MANUAL FOR

INDOOR RESIDUAL SPRAYING

IN URBAN AREAS FOR *AEDES AEGYPTI* CONTROL

PAHO

Pan American Health Organization

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1. Introduction

The seriousness of the current epidemiological situation of *Aedes*-borne viruses in Latin America, marked by co-circulation of dengue, chikungunya, and Zika viruses, the emergence of epizootics of yellow fever, and the occurrence of cases of microcephaly and other associated illnesses (e.g., Guillain-Barré syndrome), led the World Health Organization (WHO) to declare an emergency in the Americas in 2016[1]. Given the absence of a specific treatment and vaccines against dengue, chikungunya, and Zika and the limitations of current vector control strategies, WHO urged greater use of the available alternatives for improving control of the *Aedes aegypti* mosquito vector, together with complementary activities. Added to this was the problem of maintaining adequate and uniform yellow fever vaccination coverage in endemic urban centers, a situation that carried the risk of urban circulation of that disease.

The insecticide application methods currently used in *A. aegypti* control (larvicides, space spraying of adulticides from the street using vehicle-mounted heavy equipment, or ultralow volume (ULV) indoor spraying with portable equipment) have proven only partially effective. ULV spraying of adulticides from vehicles on the street provides extensive coverage areas in urban settings but with a low probability of contact with indoor populations of *A. aegypti*, limiting its entomological effectiveness (Reiter and Gubler, 1997; Castle *et al.*, 1999; Perich *et al.*, 2000). Consequently, this method can become a major source of selective pressure for insecticide resistance (Marcombe *et al.*, 2009; Ranson *et al.*, 2010, Maciel de Freitas *et al.*, 2014). Indoor ULV spraying, in contrast, is more effective in reducing mosquito populations in dwellings, but its entomological effect is temporary, lasting no longer than two or three weeks (Pant and Mathis, 1973; Koenraadt *et al.*, 2007; Gunning *et al.*, 2018).

One alternative recently recommended by the WHO Vector Control Advisory Group (VCAG)[2] and the U.S. Centers for Disease Control and Prevention[3] is indoor residual spraying (IRS), especially in *Aedes* resting sites, and deployed primarily in houses and other buildings such as schools, community centers, health centers, etc. that pose a potential risk to specific segments of the population. (Vazquez-Prokopec *et al.*, 2017a).

We call this method "IRS for urban *Aedes* control" (IRS-*Aedes*) to distinguish it from IRS for malaria or leishmaniasis (in which chemical treatment is extensively applied to the interior of the dwelling, including walls and ceiling). The goal of this strategy is to reduce vector-virus-human contact through a chemical barrier in the home that acts in two ways: a) maintaining effective control for an extended period (months) by eliminating mosquitoes that rest on the treated surfaces; and b) when pyrethroids are used, by discouraging or repelling mosquitoes that enter the home. Unlike the classical IRS used in fighting malaria and leishmaniasis, rational application of insecticides in resting sites through IRS-*Aedes* significantly reduces the time spent spraying a house and the amount of insecticide used.

[1] http://www.paho.org/hq/index.php?option=com_docman&task=doc_view&Itemid=270&gid=32405&lang=en
[2] http://www.who.int/neglected_diseases/news/mosquito_vector_control_response/en/
[3] https://www.cdc.gov/zika/public-health-partners/vector-control-us.html

A systematic review recently concluded that IRS (either in its classical form or as IRS-*Aedes*) is promising for dengue control (Samuel *et al.*, 2017). IRS-*Aedes* has yielded an 86%-96% reduction in dengue transmission in the Australian city of Cairns (Vazquez-Prokopec *et al.*, 2010; Vazquez-Prokopec *et al.*, 2017*a*) and has satisfactorily controlled pyrethroid-resistant populations of the vector (Vazquez-Prokopec *et al.*, 2017*b*). There is also historical evidence of the epidemiological impact of IRS. IRS and perifocal residual spraying with DDT (in larval sites) contributed to the elimination of *A. aegypti* in the Americas between the 1930s and 1960s. The use of IRS for malaria and yellow fever helped eliminate *A. aegypti* in the Mediterranean region (WHO, 2006*a*) and Mexico (Torres Muñoz, 1995), respectively. Furthermore, the use of IRS, alone or in combination with larval control, contributed to the elimination of *A. aegypti* in Guyana and the Cayman Islands, respectively (Giglioli, 1948; Nathan *et al.*, 1982).

Even with the evidence of IRS effectiveness in *A. aegypti* control, the tremendous effort required in terms of time and human resources has limited its widespread use in ministry of health institutional control programs. IRS-*Aedes* not only represents a rational use of insecticides but also has opened the door to reconsidering this method as part of the package of interventions in an integrated program for the management of *Aedes*-borne diseases.

Thus, WHO[4] currently recommends including IRS-*Aedes* among the tools and strategies for integrated control of the diseases transmitted by *A. aegypti*. Since IRS-*Aedes* is a modified version of the classical IRS methodology, technical guidelines are needed to standardize the use of this method, designed for urban control of the *A. aegypti* mosquito.

[4] http://www.who.int/neglected_diseases/news/mosquito_vector_control_response/en/

2.
Objectives of the manual

1. Provide technical guidelines for the strategic use of indoor residual spraying for *A. aegypti* control (IRS-*Aedes*) in urban areas.

2. Compile and standardize the criteria, instruments, technical parameters, and equipment, as well as the application technique, for strategic integration of IRS-*Aedes* in *A. aegypti* control programs.

The *Manual for Indoor Residual Spraying in Urban Areas for* Aedes aegypti *Control* is intended not only for operational personnel and middle and senior management of programs responsible for the prevention and control of *Aedes*-borne diseases, but also for the academic community involved in *Aedes* research, private pest control personnel, and the general public.

3. Indoor residual spraying

3.1. Definition

Indoor residual spraying, or IRS, consists in the application of an insecticide with residual action in a dwelling (on walls and other exposed surfaces such as ceilings) to eliminate arthropods of public health importance that land or rest on them (WHO, 2006b; WHO, 2007; WHO, 2015).

IRS is considered one of the main interventions for reducing and interrupting malaria transmission (WHO, 2006b) and has been successfully used to control the vectors of Chagas disease and leishmaniasis (WHO, 2007; WHO, 2010a). It has also been used in Mexico to control arachnids of medical importance, such as scorpions (SSA, 2014).

3.2. "Traditional" IRS in the context of *Anopheles* and malaria

The traditional definition of IRS in the context of malaria programs[5] involves the application of insecticides to surfaces where mosquitoes of the genus *Anopheles* rest, such as walls, eaves, ceilings, and other structures (including shelters for livestock and pets).

Traditional IRS basically consists of impregnating the entire wall and ceiling with insecticide (WHO, 2007; WHO, 2015). This requires moving all furniture and removing objects from the walls, increasing the time and effort required to spray each dwelling (it also requires prior willingness and preparation by the occupants). In urban areas, the time involved in preparation and the removal of personal property have been the main obstacles to the acceptance of IRS (WHO, 2006b; Paz-Soldán *et al.*, 2018).

