Global Malaria Programme

Indoor residual spraying

Use of indoor residual spraying for scaling up global malaria control and elimination

World Health Organization

Indoor residual spraying (IRS) is one of the primary vector control interventions for reducing and interrupting malaria transmission. In recent years, however, it has received relatively little attention. Recent data re-confirms the efficacy and effectiveness of IRS in malaria control in countries where it was implemented well.

Effective implementation of IRS with DDT or other recommended insecticides should be a central part of national malaria control strategies where this intervention is appropriate. It is implemented with the objective of reducing malaria morbidity and mortality and accelerating progress towards global and national malaria targets. However, there are important considerations that must be taken into account when considering whether to introduce or scale up IRS. In particular, there must be sufficient capacity to deliver the intervention effectively, prevent unauthorized and un-recommended use of public health pesticides, and manage insecticide resistance. Intensified research efforts are needed, for example to develop new insecticides, long-acting formulations and improved application technologies.

Along with producing IRS manuals and guidelines, the World Health Organization (WHO) will support countries to collect and analyse data, towards determining potential effectiveness and feasibility of IRS in the national context, and with planning and implementing the intervention. WHO requests countries to report on coverage and impact as IRS is implemented or scaled up.

This position statement is intended for public health policy makers, malaria control programme managers, development agencies, development banks, academic and research institutions and private sector corporations involved in scaling up malaria control programmes.

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WHO Position Statement

World Health Organization

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1. Introduction

1.1 Global malaria control interventions

WHO's Global Malaria Programme recommends the following three primary interventions that must be scaled up in countries to effectively respond to malaria, towards achieving the Millennium Development Goals for malaria by 2015 and other health targets:

- diagnosis of malaria cases and treatment with effective medicines;
- distribution of insecticide-treated nets (ITNs) to achieve full coverage of populations at risk of malaria; and
- indoor residual spraying (IRS) as a major means of malaria vector control to reduce and eliminate malaria transmission including, where indicated, the use of DDT.

Scaling up access and achieving high coverage of these effective interventions, particularly to populations who are at the highest risk of malaria, and sustaining their implementation, remain major challenges for achieving current global malaria control goals.

1.2 Indoor residual spraying (IRS)

IRS is the application of long-acting chemical insecticides on the walls and roofs of all houses and domestic animal shelters in a given area, in order to kill the adult vector mosquitoes that land and rest on these surfaces. The primary effects of IRS towards curtailing malaria transmission are: *i)* to reduce the life span of vector mosquitoes so that they can no longer transmit malaria parasites from one person to another, and *ii)* to reduce the density of the vector mosquitoes. In some situations, IRS can lead to the elimination of locally important malaria vectors. Some insecticides also repel mosquitoes and by so doing reduce the number of mosquitoes entering the sprayed room, and thus human-vector contact.

2. IRS in context

2.1 Malaria control and elimination since 1950

The efforts of the Malaria Eradication Programme (1955–1969) contributed to significantly reducing the global malaria burden, particularly in Asia, Latin America and Southern Africa. The eradication programme was based on IRS against the vector mosquitoes, as endorsed by the WHO Kampala Conference of 1950. These efforts, combined with other measures, led to malaria eradication from Europe, the former USSR, and several countries in Asia and

the Caribbean. About 700 million people, or more than half of the previously exposed populations, were no longer at risk (*1*).

Most of the African continent, however, was not involved in this effort. Subsequent attempts to control malaria through primary health care strategies were largely unsuccessful. The burden of malaria that remains today, much of which is in sub-Saharan Africa and in remote rural areas of Asia and Latin America or among marginalized populations, is unacceptably high. Today malaria remains a major cause of poverty and underdevelopment, and it is estimated that 3.2 billion people live at continuous risk of this disease. Each year, there are more than 350 million cases of malaria and more than a million deaths from the disease. More than two-thirds of malaria cases occur in Africa, as well as approximately 90% of deaths, which are mainly in children under five years of age.

