricate plunger cup with petroleum jelly, (not oil), or replace plunger cup.

4. **Leaks where cap joins wand**: Clean O-ring on wand and sealing surfaces. Replace O-ring if worn.

5. **Leaks where pump seals at tank**: Clean gasket sealing surfaces or replace gasket.

6. **Air leaks at hose connection**: Ensure gasket is tight. If O-rings are used, clean sealing surfaces or replace O-rings; re-attach hose. Do not use plastic as a replacement for O-rings or gaskets on the trigger handle as this will affect its structural integrity and may damage it.

7. **Liquid or air enters pump cylinder**: Clean check valve sealing surface or replace check valve.

### 3.2.5 Spare parts and maintenance tools

Each spray team should have adequate tools and a designated spray operator to conduct field preventive maintenance and repair of spray equipment. Basic tools required include: two crescent or adjustable wrenches; one Phillips and one flat-head screwdriver; and two pairs of pliers.

For certain sprayers a universal tool kit may be supplied with the sprayer.

Sprayers must be provided with an illustrated manual by the manufacturer. This manual provides:

- a description of the equipment
- operating instructions
- maintenance instructions
- information on how to solve most problems
- a list of spare parts.

Each spray team should have a plastic-bound, illustrated manual for reference.

**Spare parts** should always be available, especially gaskets, valves and nozzles. When ordering from the manufacturer or a local supplier, give the sprayer model, the part name and the identification number.

### 3.2.6 Spray equipment transport and storage

All sprayers should be secured upright in the vehicle (only after pressure is released) to prevent accidental damage during transport between field camps and spray site or while relocating field camps to new areas.

All spray equipment and associated items (tools, spare parts, etc.) should be cleaned at the conclusion of the spray season and stored in a centralized location in the district.

Spray operators must remember to carry out the following:

- inspect each sprayer for damage and repair if necessary;
- prepare an inventory of material needed to replace items lost or damaged during the spray season;
- put a small amount of oil on the leather cup of the pump plunger;
- remove and clean ‘in-line’ filter;
- store compression sprayers upside down, upright and separate from other field equipment;
- after storage, check each sprayer to make sure it is in working order before it is sent back to the field.
3.3 Human safety and environmental protection

3.3.1 Occupational safety

Spray operators must always be provided with personal protection devices and clothing including: gloves; hats; goggles or clear plastic visors to protect their faces and eyes when spraying overhead; washable cotton overalls; and field boots.

It is essential that all protective clothing and gear is bought locally before every season to ensure it is the right size and comfortable for use by spray operators.

A minimum of two sets of protective clothing should be provided. Ideally, these should be different colours for use on different days to indicate which have been washed after a day’s spraying. Extra care must be taken when spraying organophosphates.

Spray operators should be checked for any side effects including complaints of transitory skin burning or eye watering.

Special considerations for carbamate and organophosphate insecticides

The WHO Expert Committee on Vector Biology and Control has considered worker safety when applying carbamates and organophosphates and gives the following information (2):

- carbamates – no testing required;
- pirimiphos-methyl and malathion – safe enough to be applied operationally without requiring routine cholinesterase monitoring, provided protective clothing is regularly cleaned and a high standard of personal hygiene is maintained;
- fenitrothion – at the limit of acceptable toxicity for conventional indoor application. Its relatively narrow safety margin calls for strict precautionary measures and regular cholinesterase monitoring of exposed people throughout the spraying operation;
- propoxur – no cholinesterase monitoring required (it is a carbamate) but conclusions on use are similar to those with fenitrothion, i.e. it is at the limit of acceptable toxicity with narrow safety margins and strict precautionary measures must be followed.

Fenitrothion is rarely used as an IRS chemical, but if it is, the following guidelines should be observed (3).

In applying fenitrothion and diazinon, strict precautionary measures should be observed, including daily washing of overalls and use of cloth face masks, broad-brimmed hats and shoes or boots. Mixers and baggers handling the concentrate should also wear rubber boots, gloves and aprons. Any concentrate that gets onto the skin should be washed off at once. Clothes that are wetted with the insecticide should be changed immediately. Operators should not be exposed to the insecticide for longer than the predetermined working hours (usually 5–6 h). Transport should be arranged to minimize delays between the end of a day’s operations and return to base for showering, which should be mandatory. Once a week, all personnel exposed to the insecticide should be examined and their cholinesterase activity determined. Operators should be withdrawn from exposure if their cholinesterase activity decreases to 50% or more of that before exposure. Field tintometric assays are commercially available.

3.3.2 Insecticide poisoning and first aid measures

Failing to follow correct procedures during spraying operations can result in undesired exposure to insecticides or accidental insecticide poisoning. Below are some of the signs and symptoms of insecticide poisoning:

- general – extreme weakness and fatigue;
- skin – irritation, burning, excessive sweating, obvious staining;
- **eyes** – irritation, burning, excessive running, blurred vision, narrowing or widened pupils;
- **digestive system** – burning in mouth and throat, excessive salivation, nausea, vomiting, stomach cramps or pains, diarrhoea;
- **nervous system** – dizziness, confusion, restlessness, headaches, muscle twitching, staggering, slurred speech, fits or convulsions, unconsciousness;
- **respiratory system** – breathing with difficulty, wheezing, coughing, chest tightness and pain.