3.3. IRS-*Aedes* for urban *A. aegypti* control

As with the vectors of malaria, leishmaniasis, and Chagas disease, IRS in the context of urban *A. aegypti* control should be based on the biology and ecology of the vector. Numerous studies show that *A. aegypti* rests primarily on the lower part of the dwelling, on objects and walls below 1.5 m (Ritchie *et al.*, 2002; Vázquez-Prokopec *et al.*, 2009; Chadee, 2013; Tainchum *et al.*, 2013; Dzul Manzanilla *et al.*, 2017).

Thus, the first modification of classical IRS in IRS-*Aedes* is the application of the insecticide only on the lower part of walls (below 1.5 m). Studies in experimental houses indicate that spraying resting sites and walls below 1.5 m does not produce a loss of effectiveness compared with the classical method (Figure 1).

[5] http://www.who.int/malaria/publications/atoz/9789241508940/en/

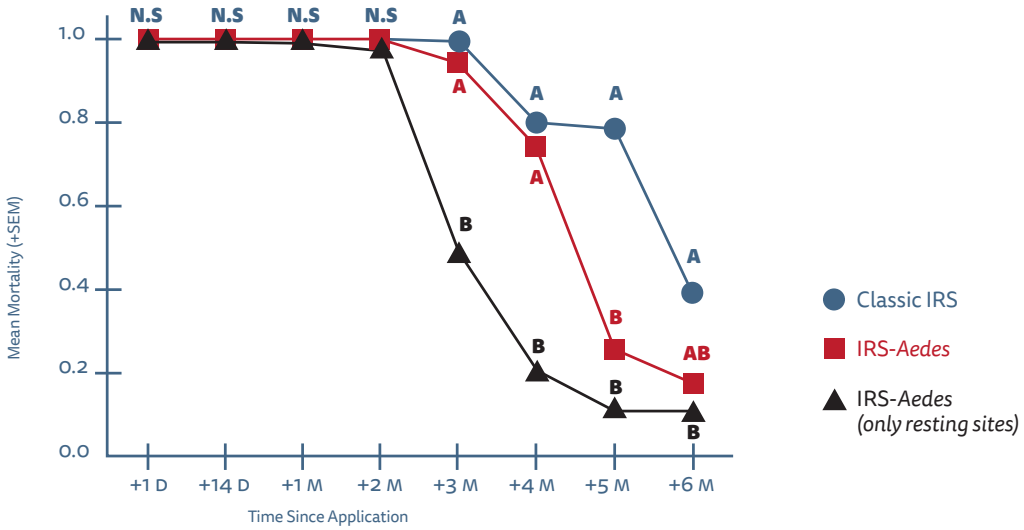


Figure 1. Mortality (and standard error, SE) of *A. aegypti* in experimental houses following application of bendiocarb using the classical method and two targeted IRS-*Aedes* spraying methods: one in which the walls and resting sites are sprayed (IRS-*Aedes*) and the other in which only the resting sites are sprayed (IRS-*Aedes* only resting sites). Taken from Dunbar *et al.* (forthcoming).

Selective application of residual insecticides based on the biology of *A. aegypti* significantly reduces the time, effort, and resources necessary for obtaining better coverage and increases community acceptance. Thus, it has been described to have a greater effect on *A. aegypti* activity and, thus, on the transmission of dengue viruses during an outbreak (Hanna *et al.*, 2001; Ritchie *et al.*, 2002; Montgomery *et al.*, 2005).

4.
Methodology

4.1. Spraying equipment

The ideal IRS equipment recommended in the WHO guidelines (2010*b*) and their most recent update (WHO, 2018) is a hand-operated compression sprayer made of corrosion-, pressure-, and UV-resistant material.

The standard IRS equipment has traditionally been a metal hand-operated compression sprayer (Figure 2, top row), but hand-operated compression sprayers with triggers can be used, and motorized equipment with a fourstroke engine and spray lance, control flow valve (CFV), and 8002E nozzle can be adapted (Figure 2, middle row).

Today, there are hand-sprayers with rechargeable batteries that produce the same droplet size, flow, and spray pattern as the standard equipment, making them an attractive alternative for urban IRS (Figure 2, bottom row).

Figure 2. IRS equipment for *A. aegypti* control (top row) and alternatives that are potentially useful with modification of their technical specifications (middle and bottom row).

Basic components of hand-operated compression sprayers

Hand-operated compression sprayers have three basic components (Figure 3): a cylindrical corrosion-, pressure- and UV-resistant insecticide tank; a T-shaped air pump with a safety valve; and the discharge system.

At the top, the insecticide tank has a pressure gauge (manometer), a pressure-release valve, an opening (90 mm) for the insecticide, and a device for connecting the discharge system. On the side, it has a bracket for attaching the spray lance (and nozzle) when not in use, a foot rest or pedal that helps with the pressurization of the tank, and a 5 cm-wide shoulder strap (± 2 cm), adjustable to 100 cm in length (Figure 3).

The application system consists of a hose of at least 1.5 m, an on/off valve (a trigger device to allow the liquid to flow), a metal spray lance (of no less than 0.5 m), a control flow valve, and the nozzle (body, tip, and cap).

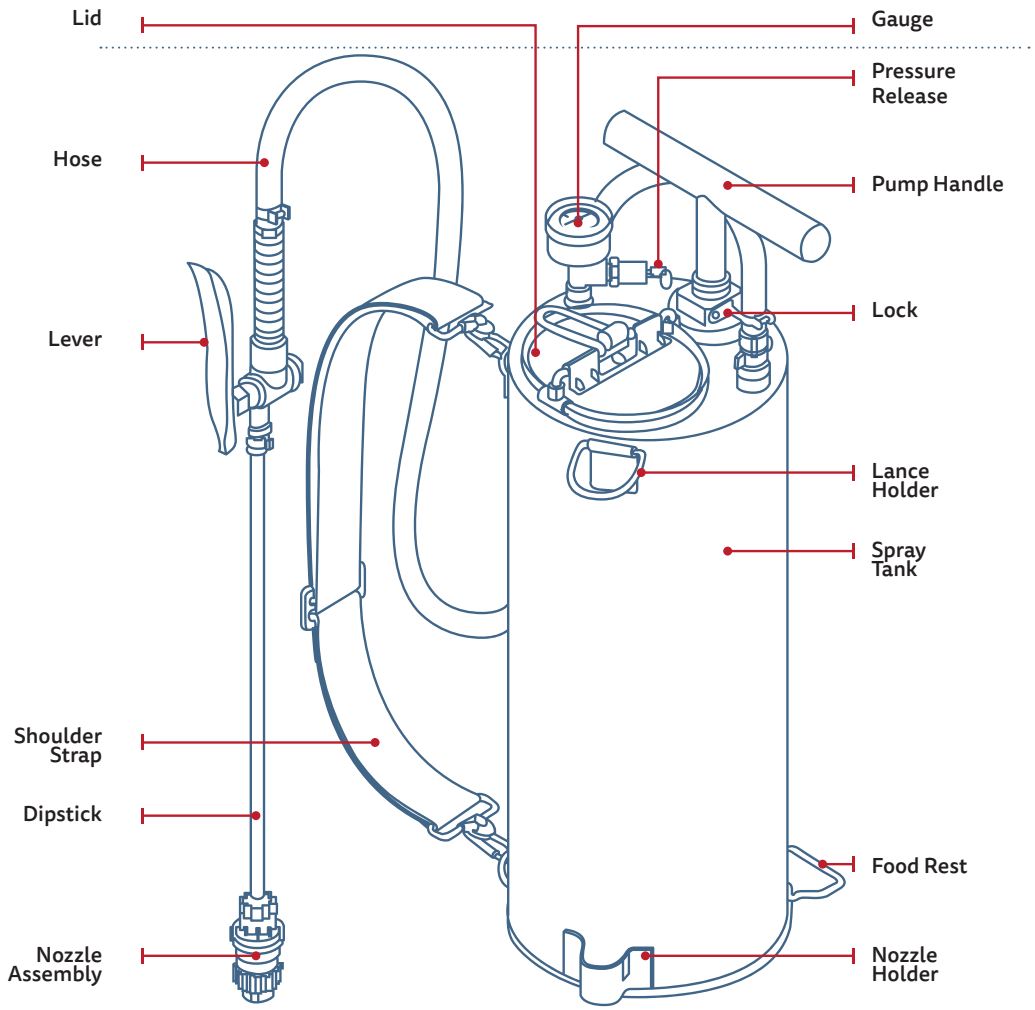


Figure 3. Illustration of traditional IRS equipment (adapted from Matthews, 2011).