Initial optimism about the possibility for prompt global eradication of malaria, due to early successes obtained largely in temperate or subtropical areas, gave way to support for more long-term control strategies (*2*). In areas where the elimination of malaria is not feasible with existing tools and technologies, the objective should be to reduce malaria burden to a level that is socially and economically acceptable.

2.2 Decline in the use of IRS

Despite its initial widespread use and contribution to the success of malaria eradication and control efforts, in recent years, the use of IRS has declined. This is due in part to lack of government commitment and financing to sustain these efforts over the long term and to concerns about insecticide resistance and community acceptance. However, another important factor has been general disapproval of DDT use, due to fears of its harmful effects on the environment and on human health, fears which are unjustified when DDT is used appropriately for IRS. In the past, DDT was widely used in agriculture and domestic hygiene, leading to massive release of the compound into the environment.

2.3 Evidence of IRS efficacy and effectiveness

Scientific evidence of IRS efficacy in reducing or interrupting malaria transmission in different epidemiological settings has been available since the 1940s and 1950s (*3,4,5*). Numerous studies have shown that IRS has substantially reduced infant and child mortality. This evidence formed the rationale for introduction of IRS as a primary intervention for malaria control and eradication.

Evidence over several decades has confirmed the effectiveness of IRS in reducing levels of infection and incidence of malaria. For example, the malaria incidence was reduced by 90% or more in major areas of tropical Asia and Southern America during the eradication programme through a combination of IRS and other measures.

In Africa, malaria eradication pilot projects were initiated from the 1950s to the 1970s in Benin, Burkina Faso, Burundi, Cameroon, Kenya, Liberia, Madagascar, Nigeria, Rwanda, Senegal, Uganda and the United Republic of Tanzania. These projects demonstrated that malaria was highly responsive to control by IRS with significant reduction of anopheline vector mosquitoes and malaria, although in most cases, transmission could not be interrupted (*6,7,8,9,10*). However, with a few exceptions, IRS was not taken to scale in large parts of sub-Saharan Africa.

The application of IRS consistently over time in large areas has altered the vector distribution and subsequently the epidemiological pattern of malaria in Botswana, Namibia, South Africa, Swaziland and Zimbabwe. The major vector, *An. funestus*, has been eliminated or reduced to negligible levels. Where present, the other major vector, *An. gambiae* s.s., which rests and bites mostly indoors, was also well-controlled. Another vector, *An. arabiensis*, which does not rest indoors as much as *An. gambiae*, is less affected by IRS, even at high coverage levels, and is responsible for low levels of transmission and seasonal increases and outbreaks (*11,12,13*).

2.4 Choosing to implement or scale up IRS

Scientific evidence therefore indicates that IRS is effective to control malaria transmission and thus reduce the related burden of morbidity and mortality as long as most premises (houses, animal shelters) (e.g. $>$ 80%) within targeted communities are treated. Furthermore, studies confirm that IRS is cost-effective, although developments such as insecticide resistance could change the cost-effectiveness over time (*14*). There is no definitive conclusion on the comparative cost-effectiveness of IRS versus ITNs since it depends on the local context. Thus, countries should maintain IRS in their malaria control strategies, where indicated, until further information, including locally-generated data, is available and can be used to fine-tune national interventions and better guide resource allocation.

In a single country, several epidemiological patterns and situations are commonly found requiring different interventions or combinations of interventions. These must be taken into account when deciding whether to use IRS. IRS can be effective in almost all settings as long as certain conditions for implementation are met.