The routes of entry, possible prevention and general first aid measures are tabulated below:

(Nota: spray operators should always read and follow instructions on product labels).

<table>
<thead>
<tr>
<th>TABLE 7</th>
<th>Prevention and treatment of poisoning</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROUTE OF ENTRY</td>
<td>PREVENTION/PROTECTION</td>
</tr>
<tr>
<td>Skin</td>
<td>Proper application techniques;</td>
</tr>
<tr>
<td></td>
<td>Proper skin protection including use of gloves and protective clothing;</td>
</tr>
<tr>
<td></td>
<td>Clean protective equipment before re-use.</td>
</tr>
<tr>
<td>Eyes</td>
<td>Use of eye protection (face shield or goggles)</td>
</tr>
<tr>
<td>Respiratory system</td>
<td>Avoid inhalation of fine dust and mist by using face masks</td>
</tr>
</tbody>
</table>

### 3.3.3 Treatment of insecticide side effects

Local health units and hospitals should be provided with simple information on the side effects of insecticides being used and on recommended treatment. In addition, supplies should be checked regarding availability of antidotes.

If suspected poisoning occurs the spray operator should seek medical help and show the empty sachet or a product label to a health professional in order to identify the source of poisoning.

The key products or antidotes that should be available for treatment are:

- Topical vitamin E (tocopherol acetate) for skin exposure
- Topical anaesthetic for eye exposure
- Atropine for ingestion exposure
- Diazepam for ingestion exposure
- Phenytoin for ingestion exposure.

### 3.3.4 Recycling and waste management

Insecticides can be hazardous to people and to the environment if they are not properly managed. Insecticide management should always include minimizing waste by recycling and disposing of empty sachets or containers through special incineration. This should be done at appropriate facilities designed for this specific purpose.

IRS supervisors and team leaders are responsible for: ensuring that their teams follow the progressive rinse method or that they recycle water used for washing sprayers; ensuring that insecticide spillages are cleaned and; ensuring that contaminated materials are disposed of through incineration. Special attention should be given to preventing contamination of food and of the floor areas of houses where children and animals would be especially exposed.
3.4 Spray application supervision

IRS spray application requires close supervision from team leaders, IRS supervisors and IRS coordinators in order to be successful. This should be provided daily by the team leader, weekly by the IRS supervisors, and monthly by the IRS district coordinators throughout the period of the spray operations. It may be important that communities are informed of proper mixing volumes so that when spray operators are mixing insecticides and sprayer charges, villagers can be assured that spray is not being incorrectly diluted. Inspections should be based on the approved forms and checklists to ensure uniformity, accuracy, and completeness. The national and provincial teams should try and ensure that there are joint inspections with ministries of environment and agriculture to ensure that they are also fully aware that full environmental standards are being maintained.

3.4.1 Purpose of supervision

The purpose of the supervisor is to solve problems and to offer support, not to criticize or find fault. The main objectives are:

- to ensure that the spray team movement schedule is strictly adhered to and the agreed target numbers of houses to be sprayed per day are being maintained;
- to take immediate corrective measures on spray application techniques and take note of any equipment deficiencies for remedial action;
- to motivate, stimulate, encourage and advise on good communication with householders and village or community leaders;
- to ensure good team work for total and complete coverage of areas to be sprayed;
- to ensure that strict discipline and standard operating procedures are maintained;
- to assess, evaluate and encourage the work output of the teams;
- to make constructive and feasible recommendations to improve quality, coverage and timely implementation of operations.

Scheduled spot checks on all spray teams allow for assessment of quality and work performance as well as monitoring coverage. Feedback on operational deficiencies should be given to the team leader and IRS field supervisors so that they can take remedial measures. Equipment must be checked regularly.

### TABLE 8

<table>
<thead>
<tr>
<th>WAYS IN WHICH INSECTICIDE WASTE CAN BE GENERATED</th>
<th>WAYS TO MINIMIZE WASTE GENERATION OR DISPOSAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surplus spray solution</td>
<td>Proper planning of needs; Prepare only enough insecticide to spray the area to be covered; Do not leave spray mixture in sprayer overnight.</td>
</tr>
<tr>
<td>Empty chemical containers e.g. sachets, bottles, drums</td>
<td>Collect and return empty containers to a central location for safe storage, destruction, incineration or burial</td>
</tr>
<tr>
<td>Sprayer leakages contaminating absorbent material</td>
<td>Mend leakages in sprayer to avoid spillages</td>
</tr>
<tr>
<td>Little or no agitation (especially with DDT) resulting in sediment in pump that requires disposal; Sprayer washing and rinsing.</td>
<td>Constant agitation during spraying to avoid sedimentation; Implement progressive rinse method using appropriate containers and recycle rinsing water for next day’s use.</td>
</tr>
<tr>
<td>Chemical fall/bounce back out during spraying</td>
<td>Correct spray technique</td>
</tr>
</tbody>
</table>

Further information on human safety and environmental protection can be found at the WHOPES Website at [http://www.who.int/whopes/recommendations/en/](http://www.who.int/whopes/recommendations/en/)
3.4.2 Supervisory tools

Supervision should be conducted using standard forms and checklists to ensure uniformity, accuracy and completeness of information. Annex A1.13 gives an example of a typical supervision checklist. Tools and checklists for supervision need to be simple, clear and short; ideally, not more than one page in length.