Pressurization of hand-operated compression sprayers

The pressurization of manual compression sprayers is the process of producing or raising pressure in the insecticide tank by injecting it with air using a hand pump. When the pressure is high enough (55 psi)[6] and the trigger is squeezed, the pressure causes the liquid to shoot out.

Pressurization of a hand-operated compression sprayer is achieved with the procedure described in the box below. Water, rather than insecticide, should be used during the training process to minimize unnecessary exposure.

1. Secure the pump handle with both hands and place a foot on the foot rest.		 0 pump strokes
2. Raise the handle to its full length and push it all the way down (one pump stroke). Observe the change (psi) in the manometer.		 1 pump stroke

[6] The psi is a unit of pressure. It is defined as the pounds-force per square inch. One psi equals 0.0689476 bar. One bar equals 1 million bares, or roughly 1 atmosphere.

3. Pump approximately 55 times. Each pump stroke should add about 1 psi, meaning that the equipment should operate at 55 psi (3.8 bar).	 22 pump strokes	 55 pump strokes

Nozzle and flow of the hand-operated compression sprayer

The nozzle and flow determine the size of the droplets, spray pattern, and dose.

The World Health Organization (2015) recommends the 8002E metal or ceramic nozzle for IRS. A CFV is needed to ensure uniform flow, since the flow (and thus the dose) depends on the pressure. The CFV for a pressure of 1.5 bar (red CFV) is recommended. The 8002E nozzle has an output of 550 ml per minute at a pressure of 1.5 bar (22 psi) with a red CFV (Figure 4).

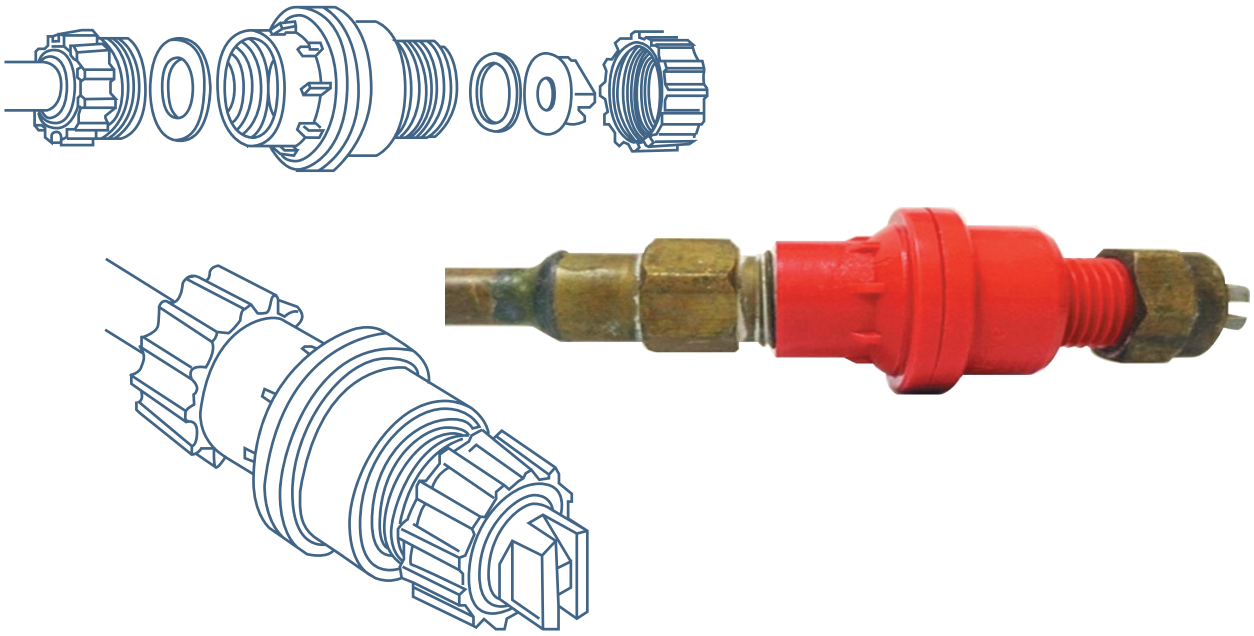


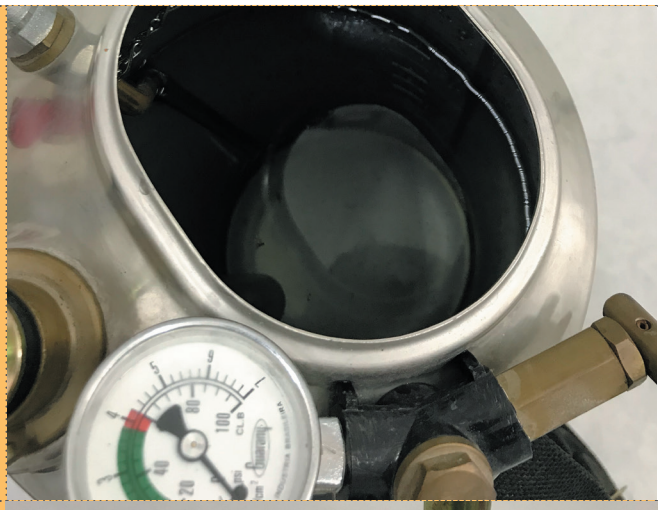
Figure 4. Recommended control flow valve (CFV) for IRS.

Calibration of hand-operated compression sprayer

The purpose of calibration is to make sure that the flow is correct. It is an indirect way of gauging the integrity of the valve.