- In unstable, epidemic-prone malaria transmission areas, IRS will prevent seasonal increase in transmission, will prevent and control epidemics and can be used for the elimination of local transmission of malaria.
- In stable-endemic malaria areas with moderately intense but seasonal transmission, IRS can prevent seasonal increase in transmission and reduce levels of infection prevalence and highly seasonal morbidity and mortality.
- In stable-hyperendemic areas where very intense seasonal or perennial transmission occurs, IRS, with a higher frequency of application than in the above instances, can reduce the level of transmission and reduce levels of infection prevalence, morbidity and mortality.*

There are some situations in which IRS is not a suitable intervention, notably where there are no structures to spray. Therefore, IRS has almost no utility in the control of malaria in forested areas of South-East Asia and the Amazon region, where personal protection measures are the best option.

The choice of IRS, or any other vector control intervention, must be made by careful consideration of the factors mentioned above, and will depend on the local context and the strategic objectives, whether elimination of local transmission, transmission control, or personal protection. The role and limitations of existing malaria vector control interventions and personal protection measures have been reviewed by a WHO Study Group and a comprehensive report recently published (*15*).

3. Realizing the potential of IRS

3.1 Selection of insecticide

There are currently 12 insecticides recommended by WHO for IRS, belonging to four chemical groups (one organochlorine, six pyrethroids, three organophosphates and two carbamates). The choice of insecticide must be informed by the following considerations:

- insecticide susceptibility and vector behaviour;
- safety for humans and the environment;
- efficacy and cost-effectiveness.

3.1.1. Insecticide susceptibility

IRS will only be effective if the target vectors are susceptible to the insecticide in use. The development of resistance to insecticides constitutes a major threat to the chemical control of malaria vectors, as it compromises the insecticide's

** IRS has commonly been the intervention of choice in these settings in areas of a particular economic interest (e.g. tourism, mining, oil extraction, agricultural schemes) that requires a rapid and very effective prevention, where financial and logistic constraints do not prevail.*

efficacy. In the past, countries deploying IRS have often been forced to switch to alternative and more expensive insecticides on account of the development of vector resistance. Outside Africa, the prevalence and distribution of insecticide resistance in malaria vectors have not, so far, been a major impediment to insecticide-based interventions, except in some areas of India, the Middle East and Central America.

However, in Africa, the potential threat of resistance to public health insecticides appears to be significant. Resistance to DDT and pyrethroids in major malaria vectors has been found throughout West and Central Africa, in some areas at a high level, as well as in several parts of Eastern and Southern Africa. Resistance to carbamates has been found in countries of West Africa, with a mechanism that also induces cross resistance to organophosphates. The selection of resistance in most malaria vectors is thought to be largely the result of past and present use of insecticides in agriculture. The precise operational implications of insecticide resistance are not yet fully understood.

A comprehensive assessment of resistance at the local level must be carried out before planning any IRS programme, especially in West and Central Africa. The possibility of insecticide resistance calls for the careful monitoring of the susceptibility of malaria vectors to insecticides throughout the world, and the sound management of resistance.

There are specific interactions between insecticides and malaria vectors. Some insecticides tend to repel more than to kill vector mosquitoes. Changes in vector behaviour induced by insecticides may have important operational implications, and it is important to be aware of them when selecting insecticides for IRS.

DDT is the only insecticide which is used exclusively for public health, and, therefore, unlike with other insecticides, resistance development to it is no longer influenced by other uses such as in agriculture. In the context of resistance management, it is, therefore, advisable to maintain the use of DDT until a suitable alternative is available.

3.1.2. Safety for humans and the environment

Another major consideration when selecting an insecticide is safety. Insecticides recommended by WHO are deemed safe for public health use under the recommended conditions of use. Concerns over the safety of DDT, a persistent organic pollutant, have also been comprehensively addressed in the framework of the Stockholm Convention on Persistent Organic Pollutants (POPs). The Convention bans the use of DDT, except for public health purposes. Therefore, DDT can be used for IRS where it is indicated, provided that stringent measures are taken to avoid its misuse and leakage outside public health.

3.1.3. Efficacy and cost-effectiveness

The choice of insecticide has implications for the cost-effectiveness of the IRS intervention. Insecticides suitable for IRS have to be sufficiently stable to maintain biological efficacy on treated surfaces over time, so as to minimize the number of spray cycles needed to cover a malaria transmission season.

