Second Edition (Rev.) May 2006 (2010 revised version)

Pesticides Used for

Outdoor Mosquito Control

For Pest Control Operators' Reference

Agriculture, Fisheries and Conservation Department

Preface

As the regulatory authority for pesticides, the Agriculture, Fisheries and Conservation Department often receives enquiries from the pest control sector and government departments regarding pesticide use for mosquito control. In view of this, we published a booklet “Pesticides Used for Outdoor Mosquito Control” (first edition) in 2003 with a view to providing guidelines on the safe and effective use of pesticides.

Based on the valuable comments we have received on the first edition, some revisions have been made in this edition, which also covers the newly registered pesticides for mosquito control. Published in July 2004, this edition of the booklet, just like its predecessor, provides technical information including the properties and characteristics of pesticides, various application methods and precautions as well as general pesticide management. It is hoped that this booklet can provide a reference for the trade and government departments alike, so that when circumstances necessitate the use of pesticides for mosquito control, they can be used properly and safely.

Importance of mosquito control

Mosquito bites not only cause nuisance and discomfort but also transmit some very dreadful diseases such as Dengue fever and Japanese encephalitis. Control measures are therefore necessary to maintain a quality living environment and reduce the threats of mosquito-borne diseases. Good sanitation and elimination of stagnant water are generally good preventative strategies to keep mosquitoes from breeding in the first place.

Integrated pest management

The Agriculture, Fisheries and Conservation Department recommends adoption of the Integrated Pest Management (IPM) approach for mosquito control. Essential components of such approach include inspection and surveillance, species identification, source reduction and mosquito habitat modification. To complement the above, biological control and chemical pesticides may also be used but only in a judicious manner. Following a proper integrated pest management approach, which is sensitive to both human health and the environment, will reduce both mosquito problems and potential pesticide exposure.

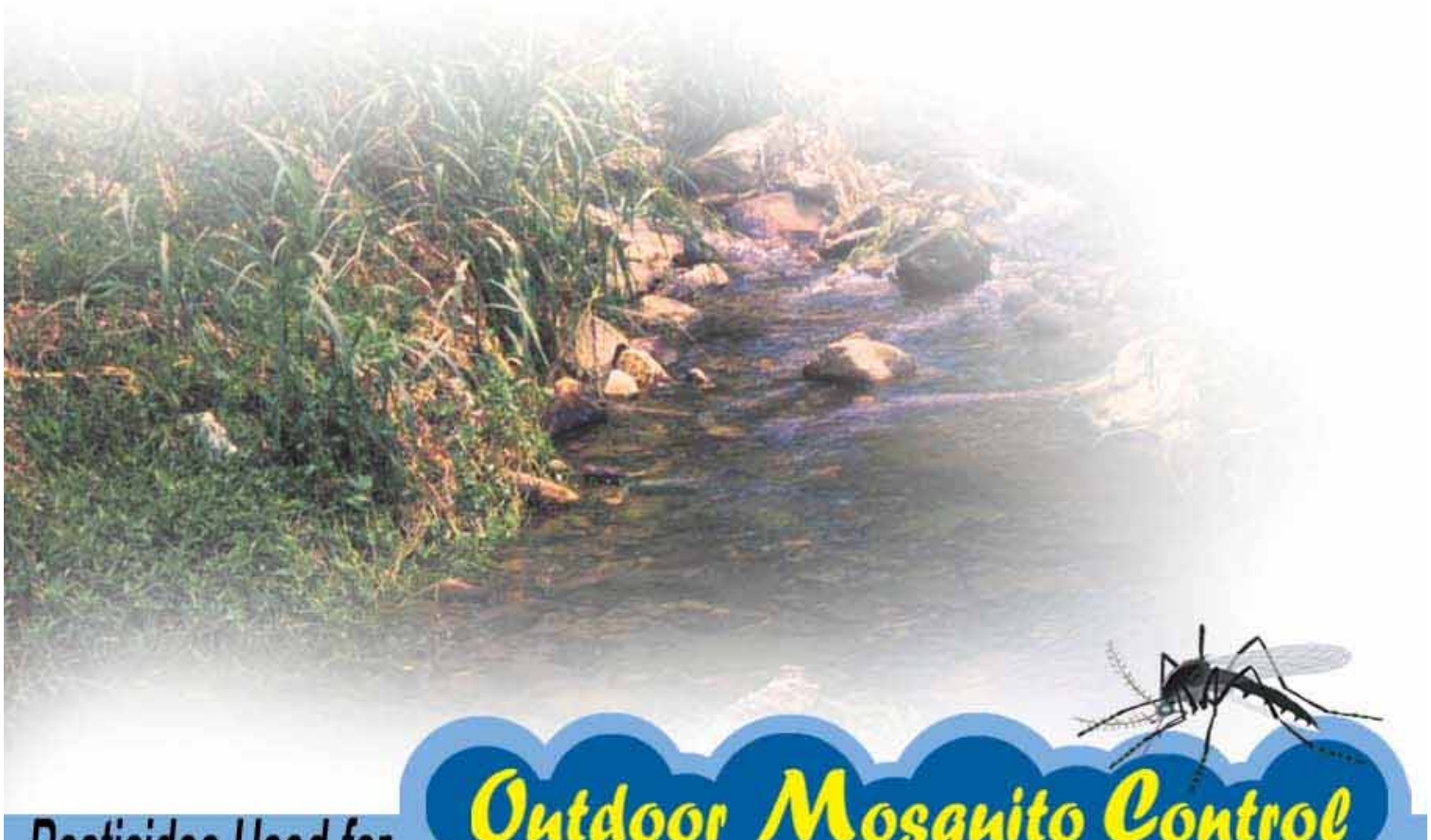
Pesticides Used for Outdoor Mosquito Control