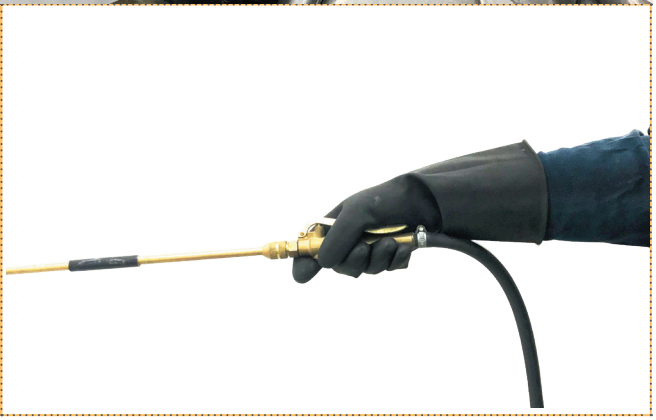
The procedure for calibrating a hand-operated compression sprayer is as follows:

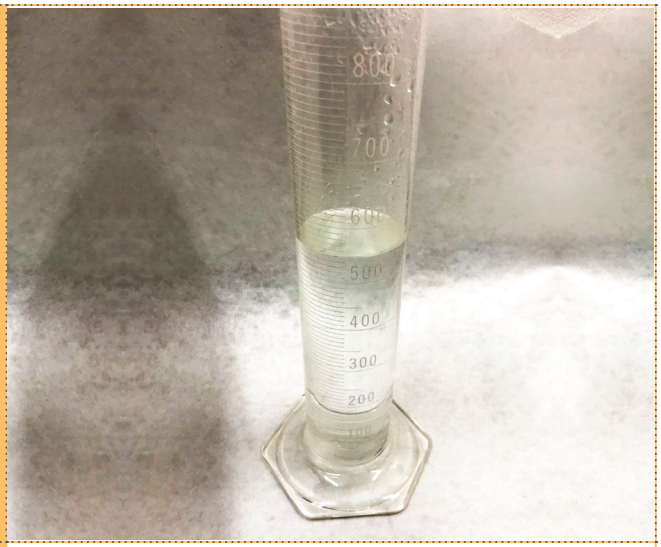
1. Fill the insecticide tank with clean water to the maximum level indicated.



2. Pressurize to 55 psi.

3. Squeeze the on/off trigger for one minute.



4. Deposit the water expelled in a container or directly in a graduated plastic or glass cylinder or beaker.	
5. Calculate the discharge or flow – that is, the number of milliliters per second expelled by the equipment.	550 ml/minute = 9.17 ml/second
6. Repeat steps 3 to 5 at least three times.	1. 548 ml/minute = 9.13 ml/second 2. 550 ml/minute = 9.17 ml/second 3. 552 ml/minute = 9.20 ml/second
7. Average the three measurements, adding the three values and dividing by three.	9.16 ml/second (standard deviation = 0.033)

The optimal criterion is the flow indicated by the manufacturer of the nozzle or CFV (5%, more or less). It is recommended that nozzles be checked after the treatment of every 200 to 300 houses (WHO, 2015). Evaluating the condition of the valve involves checking the amplitude (swathe) and spray pattern on dry walls or walls with florescent waterbased paint. If the flow is too high and the pattern is not uniform, the nozzle should be changed. The use of defective nozzles is associated with over-treatment and irregular distribution of the active ingredient of the insecticide on sprayed surfaces.

4.2. Insecticide

What insecticide can or should we use?

To select the proper insecticide formulation for IRS-*Aedes*, the following information is needed:

1. The susceptibility of *A. aegypti* to the insecticides that can be used in IRS.
2. Information on the residual action of the insecticide.
3. Registration of the insecticide and authorization for its use in public health (and in urban areas, if necessary).
4. Period in which the majority of cases of the disease are reported.

The following should also be taken into account:

1. The insecticide groups used at ULV (interior and exterior) and in larval control for integrated resistance management.
2. The toxicological categories of the insecticides, considering the risk to humans and the environment.
3. The infrastructure for insecticide transport and storage.
4. The comparative cost of the different insecticides for IRS.
5. The International Code of Conduct on the Distribution and Use of Pesticides and other international agreements.

The WHO list of recommended insecticides for IRS against malaria vectors (Table 1) includes numerous options in five chemical groups: organochlorines (OC), carbamates (C), organophosphates (OP), neonicotinoids (NN), and pyrethroids (PY).

The formulation that has dominated since the development of IRS is wettable powder (WP). All molecules recommended by WHO for IRS are formulated in WP, and some are formulated as capsule suspension (CS), emulsifiable concentrate (EC), suspension concentrate (SC), and water-dispersible granules (WG).

The molecules formulated as wettable powder were designed for and applied in rural areas with porous structures and surfaces; the EC and SC formulations are designed for the structures and surfaces customarily found in urban areas, such as walls covered in oil-based paint, etc. Microcapsulated CS, which has exhibited 9-10 months of residual action in malaria vectors, has recently been introduced (Haji *et al.*, 2015; Mashauri *et al.*, 2017). This formulation can be very useful for IRS-*Aedes* in urban areas, provided that the insecticide residues do not stain treated surfaces.

The insecticides and doses to apply with IRS are governed by the regulations of each country. The table below lists the insecticides for IRS-malaria (WHO, 2019):

Table 1. Residual pesticide molecules for indoor spraying.

Molecule	Chemical group	Mode of action
DDT	OC	Contact
Malathion	OP	Contact
Fenitrothion	OP	Contact and airborne
Pirimiphos-methyl	OP	Contact and airborne
Bendiocarb	C	Contact and airborne
Propoxur	C	Contact and airborne
Alpha-cypermethrin	PY	Contact
Bifenthrin	PY	Contact
Cyfluthrin	PY	Contact
Deltamethrin	PY	Contact
Etofenprox	PY	Contact
Lambda-cyhalothrin	PY	Contact
Clothianidin	NN	Contact

Given pyrethroid resistance in *A. aegypti* and its extensive geographical distribution (Moyes *et al.*, 2017), carbamates and organophosphates are considered the best alternatives to pyrethroids for IRS.

Preparation of the insecticide

In preparing the insecticide, the product instructions should always be followed. A generic insecticide is used here as an example.

1. In a container (preferably graduated) that holds more than 7.5 liters, add 3 liters of clean water.

2. Open the product, bearing in mind the need for protective equipment.

   (Note: This procedure will vary with the insecticide formulation and distribution method, which depend on the brand and the insecticide.)

3. Add approximately half of the product needed for one load.

4. Stir until thoroughly blended.

5. Add 2 liters of clean water to the mixture and stir again.

6. Add the remaining half of the packet and continue stirring until the mixture is thoroughly blended.

7. Rinse the packet three times with a liter of water and add the water to the mixture.

8. Pour the mixture into the insecticide tank.

9. With another 1.5 liters of water, rinse the container in which the mixture was prepared three times and pour the water from each rinse into the insecticide tank.

   The final content of the mixture will be 7.5 liters, and the tank should have a minimum capacity of 10 or 12 liters.

10. If you have a hand-operated compression sprayer, pressurize and shake it to finish mixing the insecticide with the water.

Calculating the dose

The IRS dose is the amount of active ingredient (a.i.) per square meter (m^2), expressed in grams or milligrams (1 g = 1,000 mg). Specifically, the recommended dose for IRS depends on the insecticide used. For example, the dose of bendiocarb (C) ranges from 0.1 g (100 mg) to 0.4 g (400 mg) per square meter.

For example, to apply the recommended doses, the dose of bendiocarb per square meter is calculated as follows:

1. One 125 g packet at 80%.
2. Concentration of active ingredient, 100 g (125 × 0.8) / 7,500 ml (7.5 l × 1,000) = 0.01 g/ml.
3. Flow per minute = 550 ml; flow per second = 9.16 ml.
4. Amplitude = 0.75 m.
5. Height = 1 m.
6. Velocity = 2.2 seconds/linear meter.

$$dose = (y/x) \times z \quad \text{..... (Equation 1)}$$

where:

y = milliliters applied per linear meter. This value is calculated by multiplying the flow per second (9.16 ml) by the velocity (2.2 s/m).

x = milliliters applied per linear meter. This value is calculated by multiplying the flow per second (9.16 ml) by the velocity (2.2 s/m).

z = concentration of active ingredient in the mixture.