Provincial and district IRS coordinators, disease control officers and entomologists should conduct field visits to supervise IRS, to note operational problems, and to correct them on the spot using the same standardized checklists.
References and web links


Useful resources and web links
Chapter 1: IRS Policy and Strategy

Global Malaria Action Plan:
http://www.rbm.who.int/gmap/index.html

Integrated Vector Management:
http://www.who.int/neglected_diseases/vector_ecology/en/
- WHO Position Statement on Integrated Vector Management
- Global Strategic Framework for Integrated Vector Management
- Core Structure for training curricula on Integrated Vector Management
- Handbook for Integrated Vector Management
- Guidance on policy-making for IVM

WHO Expert Committee on Malaria: Twentieth Report, Volume 20:
http://whqlibdoc.who.int/trs/WHO_TRS_892.pdf

Vector control for malaria and other mosquito-borne diseases: report of a WHO study group
WHO technical report series, 857:

Malaria Vector Control: Decision making criteria and procedures for judicious use of insecticides:

Global Plan for Insecticide Resistance Management in Malaria Vectors (GPIRM):
http://www.who.int/malaria/vector_control/ivm/gpirm/en/

WHO interim position statement – the role of larviciding for malaria control in sub-Saharan Africa:

Chapter 2: Management of an IRS Programme

Epidemiological Surveillance

Disease Surveillance for Malaria Control & Elimination Operational manuals:
http://www.who.int/malaria/surveillance_monitoring/operationalmanuals/en/

Malaria Indicator Survey: Basic Documentation for survey design and implementation. RBM Monitoring and Evaluation Reference Group:

Malaria elimination: A field manual for low and moderate endemic countries:

Indicators to measure the impact of malaria control:

Entomological Surveillance

Entomological field techniques for malaria control Part I: learner’s guide; part II: tutor’s guide:

Manual on practical entomology in malaria:
http://whqlibdoc.who.int/offset/WHO_OFFSET_13_(parti).pdf
Test procedures for insecticide resistance monitoring in malaria vectors, bio-efficacy and persistence of insecticides on treated surfaces:

Supplies for monitoring insecticide resistance in disease vectors – Procedures and Conditions:

Selection of insecticides
Decision-making for judicious use of insecticides (Facilitator’s guide & Participant’s guide):

Use of DDT
The use of DDT in malaria vector control: WHO position statement on DDT:

Insecticide use Code of Conduct and other international instruments
International Code of Conduct on the Distribution and Use of Pesticides:
http://www.fao.org/docrep/005/Y4544E/Y4544e00.htm

Rotterdam Convention on the Prior Informed Consent Procedure for Certain Hazardous Pesticides and Industrial Chemicals in International Trade:

Stockholm Convention on Persistent Organic Pollutants:
http://chm.pops.int/

Guidelines on public health pesticide management policy for the WHO African Region | French:

Guidelines on public health pesticide management policy for the WHO South-East Asia Region:
http://www.who.int/whopes/resources/SEA_CD_214.pdf

Storage
Pesticide storage and stock control:
http://www.fao.org/docrep/V8966E/V8966E00.htm

Procurement and registration
Guidelines for procuring public health pesticides:
http://whqlibdoc.who.int/publications/2012/9789241503426_eng.pdf

Guidelines for quality control of pesticides:

Guidelines for the registration of pesticides:

Guidelines on public health pesticide management policy for the WHO African Region:
Insecticide Resistance
Global Plan for Insecticide Resistance Management in Malaria Vectors (GPIRM):
http://www.who.int/malaria/vector_control/vm/gpirm/en/

Insecticide Resistance Action Committee: Prevention and management of insecticide resistance in vectors and pests of public health importance:
http://www.irac-online.org

Equipment
Equipment for vector control – Specification guidelines:
http://whqlibdoc.who.int/hq/2006/WHO_CDS_NTD_WHOPES_2006.5_eng.pdf

Pesticides and their application, for the control of vectors and pests of public health importance:

Occupational safety
Recognition and Management of Pesticide Poisonings:
http://www.epa.gov/opp00001/safety/healthcare/handbook/handbook.htm

http://whqlibdoc.who.int/trs/WHO_TRS_634.pdf

Sound management of pesticides and diagnosis and treatment of pesticide poisoning – A resource tool:
http://www.who.int/whopes/recommendations/IPCSPesticide_ok.pdf

Generic risk assessment model for indoor residual spraying of insecticides — First Revision:

The WHO Recommended Classification of Pesticides by Hazard:
http://www.who.int/ipcs/publications/pesticides_hazard/en/

Environmental Safety
PMI Best Management Practices for Indoor Residual Spraying in Vector Control Interventions:

Guidelines for the management of small quantities of unwanted and obsolete pesticides:
http://www.fao.org/docrep/X1531E/X1531e00.htm

Budgeting and costing
PEEM guidelines 3: Guidelines for cost-effectiveness analysis of vector control:

An economic analysis of the costs of indoor residual spraying in 12 PMI countries, 2008–2010:

IRS Campaign Budget Template (Excel Workbook):
http://www.rbm.who.int/toolbox/tool_IRStoolkit.html
Chapter 3: Conducting a house spray

Manual for indoor residual spraying. Application of residual sprays for vector control, third edition:

IRS Training Guide for Spray Operations:
ANNEX 1

IRS check lists and forms
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### Example of sprayable surface record form for baseline estimation of insecticide quantification needs

(This is for initial quantification purposes only, not for all IRS spray operations)

<table>
<thead>
<tr>
<th>HOUSEHOLD NUMBER</th>
<th>GPS COORDINATES</th>
<th>TYPE OF HOUSE</th>
<th>HOUSEHOLD NUMBER</th>
<th>GPS COORDINATES</th>
<th>TYPE OF HOUSE</th>
<th>HOUSEHOLD NUMBER</th>
<th>GPS COORDINATES</th>
<th>TYPE OF HOUSE</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>2</td>
<td></td>
<td></td>
<td>3</td>
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<td></td>
</tr>
<tr>
<td>4</td>
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<td></td>
<td>5</td>
<td></td>
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<td>6</td>
<td></td>
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<tr>
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<td></td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL SURFACE AREA (SQ METER)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
</tr>
<tr>
<td>B</td>
</tr>
<tr>
<td>C</td>
</tr>
<tr>
<td>D</td>
</tr>
<tr>
<td>E</td>
</tr>
<tr>
<td>F</td>
</tr>
<tr>
<td>G</td>
</tr>
<tr>
<td>H</td>
</tr>
<tr>
<td>I</td>
</tr>
<tr>
<td>J</td>
</tr>
<tr>
<td>K</td>
</tr>
</tbody>
</table>

#### Dimensions of Surfaces

- ROOM 1 (LxH) x 2 + (WXH) x 2 + CEILING (WXL)
- ROOM 2 (LxH) x 2 + (WXH) x 2 + CEILING (WXL)
- ROOM 3 (LxH) x 2 + (WXH) x 2 + CEILING (WXL)
- ROOM 4 (LxH) x 2 + (WXH) x 2 + CEILING (WXL)
- KITCHEN (LxH) x 2 + (WXH) x 2 + CEILING (WXL)

#### Example of sprayable surface record form for baseline estimation of insecticide quantification needs
## A1.2 Example of house spray card

**District** ........................................................................................................... **Ward** ..............................................

**House ID No** ...................................................................................................

**Date Issued** ........................................................................................................

**GPS:** Longitude ............................................................................................ **Latitude** ...........................................

**Head of household** ...........................................................................................

<table>
<thead>
<tr>
<th>DATE SPRAYED</th>
<th>SPRAY OPERATOR</th>
<th>NUMBER OF OCCUPANTS</th>
<th>NUMBER OF ROOMS UNIT</th>
<th>INSECTICIDE USED</th>
<th>SPRAY CHECKED AND COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ADULTS       CHILDREN</td>
<td>SPRAYED  UNSPRAYED</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>1 2 3 4 5     1 2 3 4 5</td>
<td>1 2 3 4 5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### A1.3 Example of annual reporting on insecticides used for vector control

Committed by: Name ..............................................................................................................................
Postal address ........................................................................................................................................
...........................................................................................................................................................
...........................................................................................................................................................
...........................................................................................................................................................
Tel: ................................ Fax: .................. Email: .................................................................
Date: month/year....................................................................................................................................

<table>
<thead>
<tr>
<th>YEAR</th>
<th>COMPOUND</th>
<th>CLASS</th>
<th>FORMULATION</th>
<th>CONCENTRATION</th>
<th>TYPE OF APPLICATION</th>
<th>FOR CONTROL OF</th>
<th>AMOUNT OF FORMULATION USED (KG OR L)</th>
<th>AMOUNT OF A.I.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>DDT</td>
<td>organochlorine</td>
<td>75WP</td>
<td>75%</td>
<td>Indoor residual spraying</td>
<td>malaria</td>
<td>1000 kg</td>
<td></td>
</tr>
<tr>
<td></td>
<td>deltamethrin</td>
<td>pyrethroid</td>
<td>25WG</td>
<td>25%</td>
<td>Indoor residual spraying</td>
<td>malaria</td>
<td>1000 kg</td>
<td></td>
</tr>
</tbody>
</table>
## A1.4 Timeline for implementation of IRS