DDT has long been the cheapest insecticide and the one with the longest residual efficacy against malaria vectors (6–12 months depending on dosage and substrate). Other insecticides have relatively shorter residual effect (pyrethroids: 4–6 months; organophosphates and carbamates: 2–6 months). Thus, the use of DDT alternatives might require two to four spray cycles per year instead of one, depending on the length of the transmission season, with important operational and financial implications for spraying programmes.

Currently, the cost of using some of the pyrethroid insecticides is almost equivalent to that of using DDT, but other alternatives might be at least four times more expensive depending on the number of spray cycles required. The widescale use of organophosphates or carbamates in areas of year-round high-level transmission might be very difficult to sustain unless improvements in their formulations result in higher residual efficacy and lower cost.

3.2 Effective implementation

Malaria vector control operations have to be targeted, treating only where and when necessary. IRS is a method for community protection, and given its mode of action, the highest possible level of coverage is required to achieve the maximum impact on malaria transmission. Achieving this level of coverage and timing spraying correctly (in a short period of time before the onset of the transmission season) are crucial to realize the full potential of IRS. IRS is indicated only in those settings where it can be implemented effectively, which calls for a high and sustained level of political commitment. Transmission control operations based on IRS, or any other vector control intervention, have to be maintained at high coverage levels for extended periods of time, for as long as impact is needed.

IRS requires effective leadership and management for planning, organization and implementation. Operations must be managed by skilled professional staff, based on an analysis of local epidemiological data and a sound understanding of transmission patterns, vector behaviour and insecticide resistance status. Significant strengthening of human and technical resources, accompanied by sufficient financial resources, is needed to develop or reorganize existing IRS operations.

Finally, community acceptance of house spraying and cooperation, for example by allowing access and removing some household contents prior to spraying, are critical for the programme to be successful. Repeated spraying of houses commonly generates fatigue and refusal by householders. Reduced acceptability has been an impediment to effective IRS implementation in various parts of the world.

3.3 Preventing unauthorized and un-recommended use of public health pesticides

When implementing IRS, it is critical to ensure that adequate regulatory control is in place to prevent unauthorized and un-recommended use of public health pesticides in agriculture, and thus contamination of agricultural products. Pesticide contamination can have serious ramifications for trade and commerce for countries exporting agricultural products.

Maximum residual limits (MRLs) of pesticides in food products intended for human or animal consumption are established and strictly enforced by some countries. The standards vary across countries and according to the type of pesticide (see Annex), resulting in different requirements for exported agricultural products. For example, MRL levels for DDT for the European Union usually range from five to ten times lower than equivalent levels for other countries, such as Japan and the United States. Therefore, to export to the European Union, countries must ensure that their products meet much more stringent standards than they must meet for other countries.

DDT, as a persistent organic pollutant, is now banned for agricultural use. There is, however, no justification for preventing the use of DDT for IRS based solely on fear of contamination of agricultural products, provided a clear national policy and adequate safeguards for storage, transport and disposal are in place and there is adherence to WHO recommendations.

4. Research and development

Growing concerns over insecticide resistance in malaria vectors, and the particularly heavy reliance of ITN interventions on pyrethroid insecticides, call for research and development on new insecticides as alternatives to DDT and pyrethroids. Innovative approaches and alliances may be needed to increase financing and improve research efforts. In addition, studies must be carried out in the field, particularly in Africa, to assess the potential impact of resistance on efficacy and effectiveness of IRS for different resistance mechanisms, insecticides and vectors.

More effective, longer-acting and user-friendly formulations of existing insecticides are needed, as well as improved technologies for their application.

Research and development on refined tools, for example those based on improving malaria surveillance and use of remote sensing technologies, should be undertaken, as well as entomological and epidemiological field investigations to optimally select, combine and target vector and malaria control interventions at country level.