Filling in equation 1, we obtain:

$$\textbf{dose} = \left(\frac{9.16\ ml/s \times 2.2\ s/m}{1m \times 0.75\ m} \right) \times 0.01\ g\ a.i./ml$$

$$\textbf{dose} = \left(\frac{20.1\ ml}{0.75\ m^2} \right) \times 0.01\ g\ a.i./ml$$

$$\textbf{dose} = \left(\frac{26.9\ ml}{m^2} \right) \times \left(\frac{0.01\ g\ a.i}{ml} \right)$$

dose = 0.27 g a.i./m^2

4.3. Application of IRS-*Aedes*

Parameters of the application technique

Table 2 indicates the parameters of the application technique suggested for IRS-*Aedes* in urban areas to guarantee the proper dose and uniform application.

Table 2. Parameters of the application technique for IRS-*Aedes* in urban areas.

Parameter	Definition	Value
Dose	Amount of insecticide sprayed on the surface, expressed in grams of active ingredient per square meter.	See manufacturer's indications
Distance	Distance from the nozzle to the wall surface.	45 cm
Amplitude	Width of the application swathe.	75 cm
Overlap	Overlapping of two application swathes.	5 cm
Altitude	Maximum height of the swathe. To standardize the height to 1.5 m, the brigade supervisor will measure each spray operator with a tape measure or other device to determine the height to which the extended arm should be raised to reach a meter and a half.	1.5 m
Velocity	The time it takes the application swathe to travel per linear meter.	2.2 seconds
Pressure	The force exerted by a gas, liquid, or solid on a surface.	22 psi (1.5 bar) with CFV
Flow	The amount of insecticide mixture discharged by the spraying equipment, in milliliters per minute.	550 ml/min
Droplet size	Diameter of the droplets produced in the application.	120-200 µm

Procedure for the use of IRS-*Aedes* for urban *A. aegypti* control

Figure 5 illustrates the technique for IRS-*Aedes* in urban areas (modified from WHO, 2015).

The residual insecticide will be applied in vertical swathes 1.5 m high (or the lower half of the wall) and 75 cm wide, with a 5 cm overlap on sprayable surfaces (see illustration below). The insecticide should be sprayed from top to bottom, until each swathe is complete. One way of doing this is to take a step sideways at the end of each swathe and begin a new one. The time it takes for half the swathe to travel is 3.3 seconds, and this is achieved by mentally counting "one thousand and one, one thousand and two, one thousand and three" (WHO, 2015).

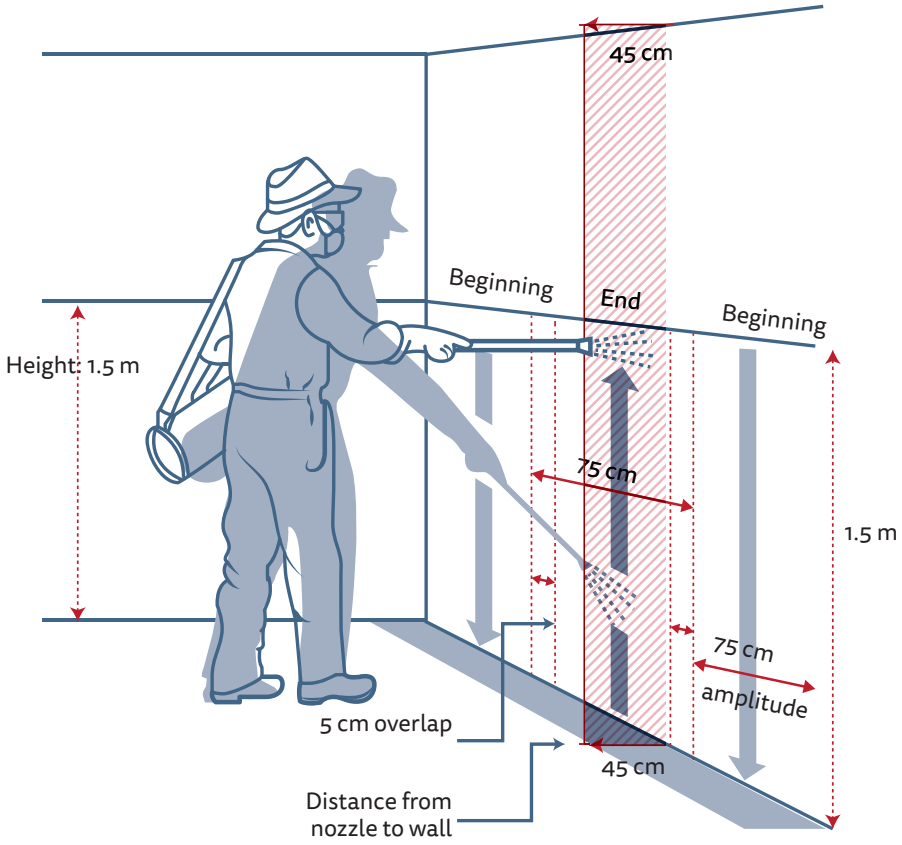


Figure 5. Illustration of the IRS technique for urban *A. aegypti* control (adapted from WHO, 2015).

Given the density of the insecticide, the tank must be shaken periodically to keep the product well-blended in the aqueous solution. The following method for shaking the tank is recommended (Figure 6) before spraying each house and room, or every 20 swathes sprayed. Periodically shaking the mixture homogenizes the solution, reducing the potential for uneven distribution of the active ingredient on

treated surfaces.

Figure 6. Recommended method for shaking the tank and keeping the mixture blended.

Where to spray in the house

In urban areas, the surfaces that should be treated with IRS-*Aedes* are the preferred sheltering or resting sites of *A. aegypti*. The ultimate goal is to spray both the exposed surface below the midpoint of the wall (≤ 1.5 m) and the mosquito's resting sites–i.e., the legs and backs of chairs, tables, sofas, and other furniture (Figure 7). For example, a very heavy piece of furniture placed against a wall, such as a wardrobe, should not be moved; instead, to spray the insecticide, the lance should be inserted behind it (if there is space between the wall and the furniture), below it (if there is space between the floor and the furniture) and on the lateral surfaces. Furthermore, it is recommended that residual insecticides be sprayed on door- and window frames.

Waterproof surfaces and some soft surfaces (tile, veneers, enamel, plywood, carpeting, or wallpaper) should not be sprayed, since the insecticide does not adhere to them.

Since IRS for urban *A. aegypti* control is applied only to exposed wall surfaces, it is unnecessary to ask the occupant to remove objects from the house or place them in the center of each room, although covering utensils, water, food, and toys is recommended.

In each house, spraying should begin in the rooms at the rear and proceed toward the front. In each room, the technique is applied clockwise. When the building has two or more floors (apartments), spraying should begin on the upper floor and proceed downward, always beginning with the rooms at the rear of the building and concluding with those at the front. The exposed wall surfaces are sprayed first, followed by the resting sites.

Bedrooms, living room and dining room, and bathroom should be sprayed (if the walls are not tiled), since they are the *A. aegypti* mosquito's preferred resting and sheltering sites (Dzul Manzanilla *et al.*, 2017).