<table>
<thead>
<tr>
<th>KEY ACTIVITIES</th>
<th>EXPECTED RESULT OUTCOME INDICATOR</th>
<th>RESPONSIBILITY</th>
<th>TIME FRAME</th>
<th>ESTIMATED COST</th>
</tr>
</thead>
<tbody>
<tr>
<td>Geographical reconnaissance and mapping and collection of baseline data, or</td>
<td>No of houses sprayed</td>
<td></td>
<td>JAN</td>
<td></td>
</tr>
<tr>
<td>updating surveillance and information and research data</td>
<td></td>
<td></td>
<td>FEB</td>
<td></td>
</tr>
<tr>
<td>Environmental impact assessment (where required)</td>
<td></td>
<td></td>
<td>MAR</td>
<td></td>
</tr>
<tr>
<td>Annual update of GR and areas targeted for spraying</td>
<td></td>
<td></td>
<td>APR</td>
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<tr>
<td>Estimate annual resource needs</td>
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<td>MAY</td>
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<tr>
<td>Procure insecticides, equipment and transport</td>
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<td></td>
<td>JUN</td>
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<tr>
<td>Establish spraying schedule</td>
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<td>JUL</td>
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<tr>
<td>Conduct training of district coordinators and supervisors and team leaders</td>
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<td>AUG</td>
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<tr>
<td>Recruit and train spray operators</td>
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<td>SEP</td>
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<tr>
<td>Provincial and district campaigns to educate and inform and mobilize communities</td>
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<td>OCT</td>
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<tr>
<td>Conduct spraying</td>
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<tr>
<td>Conduct supervision</td>
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<tr>
<td>Track timing, quality and coverage of spraying operations, environmental compliance</td>
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<tr>
<td>Conduct vector sentinel site surveillance (bioassays, susceptibility, vector composition and behaviour)</td>
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<tr>
<td>Evaluate IRS coverage both as operationally reported and from actual survey</td>
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<tr>
<td>Evaluate impact on vectors and malaria</td>
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<tr>
<td>Conduct IRS review – including reviewing annual reports &amp; other relevant documents</td>
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</tbody>
</table>
## Example of capital and operational budgets for an IRS campaign

<table>
<thead>
<tr>
<th>ITEM</th>
<th>NO OF UNITS</th>
<th>UNIT COST</th>
<th>TOTAL COST</th>
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</thead>
<tbody>
<tr>
<td><strong>CAPITAL</strong></td>
<td></td>
<td></td>
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<tr>
<td>Baseline epidemiological and entomological review and survey</td>
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<tr>
<td>Environmental impact assessment</td>
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<tr>
<td>Compression sprayers</td>
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<tr>
<td>Equipment, spares and replacement parts</td>
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<td>Tool kits</td>
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<tr>
<td>Protective sheeting to cover household goods</td>
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<tr>
<td>Transport: truck/boats for 3–4 spray teams</td>
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<td>Transport: supervisors’ motorcycles</td>
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<tr>
<td>Transport: coordinators’ 4 X4s</td>
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<tr>
<td>Malaria camps – storage and base</td>
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<tr>
<td><strong>RECURRENT</strong></td>
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<tr>
<td>Spray insecticides</td>
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<tr>
<td>Salaries of spray operators for 4–8 weeks (adjust to minimum wage)</td>
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<tr>
<td>Personal protection equipment (overalls, gloves, helmets, face shields with screen)</td>
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<tr>
<td>Collection and disposal of empty sachets and containers</td>
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<tr>
<td>Travel and per diems for supervisors and coordinators for duration of the campaign</td>
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<tr>
<td>Transport hire and fuel costs</td>
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<tr>
<td>Annual training of coordinators and supervisors</td>
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<tr>
<td>Annual training of spray operators</td>
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<tr>
<td>Annual IEC and community mobilization materials</td>
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<tr>
<td>Annual review of environmental compliance and pesticides management</td>
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<tr>
<td>Monthly, quarterly and annual operations management meetings</td>
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<tr>
<td>IRS data entry and summary reports sheets</td>
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<tr>
<td>Malaria prevalence surveys (optional)</td>
<td></td>
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<tr>
<td>Entomological studies and sentinel sites</td>
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<tr>
<td>Annual post spray review and annual report production</td>
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</table>
A1.6 Code of Conduct


The following code of conduct incorporates features of a code currently being used successfully in several malaria vector control programmes in sub-Saharan Africa. It is given here as an example for use in other programmes.

Indoor residual spray team members, including spray operators and team leaders/supervisors, have a duty to always act in a professional manner and maintain good relations with the villagers. Their behavior and demeanor should be beyond reproach. Spray team personnel should never say or do anything to each other or to a member of the community that will upset or offend local leaders, householders or their customs. Sometimes spray teams will be offered food. Accepting these gifts should be discouraged as it may cause undue hardship to householders where food and/or water may be in short supply or difficult to obtain. Therefore, spray team members must provide their own food and/or snacks at all times and in all locations. All members must agree to comply with the following:

Rule 1: Spray team members must wear their uniform properly and maintain it in clean and in good working order.