5. Conclusion and recommendations

WHO reaffirms the importance of IRS as one of the primary interventions for reducing or interrupting malaria transmission. WHO's Global Malaria Programme will work together with countries, development agencies, research institutions and the private sector to review, expand and improve IRS interventions, where they can be implemented properly, to complement or supplement other interventions as part of national malaria control policies and programmes.

WHO recommends that national governments should:

1. Introduce and/or scale up coverage of targeted IRS as a primary malaria control intervention in countries where available data indicates that it can be effective towards achieving malaria targets.
2. Take all necessary steps to ensure effective implementation of IRS interventions, including selecting the appropriate insecticide, spraying where and when necessary and sustaining a high level of coverage, and to prevent unauthorized or un-recommended use of public health insecticides.
3. Strengthen the managerial capacity of national malaria control programmes and improve human, technical and financial resources for the timely delivery and high coverage of effective interventions including IRS, with adequate monitoring and evaluation.

WHO will:

1. Support countries to strengthen field entomological and epidemiological services to carry out epidemiological stratification, map distribution of malaria vectors and document key features of their behaviour and insecticide resistance in relation to transmission of malaria.
2. Support countries with planning, implementation, monitoring and evaluation of the intervention, including fostering linkages between the public and private sectors for improving product support on malaria insecticides in the areas of quality control, public information and health worker education and training for IRS.
3. Promote heightened research and development efforts to improve the formulation of existing insecticides for longer duration of efficacy and support the development and deployment of new long acting insecticides and novel tools for malaria control.

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ANNEX

Food residue limits of selected pesticides that are recommended for indoor residual spraying (expressed as maximum residual limits (MRLs) or tolerance levels: ppm = parts per million in mg/kg)

Pesticides recommended for IRS		Examples of food types	US tolerance levels* (ppm)	Japan (MRLs ppm)	European Union (MRLs mg/kg)
Chemical groups	Name of pesticide				
Organochlorine	DDT	Avocado	0.2	0.5	0.05
		Corn	0.1	0.2	0.05
		Cherries	0.2	0.2	0.05
		Eggs	0.5	0.1	0.05
		Mango	0.2	0.5	0.05
		Onion	0.2	0.5	0.05
		Papaya	0.2	1.0	0.05
		Pineapples	0.2	0.5	0.05
		Peanuts	0.2	0.2	0.05
		Tomato	0.05	0.2	0.05
Organophosphates	Malathion	Apple	8	0.5	0.5
		Carrots	8	0.5	0.5
		Orange	8	4	2
		Mango	8	8	0.5
		Pepper	8	0.5	3
		Pineapple	8	8	0.5
		Potato	8	0.5	0.5
		Onions	8	8	3
		Tomato	8	0.5	3
		Yams	1	0.5	0.5
Pyrethroids	Cyfluthrin	Apple	N-E	1.0	0.2
		Carrot	0.2	0.1	0.02
		Pepper	0.5	5	0.3
		Potato	0.01	0.1	0.02
		Pineapple	N-E	0.02	0.02
		Mango	N-E	0.2	0.02
		Milk (dairy)	1	0.04	0.02
		Onion	N-E	2	0.02
		Tomato	0.2	2	0.05
		Yams	N-E	0.1	0.02
	Deltamethrin	Apple	1.0	0.5	0.1
		Bananas	N-E	0.5	0.05
		Beans	N-E	0.1	1
		Corn (sweet)	0.03	1.0	0.05
		Mangoes	N-E	0.5	0.05
		Onion	0.1	0.5	0.1
		Papaya	N-E	0.5	0.05
		Pepper	0.3	0.5	0.05
		Peanuts	N-E	0.1	0.05
		Tomato	0.2	0.5	0.2

* For DDT, figures presented are action levels. The FDA takes action to make the food item unavailable to the consumer when these action levels are exceeded. N-E = MRL or tolerance level not established

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