IRS is not recommended in the kitchen because of the risk of poisoning and the fact that the percentage of *A. aegypti* that rest there is low (Dzul-Manzanilla *et al.*, 2017).

Figure 7. Examples of sprayable surfaces within the home for urban *A. aegypti* control. It is important to use insecticides that do not stain treated surfaces or leave very visible streaks to ensure the acceptability of spraying.

Application cycles

Application cycles for urban *A. aegypti* control should be designed to control transmission peaks in endemic areas and depend on the abundance of the vector, the transmission season, the insecticide's residual action, and financial resources.

In the specific case of *A. aegypti* and the arboviral diseases transmitted by the species, the abundance of the vector and transmission in tropical urban areas usually coincide with the rainy season, which lasts four to five months each year. Thus, for *A. aegypti* control in endemic areas with highly intense transmission, the ideal is to use spraying cycles that at the very least cover the high transmission period.

The frequency of application depends on the insecticide's residual action and the budget for the intervention. Mathematical simulations for insecticides with up to five months of residual action show that the greatest epidemiological impact is obtained if the IRS-*Aedes* technique is applied proactively before the transmission period, rather than reactively to the presence of cases (Hladish *et al.*, 2018). Assuming residual action of three months, spraying cycles could be programmed every four months (Figure 8). Insecticides with residual action of five to seven months (e.g., bendiocarb or pirimiphos-methyl) would allow for one spraying cycle per transmission season.

If resources are limited, it is recommended that at least one application cycle be completed between the start of the rainy season and the period immediately before the surge in transmission.

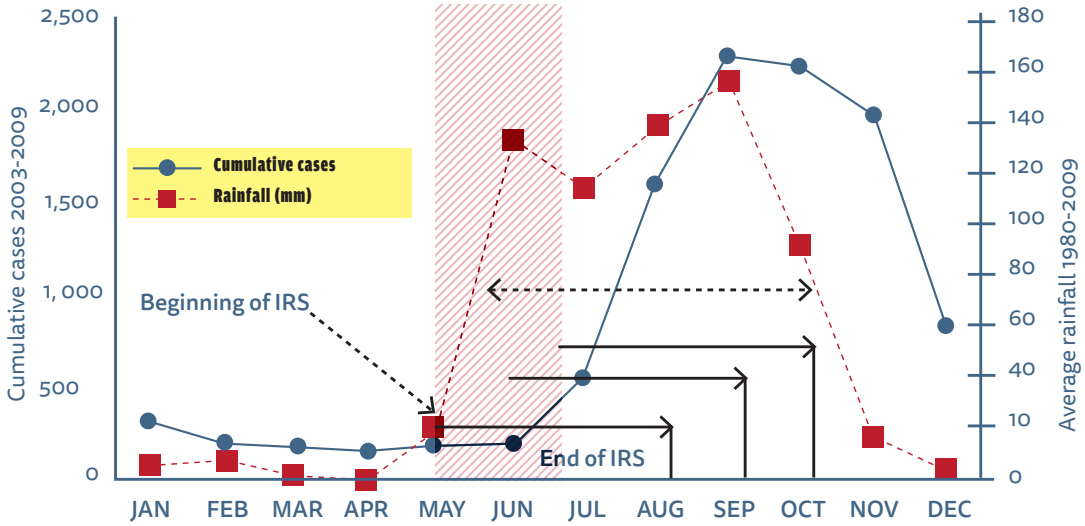


Figure 8. Epidemic curve of dengue cases (gray line) from 2003 to 2009, by month, in Acapulco, Mexico (Source: National Epidemiological Surveillance) and average monthly rainfall pattern during 1980-2009 (red line) in that city. The dotted black line indicates the rainy season and the solid black lines, the anticipated residual action of the insecticide (four months in the case of bendiocarb) for 50% and 100% of the area treated.

IRS-*Aedes* is recommended in areas in need of this intervention. For example, the use of IRS-*Aedes* in areas with high transmission of dengue and other *Aedes*-borne diseases (parts of the city with a historically disproportionate number of cases) will facilitate its scaling-up and increase its cost-effectiveness (Bisanzio *et al.*, 2018). For this, historical information on cases in different areas over time (e.g., neighborhoods, census districts, etc.) can be used, along with statistical analyses, to identify the areas with a disproportionately high number of cases (Bisanzio *et al.*, 2018).

Geographic information systems that combine epidemiological data with city cartography allow for rapid visual characterization to identify the critical points reporting more cases each season. Furthermore, IRS-*Aedes* should be a priority in areas considered to pose a potential risk to specific segments of the population (schools, hospitals, points of potential introduction of the viruses), based on entomological or epidemiological information.

Recommendations pre- and post-IRS-*Aedes*

Pre	Post
1. Explain the purpose of IRS to the occupants of the house. This includes informed consent (see box below).	1. After IRS, do not re-enter the house for at least 60 minutes. People allergic to insecticides should wait at least 24 hours before reentering.
2. Ask the occupants of the house to prepare to leave and take their pets with them. Rooms occupied by people with special needs (a history of allergies, chronic degenerative diseases, cancer, differing abilities, and mental deficiencies) or who cannot leave will be excluded.	2. Open doors and windows once IRS has ended to ventilate the rooms and dry the surfaces. Turn on any fans.
3. Put away all objects of value, such as personal papers (birth certificate, receipts for electrical bills, passport, visa, etc.), money, cell phones, etc.	3. Thoroughly wash dishes, kitchen utensils, and baby accessories with soap and water before use.
4. Cover dishes, glassware, kitchen utensils, food, water, clothing, toys, baby accessories, furniture, household appliances, and computers.	4. Sweep up all dead insects and arachnids, clean and wash away the residual spray left on the floor, table, chairs, and toys, before children and pets return.

5. Remove linens, pillows, and covers.	5. Do not clean or wash the walls/doors that were sprayed.
6. Take pets outside. In the event that they cannot be taken out, cover cages and fish tanks.	6. Avoid contact with the sprayed walls. Change linens.
	7. If your skin becomes irritated, wash it with copious amounts of water. If the problem persists, go immediately to the nearest health center. If your eyes are affected, wash them for 10 minutes with copious amounts of running water.

Informed consent

The informed consent form is a valuable tool for verifying that staff are actually informing the population about the recommendations to follow before and after IRS-*Aedes*. For regulatory reasons, informed consent cannot be obtained in all cities. When it can be, the consent form serves as protection when occupants of the house raises a complaint (Annex II). When obtaining informed consent, a pamphlet containing the recommendations is given to the occupant, together with the house spray card (Annex III).

Recommendations for health centers or physicians

Symptoms and signs of poisoning

MILD: Headache, blurred vision, nausea, vomiting, and diarrhea.

ACUTE: Pupil contraction, salivation, tearing, watery nasal discharge, severe weakness, cramps.

Ninety-nine percent of adverse reactions to IRS are eye or skin reactions to the insecticides and occur when occupants do not follow the post-spraying recommendations. The prevalence of such incidents could be extremely low: 0.004 (5/132,000).[7]

[7] An emergency dengue prevention and control operation conducted in the city of Iguala, Mexico, from 16 July to 7 September 2012 to eliminate infected mosquitoes and dengue transmission included the following activities: 31,583 houses treated for larval control, 4,190 hectares treated with space spraying, and 32,643 houses treated with propoxur using rapid IRS. In a protected population of 132,000 in 173 neighborhoods, there were five cases of skin and eye reactions to the insecticides, all in children. In all cases, the post-IRS recommendations were not followed.