Rule 2: Spray team members must properly wear their personal protective equipment (PPE) while spraying.

Rule 3: Spray team members must be respectful and courteous towards house residents and their property at all times.

Rule 4: Spray team members must never ask villagers to provide food, money or water for their sprayers.

Rule 5: Spray team members, particularly the team leaders, should give clear instructions to the residents so they can adequately protect themselves, their family members and domestic animals and pets from exposure to the insecticide applied. They should also instruct the householders to sweep the floor of the house and the ground immediately around it of all dead insects, and burn or bury them during the course of two days after spraying.

Rule 6: Spray team members must comply with all directives given by their team leaders and programme managers.

Spray operators

Spray operators are often selected from the community and employed for a period ranging from a few weeks to a few months, depending on the complexity of the campaign. They are trained to apply insecticide. They should, under the jurisdiction of the ministry of health or other pertinent local authority undertaking the IRS campaign, be able-bodied, able to work with minimum supervision and be able to read and write. Spray operators should be at least 18 years old, physically fit, healthy and able to operate the sprayer. If women are employed, they must understand that they must not be pregnant or lactating at the time of recruitment or become pregnant during any part of the spray campaign, and that pregnancy can be grounds for relocation away from active spraying. Spray operators should be responsible persons who can communicate with residents. Once teams are selected, spray operators are trained in the proper insecticide application techniques, effective communication and record keeping.
Duties of spray operators

- report for duty on time and ready to work;
- respect local customs, laws and regulations;
- keep his/her sprayer, tools personal protection, etc. clean and in good working order and assume total responsibility for all the equipment under his/her care;
- apply all insecticides following the programme’s procedures, protocols and directives, and be accountable for all insecticide sachets issued to him/her;
- wear personal protection equipment as instructed while spraying and protect him/herself and the environment from insecticide contamination;
- maintain accurate records of his/her activities while on duty as a spray operator;
- be courteous and respectful to the householders and residents and their property;
- conduct complete and comprehensive spraying of assigned homes;
- explain the purpose of spraying and the precautions being taken as well as answering any question posed by the resident or his/her family;
- assist the householder, if necessary, to move furniture and other belongings;
- report any problem to his/her team leader as soon as they arise;
- carry out instructions given by the team leader in a timely fashion;
- thank each householder for his/her cooperation and answer or address any concerns upon completing his/her work.

Duties of team leaders and supervisors

- assist in the training of spray operators and guide them in the proper completion of their duties. Do this according to the established procedures and protocols, and in a timely fashion;
- keep all spray personnel up-to-date and informed as to their progress and that of the campaign;
- continually and routinely check their team members to make sure their equipment is kept clean and in working condition;
- carry out or supervise minor field repairs to sprayers and personal protection equipment;
- supervise his/her spray team members during spraying operations and ensure their work is carried out according to instructions and following established protocols and procedures;
- conduct sporadic checks on application equipment and nozzles so that appropriate discharge and application rates are maintained;
- ensure his/her team members have adequate supplies of insecticide, water, record cards, replacement PPE, etc;
- ensure that zone maps are always available (or produced) and are updated as his/her team members progresses from village to village;
- ensure home owners and residents are notified of spray operations at least a day in advance;
- contact the village leaders as soon as his/her spray squad enters the village;
- make appropriate corrections on method or technique not executed correctly by any of his/her team members;
- verify that spraying has been conducted according to the established plan upon completion of the day’s work;
- ensure all data recorded by team members is correct and accurate and rectify any deficiencies noted;
- prepare daily progress reports accurately at the completion of daily spraying;
- supervise the cleaning of application equipment at the end of the day’s work;
- report to the supervisor the progress of the squad and include remarks on the work of each spray operator;
- carry out any other instructions given by his/her superior or any other senior programme officer;
- ensure each team member in his/her team maintains a professional image and conducts him/herself with cultural sensitivity.
A1.7 Examples of IRS operations organizational charts

Example 1a: Organization at central level

Example 1b: Organization at provincial/district level
Example 1c: Organization at sub-district level

Sub district IRS supervisor

Group leader 1

Group leader 2

Group leader 3

Team leader 1

Team leader 2

Team leader 3

Spray operator 1

Spray operator 2

Spray operator 3
### Example of daily reporting form for spray operators

**District** .......................................................... **Parish/Ward** ................................**Village** .......................................................... **Date** ..........................................................

**Name and ID No of Spray Operator** .......................................................... **Signature** ..........................................................

<table>
<thead>
<tr>
<th>NO</th>
<th>TARGET H/ HOLD ID NUMBER</th>
<th>TARGET HOUSEHOLD GPS NO</th>
<th>NO OF PEOPLE IN HOUSEHOLD</th>
<th>TOTAL NO OF ROOMS/STRUCTURES/UNITS IN HOUSEHOLD</th>
<th>TOTAL NO OF ROOMS/STRUCTURES/UNITS IN HOUSEHOLD UNSPRAYED</th>
<th>NO OF MOSQUITO NETS HANGING</th>
<th>NO OF LONG-LASTING MOSQUITO NETS OR THOSE RETREATED IN THE LAST YEAR</th>
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**KEY TO REFUSALS**

<table>
<thead>
<tr>
<th>SC: sick</th>
<th>NB: newborn</th>
<th>F: funeral</th>
<th>O: other</th>
</tr>
</thead>
</table>

**Insecticide used:** Compound .......................................................... **Formulation** .......................................................... **Dosage Concentration** ..........................................................