Antidote and treatment

ADULTS: Administer two 0.5 mg tablets of atropine, monitor progress, and repeat the dose if necessary. The treatment of children should be supervised by a pediatrician or internist. If the symptoms are severe, slowly administer of 2-4 mg of atropine intravenously, until the atropinization is complete. For organophosphate and carbamate poisoning, atropine should be used as the antidote; in the case of organophosphates, oximes may be necessary. Oximes are indicated only for the treatment of organophosphate[8] poisoning.

Protective equipment

Detailed information on the protective equipment necessary for IRS-*Aedes* can be found in the operations manual for malaria control.[9] Chapter 5 (page 38) of the manual contains all the information about protective equipment and the indications for its proper use.

According to WHO,[10] the articles that can be used as personal protective equipment (PPE) are (Figure 9):

HEADGEAR. Hats should be made of waterproof material and have a broad brim to protect the face and neck. They should be able to withstand regular cleaning or be replaced regularly.

NETTING AND VISORS. Plastic netting protects the face from spray droplets and permits adequate visibility. Another alternative is transparent visors or face masks, which are more comfortable, especially in warm locations.

SHIELDS. Short shields made of light plastic can be hung from the hat to protect the shoulders.

OVERALLS. Overalls should be made of light-weight, durable cotton fabric and be washed regularly, depending on the frequency with which the insecticide in question is sprayed. Washing with soap, detergent, or washing soda is sufficient for organophosphate or carbamate formulations. If organochlorines are used, they may need to be soaked in light kerosene before washing.

APRONS. Rubber or polyvinyl chloride (PVC) aprons provide protection from spills of liquid concentrates.

RUBBER BOOTS. Boots complete the apron's protection. They should go under the overall to prevent the insecticide from leaking inside.

GLOVES. PVC or rubber gloves or gauntlets are necessary for handling the concentrates. PVC gloves should not be used to handle pyrethroids, since the PVC can absorb them. Rubber gloves should be used for handling organic-solvent-based concentrates.

[8] http://www.bvsde.paho.org/tutorial2/e/unidad2/index.html
[9] https://www.pmi.gov/docs/default-source/default-document-library/tools-curricula/irs_training.pdf?sfvrsn=4
[10] http://apps.who.int/iris/bitstream/handle/10665/69795/WHO_CDS_NTD_WHOPES_GCDPP_2006.1_eng.pdf?sequence=1

FACE MASKS. Masks made of gauze or similar materials can filter out wettable powder particulates in water and can reduce the inhalation of dust and facial skin exposure if such protection is considered desirable. They should be washed regularly; in some cases, they must be replaced for the second half of the work day to prevent facial contamination.

RESPIRATORS (MASKS WITH FILTER CARTRIDGES). These can cover either half the face (nose and mouth) or the entire face (eyes, nose, and mouth). Respirators are designed to protect the spray operator from formulations of highly toxic powder and prevent the inhalation of hazardous agrochemicals. The cartridge should be replaced periodically. For a respirator to be effective, it must fit properly over the nose and mouth (so that no air enters through the edges) and be cleaned regularly. Although respirators are usually not required for vector control, they represent additional protection for the spray operator.

Figure 9. Example of personal protective equipment. Appropriate clothing should generally be used when spraying, protecting the face with a mask and goggles or a face shield.

Before putting on the personal protective equipment:

1. Make sure that the gloves, overall, mask, and boots are not torn/broken or soiled.
2. Before removing the protective equipment, wash boots and gloves with water.

After using the personal protective equipment:

1. Wash your hands and face with soap and water; also, before eating, smoking, drinking, or using the toilet.
2. At the end of every work day, take a shower, wash up, and put on clean clothes.
3. Wash your uniform and all equipment with soap and water; keep them separate from the rest of the family's clothes.
4. Change mask cartridges or filters when you detect the odor of pesticide; that is, follow the instructions on the label; replace them if they make breathing difficult, if the filter gets wet or breaks, and if it tastes or smells of insecticide.
5. Keep the mask in a tightly closed plastic bag.

General recommendations:

1. Do not eat, smoke, or drink while spraying or do so near the place that was sprayed.
2. Do not eat near the spraying equipment, the insecticide, or the place that was sprayed.
3. Do not remove the tip of the nozzle with your mouth.
4. Never handle nozzles or spraying equipment unprotected.
5. Never mix the insecticide with your hand.
6. When spraying, do not touch unprotected parts of your body.
7. If the insecticide comes into contact with your skin, immediately wash the exposed area with soap and water.
8. If you feel sick, report it immediately to the supervisor.

4.4. Organization of operational personnel

When organizing personnel, it is recommended that an individual responsible for notification be included for every given number of spray operators (depending on the operational organization of each country). This staff can work in tandem with the spraying brigades (notifying households at the time of the intervention) or separately, notifying them the day before, which tends to increase coverage and acceptability in the community.

Requirements for notification staff

Notification staff must:

1. Be a responsible man or woman over the age of 18.
2. Have very good communication skills and previous experience working with the community.
3. Know how to read, write, and perform basic mathematical operations (addition, subtraction, and division).
4. Take the IRS-*Aedes* course[11] and pass the test.

[11] A typical course should provide specific technical and specialized information on the vector control activities to be performed, explain the connections between activities (e.g., vector control and entomology), spell out the duties, responsibilities, rights, and obligations of staff in each vector control activity, and describe the organization of the vector control program and workplace infrastructure. These courses include a specific and detailed description of all vector control activities (standard operating procedures or SOPs) and an explanation of the biology of the vector.

Requirements for spray operators

Spray operators and notification staff must:

1. Be a responsible man or woman over the age of 18 years. Pregnant women should be excluded due to the risks of insecticide exposure. If they are already working when they become pregnant, a change of activity will be necessary.
2. Be strong and able to operate and fill the equipment during the work day.
3. Know how to read, write, and perform basic mathematical operations (addition, subtraction, and division).
4. Take the IRS-*Aedes* induction course and pass the test.

Functions of notification staff

1. Arrive at work on time and ready to work.
2. Work directly in the field, contacting home owners to explain IRS to them and the need to prepare the house before the spray operators arrive.
3. Obtain their informed consent for IRS (Annex II) whenever possible.
4. Clear up any doubt or question that arises from the explanation.
5. Be courteous and respectful to heads of household and other occupants.
6. Serve as the visible point of contact for the community.

Functions of spray operators

1. Arrive at work on time and ready to work.
2. Keep equipment, tools, personal protection equipment, and accessories clean and in good working order and be fully responsible, especially for the equipment under their care or safekeeping.
3. Apply all insecticides following program procedures, protocols, and instructions; be responsible for all insecticide containers or receptacles (packets) used during the work day.
4. Use the personal protective equipment during IRS according to the instructions for personal and environmental protection against contamination with the insecticide.
5. Use the attached form (Annex 1) to keep an accurate record of activities as IRS operators and notification staff.
6. Be courteous and respectful to the heads of household and other occupants.
7. Respect property in the houses (whether material goods or items of religious or sentimental value).
8. Correctly perform IRS-*Aedes* in the assigned houses.
9. Explain the purpose of IRS-*Aedes* and the precautions that should be taken; answer any questions from the head of household or his/her family.
10. If necessary, help the family move any belongings.
11. Communicate any problem to the brigade chief as soon as it arises.
12. Follow the instructions of the team leader in a timely manner.
13. Thank the occupants for cooperating with IRS and answer any questions they have.

14. At the end of the day, review the information and give it to the brigade chief.
15. At the end of the day, turn in the remaining insecticide and containers from the insecticide used.
16. Calibrate the equipment with clean water at the start of the work day to ensure that it is in good working order.
17. Prepare the insecticide and clean water mixture according to the instructions.
18. Wash and perform maintenance on the equipment at the end of the work day.

Code of conduct[12]

Every application of public health insecticide, including IRS-*Aedes*, should be performed by trained personnel who always behave professionally and maintain excellent relations with the community, fully respecting customs, community leaders, and all people.

Rule 1. Wear the work uniform.

Rule 2. Wear visible identification.

Rule 3. Always be courteous to occupants and the community.

Rule 4. Never request food or money from the community.

Rule 5. Never give the population insecticide.

Rule 6. Give the population clear and precise instructions for before and after IRS.

Rule 7. Follow managers' instructions and directions.

[12] Adapted from Lluberas (2002) and WHO (2015).

5.
Evaluation

5.1. Objectives

The general objectives of IRS-evaluation are to:

1. Determine the effectiveness of IRS-*Aedes* in entomological terms (if the historical information on cases is known, its effectiveness could be estimated epidemiologically by comparing the number of cases with those observed in the endemic channel, averaging the weekly cases of the last 5 or 10 years).
2. Determine the residual action of IRS-*Aedes*.
3. Identify any adverse reactions to IRS-*Aedes* in the community and operational personnel.
4. Determine the degree of acceptance by the community and operational personnel.

5.2. Effectiveness of IRS-*Aedes*

The ultimate goal of IRS-*Aedes* is to protect the human population where it is performed, interrupting the cycle of human-mosquito contact.

The insecticide is expected to reduce the density and longevity of *A. aegypti* and the rate of infection from the mosquito in the population. The studies conducted in Mexico and Australia show reductions of close to 70% in ovitrap indexes and the density of adults collected in the home when IRS-*Aedes* is performed in houses without other control methods.

One of the best methods for determining the entomological impact is household mosquito collection using aspirators indoors (e.g., Prokopack and CDC Backpack), which make it possible to obtain a sample indicating the size of the mosquito population with a higher probability of contact with the human population. The procedure takes no more than 10 minutes per house and requires a representative sample of houses to calculate the following indexes: average number of *A. aegypti* per house, average number of *A. aegypti* females per house, and average number of blood-fed *A. aegypti* females per house.

Ovitraps for collecting adult mosquitoes are an alternative to aspiration; these devices can be placed in a representative sample of houses in treatment and control areas. The use of ovitraps is less sensitive for determining the impact if IRS-*Aedes* is not combined with methods to control peridomestic breeding sites.

Using epidemiological indicators of the impact of vector control methods creates difficulties for operational evaluation due to the low rate of reporting of symptomatic clinical cases to health systems, human movements that influence where people are exposed to the virus, and the fact that not all surveillance programs can map the incidence of cases at the dwelling or city block level.

Within the framework of control programs, if georeferenced information on the location of the clinical cases reported to the health system is available, the effectiveness of the interventions can be determined by comparing the incidence of cases of disease in treated and untreated areas (e.g., Vázquez-Prokopec *et al.*, 2010; Vázquez-Prokopec *et al.*, 2017a).

If spraying coverage is sufficiently high (more than 60% for *Aedes*), indicators of the number of cases (dengue, chikungunya, and Zika) at the city level can be used to compare the epidemiological impact, bearing in mind that there is wide variation between years and comparison of these data with a control city that has not received the intervention is recommended.

5.3. Residual action and effectiveness of IRS-*Aedes*

Residual action is the time that treated surfaces remain effective in killing mosquitoes exposed in cone bioassays (WHO, 2006c). The operational criterion for residual action through wall tests is the number of months that mortality is greater than or equal to 80% (WHO, 2006c).

Effectiveness in reducing the densities of *A. aegypti* females at the population level is determined by collecting mosquitoes at rest – e.g., with Prokopack aspirators (Vázquez-Prokopec *et al.*, 2009).

In the case of abundant blood-fed females, residual action is the number of months that the numbers are lower than the baseline levels or the effect of IRS is no longer significant over time.

5.4. Adverse effects of IRS-*Aedes*

Since both spray operators and the population are at risk of exposure to the insecticide, periodic surveillance should be conducted.

Workers should undergo an initial medical check-up to determine their health status and should be administered a questionnaire on occupational exposure and domestic insecticide use. As part of the check-up, spray operators may be tested for serum acetylcholinesterase.

5.5. Acceptance by the community and operational personnel

Community acceptance of IRS is critical to obtaining an impact on transmission at the population level.

Coverage of IRS-*Aedes* over 60% is linked with a reduction in transmission (Vázquez-Prokopec *et al.*, 2010). Questionnaires and focus groups can be designed to identify the factors that limit IRS-*Aedes* acceptability and coverage, which include aspects related to the application of the insecticide, such as visible stains on the wall, the odor of the insecticide, the benefits of IRS, etc.

Among operational personnel, aspects of the technique and preparation are addressed. Feedback from operational personnel to supervisory personnel and decision-makers will make it possible to tailor the IRS-*Aedes* methodology to environmental or cultural situations that alter its effectiveness.

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7.
ANNEXES

Annex I. IRS Daily Reporting Form

IRS Daily Reporting Form

Location or Neighborhood: _____ **Municipality:** _____ **District:** _____

Epidemiological Week: _____ **Spray Operator No.:** _____

Brigade No.: _____ **Sector No.:** _____

Nº	Address	Neighborhood	Sector	Block	Dwelling				Occupants		Insecticide used	HD
					C	U	NP	S	<5	5>		
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												
16												
17												
18												
19												
20												

*C=Closed; U=Unoccupied; NP=Not Permitted; S=Sprayed.

Comments: _____

Name of spray operator: _____

Supervisor: _____

Annex II. Informed consent

INFORMED CONSENT

Neighborhood:_____	**Municipality:**_____	**Health Distr.:** _____	**State :**_____
Date:_____	**RFC Applied:**_____	**RFC Brigade Chief:**_____	**Epid. Week:**_____

I hereby declare that I received and understand the health worker's explanation of risks and prevention measures associated with the use of the insecticide applied in my home for control of the mosquito that transmits dengue, chikungunya, and Zika. Once the insecticide has been applied, my home will be restored to me and I will take responsibility for following the recommendations received.

No.	Name	Residence	Sector	Block	Authorizing signature
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					

Annex III. Example of house spray card

District: ..... Ward: .....

House ID No .....

Date Issued: .....

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

Head of Household: .....

Date sprayed	Spray operator	Number of occupants		Number of rooms / units										Insecticide used	Comments
		Adults	Children	Sprayed					Unsprayed						
				1	2	3	4	5	1	2	3	4	5		

Pan American Health Organization

World Health Organization
REGIONAL OFFICE FOR THE Americas

525 Twenty-third Street, NW
Washington, D.C., 20037
United States of America
Tel: +1 (202) 974-3000
www.paho.org