Total number of insecticide sachets/bottles issued for the day ..........................................................................................

Total number of empty sachets bags/bottles returned ............................................................................................................

Spray Operators remarks on operational problems and suggested solutions ..........................................................................................


**Spray team leaders' daily calculation**

1. Daily house hold coverage: (Total number of sprayed houses/Total number of houses) ..........................................................

2. Daily rooms/structure coverage: (Total number of sprayed rooms/structures/Total number of rooms/structures) ..........................................................

**Spray team leader remarks** ..........................................................................................................................................................

**Signature of spray operator** .......................................................................................................................................................


### Example of daily/weekly reporting form for spray team leaders

**Example of daily/weekly reporting form for spray team leaders**

<table>
<thead>
<tr>
<th>DAY/WEEK</th>
<th>SPRAY OPERATOR</th>
<th>TOTAL NO. OF HOUSEHOLDS SPRAYED</th>
<th>TOTAL NO. OF PEOPLE IN SPRAYED HOUSEHOLD</th>
<th>TOTAL NO. OF ROOMS, STRUCTURES, UNITS IN HOUSEHOLD SPRAYED</th>
<th>PROPORTION OF HOUSEHOLDS NOT SPRAYED (%)</th>
<th>NO. OF MOSQUITO NETS HANGING</th>
<th>NO. OF LONG-LASTING MOSQUITO NETS OR THOSE RETREATED IN THE LAST YEAR</th>
<th>TOTAL NUMBER OF INSECTICIDE SACHETS/BOTTLES USED</th>
<th>TOTAL NUMBER OF EMPTY SACHETS/BOTTLES RETURNED</th>
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Spray Team leader remarks on operational problems and suggested solutions

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..........................................................................................................................

Signature of spray team leader ...............................................................................

A1.10 Example of monthly reporting form for district IRS coordinators

<table>
<thead>
<tr>
<th>WEEK</th>
<th>SPRAY TEAM</th>
<th>TOTAL NO. OF HOUSEHOLDS TARGETED TO BE SPRAYED FOR CYCLE</th>
<th>TOTAL NO. OF HOUSEHOLDS SPRAYED</th>
<th>PROPORTION OF HOUSEHOLDS SPRAYED (%)</th>
<th>TOTAL NO. OF PEOPLE IN SPRAYED HOUSEHOLD</th>
<th>TOTAL NO. OF ROOMS, STRUCTURES, UNITS IN HOUSEHOLD SPRAYED</th>
<th>PROPORTION OF HOUSEHOLDS NOT SPRAYED (%)</th>
<th>NO. OF MOSQUITO NETS HANGING</th>
<th>NO. OF LONG-LASTING MOSQUITO NETS OR THOSE RETREATED IN THE LAST YEAR</th>
<th>TYPE I INSECTICIDE</th>
<th>TYPE II INSECTICIDE</th>
<th>TYPE I INSECTICIDE</th>
<th>TYPE II INSECTICIDE</th>
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</table>

District IRS coordinator remarks on operational problems and suggested solutions

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..........................................................................................................................

..........................................................................................................................

Signature of district IRS coordinator
..........................................................................................................................
A1.11 Example of checklist for cleaning the sprayer in the field

Checklist for cleaning the sprayer in the field

☐ When is the sprayer to be cleaned?
  ☐ At the end of the day’s spraying
  ☐ If changing from one product to another.

☐ What protective clothing should be worn when cleaning the sprayer?
  ☐ Long trousers
  ☐ Long sleeved shirt
  ☐ Eye protector/goggles
  ☐ Gloves
  ☐ Boots
  ☐ Apron
  ☐ Mouth/nose masks.

☐ Is the correct cleaning procedure being followed?
  ☐ Empty the spray tank of spray mix through progressive rinse into plastic containers (note disposal procedure);
  ☐ Fill tank to about ¼ of its volume with clean water, close lid and shake;
  ☐ Spray some of the water through nozzle and lance to clean hose, lance and nozzle;
  ☐ Empty rest of water from tank onto progressive rinse containers (note safety measures and contamination). In the case of DDT, spray pumps should be thoroughly washed at the end of the day by rinsing with clean water (triple rinse). Rinse water should be poured into a dedicated container, tank, mixing drum or water trailer and used the next day for making up the first spray solution. Rinse water MUST not be disposed of into the environment;
  ☐ Repeat the process at least twice with more water;
  ☐ Dismantle trigger assembly, cleaning lance filter in bucket of water;
  ☐ Dismantle nozzle assembly, clean nozzle filter and nozzle components in bucket of water;
  ☐ Clean outside of sprayer including the straps;
  ☐ Do not drain sprayer onto waste ground but recycle the waste water into progressive rinse containers;
  ☐ Store sprayer by removing the lid and hang upside down to fully drain inside the store.

WARNIGN! Do not drain sprayer – always recycle the waste water through progressive rinse method.
A1.12 Example of checklist for maintenance of sprayers

Checklist for maintenance of sprayers

District ................................................................................................................. Ward ........................................
Evaluator .................................. Supervisor .....................................................  Date ..........................

Checklist for maintenance schedules:

1. Checklist for pre-spray checks

Visual Checks:

☐ Cleanliness of pump ☐ poor ☐ good
☐ Strap ☐ poor ☐ good
☐ Cleanliness of nozzle ☐ poor ☐ good

☐ Fill with water and pressurize and check:

☐ Pressure gauge functioning ☐ Yes ☐ No
☐ Pump pressuring smoothly ☐ Yes ☐ No
☐ Pressure retained if left for 5 minutes ☐ Yes ☐ No
☐ Trigger valve stops cleanly – no drips ☐ Yes ☐ No
☐ No obvious leaks or drips at hose connections ☐ Yes ☐ No
☐ No obvious leaks or drips around trigger ☐ Yes ☐ No
☐ No obvious leaks or drips at nozzle ☐ Yes ☐ No
☐ Strap pattern not even ☐ Yes ☐ No

2. Checklist for periodic checks:

☐ All elements of the pre-spray checks (see above)
☐ Dismantle pump and check

☐ Condition of piston and signs of wear ☐ poor ☐ good ☐ very good
☐ Condition of outlet valve ☐ poor ☐ good ☐ very good

☐ Dismantle trigger valve assembly and check

☐ Condition of trigger valve for wear ☐ poor ☐ good ☐ very good
☐ Condition of seals or ‘O’ rings for wear ☐ poor ☐ good ☐ very good

☐ Reassemble sprayer, fill with water, pressurize and measure

☐ Flow rate at full working pressure ☐ poor ☐ good ☐ very good
☐ Nozzle discharge pattern ☐ poor ☐ good ☐ very good

Two safety rules for dismantling and checking sprayers

☐ Always wear gloves and long sleeves when dismantling sprayers.
☐ Always ensure that sprayer is not pressurized before dismantling.
A1.13 Example of spray team leader and IRS supervisor’s checklist

Spray Team leader and IRS supervisor’s checklist

District ....................................................................................................................................................
Ward ................................................................ Village .........................................................................
Team leader ...........................................................................................................................................
Number of spray operators ................................................................ .................................................
Name of village being sprayed ................................................................ ............................................
Estimate of number of target structures ................................................................ ............................
Name of team leader ................................................................ ............................................................
What was the spray operator doing on your arrival ............................................................................

Observe the use of protective clothing: Overalls .......... Boots  ..........
Mouth/nose mask/face shield .......... Hat .......... Gloves ..........
Procedure before starting to spray:
Inhabitants informed? □ Yes □ No
Are food items, water containers, cooking utensils covered/ taken outside? □ Yes □ No
Are the inhabitants outside during spraying and until 60 minutes after? □ Yes □ No
Are domestic animals outside during spraying and until 60 min after? □ Yes □ No
Spraying technique:
Is the sprayer filled correctly? □ Yes □ No
Is the sprayer pressurized correctly? □ Yes □ No
Is the sprayer pressure gauge checked frequently and pressure maintained between 2.45–3.80kPa (35–55psi) or (2.5–3.8 bar)? □ Yes □ No
Is the sprayer handled and carried correctly? □ Yes □ No
Is the sprayer shaken periodically before and during spraying? □ Yes □ No
Is the nozzle held at a constant distance from the target (45cm)? □ Yes □ No
Is the nozzle moved at a constant speed over all surfaces? □ Yes □ No
Is proper foot work performed so that adjacent swaths overlap for uniform spray coverage? □ Yes □ No
Is the pressure released when the sprayer is not in use? □ Yes □ No
Is distribution of insecticide on wall adequate? □ Yes □ No
Is distribution of insecticide on roof/ceiling adequate? □ Yes □ No
Does spray operator spray behind and under furniture? □ Yes □ No
Does spray operator spray under the eaves? □ Yes □ No
Does spray operator spray behind the doors? □ Yes □ No
Does spray operator avoid environmental pollution? □ Yes □ No
Does spray operator eat, drink, or smoke without first washing? □ Yes □ No
Does spray operator complete daily record form? □ Yes □ No
Any comments from household members ....................................................................................
Any comments from village or community leaders ........................................................................
Positive feedback
Areas requiring attention and action
Proposed Solutions and Recommendations
Team Leader/ District IR Supervisors Name and Signature
For more information, please contact:

Vector Control Unit
Global Malaria Programme
20 avenue Appia
1211 Geneva 27
Switzerland

gmpvectorcontrol@who.int
http://www.who.int/malaria