Pesticides used for outdoor mosquito control

I) Introduction

Pesticides used for outdoor mosquito control can be broadly divided into larvicides and adulticides, depending on the stages of the mosquitoes to be treated. Larvicides are intended for killing immature mosquitoes in their aquatic habitat while adulticides are intended for killing the flying adult mosquitoes.

Since larvicides are directed at the most concentrated developmental stage of mosquitoes, they can provide very effective control and reduce the need for adulticides later. To that end, when it is necessary to resort to chemical control, the use of larvicides should always be the backbone of the programme with adulticides as a supplement only.



Pesticides Used for Outdoor Mosquito Control

II) Larvicides

When it is not possible to eliminate stagnant water that may become breeding grounds of mosquitoes, and there are no alternative methods of control, larvicides may be applied to the water bodies. The success of larval control depends upon many factors such as the chemical ingredients and formulation of the selected larvicides; the timing, rates and methods of application; and the physical and environmental conditions.

A list of registered pesticides that can be used as mosquito larvicides is presented in Table 1 . For specific rates and safety precautions on the use of larvicides, always follow the directions on the product's label.

Table 1: Registered mosquito larvicides in Hong Kong and their characteristics

Active ingredient(s) [Registration No.]	Methods of application (refer to label for details)	Characteristics
Bacillus thuringiensis subsp. *israelensis* (Bti) [2P12]	• Apply granules / briquette / diluted spray to water bodies	• Microbial pesticide • Low toxicity to humans • Ingested by larvae to cause gut paralysis and death • Target specific • More effective in the early stage of larval development • Environmentally friendly
Bacillus sphaericus (Bs) [2P282]	• Apply granules / diluted spray to water bodies	• Nature and mode of action are similar to those of Bti • Very effective even in the presence of high levels of organic matters • Environmentally friendly
S-Methoprene [2P249]	• Apply granules / diluted spray to water bodies	• Insect growth regulator • Inhibit the development of larvae • More effective in the late larval stage • Environmentally friendly
Temephos [2P179]	• Apply granules / diluted spray to water bodies	• Organophosphate • Contact action • May be used in rotation with other larvicides to prevent the development of resistance
Larvicidal oil [2P276]	• Apply directly to water bodies	• Petroleum distillate • Form a thin film on the water surface and kill larvae and pupae by suffocation • No resistance problem
Monomolecular film (MMF) [2P283]	• Apply directly to water bodies	• Degradable surfactant • Form a very thin monomolecular film (MMF) on the water surface and kill larvae and pupae by suffocation • Less impact on fish and plant, environmentally friendly • No resistance problem

1) *Bacillus thuringiensis* subsp. *israelensis* (Bti)

Bacillus thuringiensis subsp. *israelensis* (Bti) is a microbial insecticide made from naturally occurring soil bacteria. The insecticide, which is proven to be effective against mosquito larvae, has a low level of toxicity to humans. With its highly specific mode of action against a narrow host spectrum, it does not pose risks to other non-target organisms or the environment when used properly. However, it is not very effective in highly polluted water.

Bti is most effective when used in the early larval stage when the larvae are actively feeding. When ingested by the larvae, it will disrupt their gut cells and cause death. If it is used for preventive control, repeated application at a 7-day interval is recommended in most situations. Some Bti products with a sustained release formulation may offer an extended larvicidal activity.

2) *Bacillus sphaericus* (Bs)

Bacillus sphaericus (Bs) is also a microbial insecticide with a nature and mode of action very similar to those of Bti. Bs, which is also highly specific to the larvae of mosquitoes, should be applied in the early larval stage when larvae are actively feeding. Comparing with Bti, Bs is particularly effective against *Culex* spp. and it can also be used in water with high organic contents, such as lagoons or stagnant catch basins.

3) S-Methoprene

S-Methoprene is an insect growth regulator (IGR) that retards the development of larvae and prevents mosquitoes from developing into adults. Larvae treated with the chemical fail to molt successfully and simply die during the pupal stage. The target-specific S-Methoprene will not affect fish, waterfowl, mammals or the environment when applied at the recommended use rate.

There are many different formulated S-Methropene products in the market; some only have little residual activity and are intended to target at and control a single brood of mosquitoes while others are slow-release formulations offering an extended period of control which lasts from 30 up to 150 days. It is important to note that the chemical must be present in the water when the larvae are in the late developmental stage for it to be effective.

4) Temephos

Temephos is an organophosphate with a relative low toxicity of its kind. It is highly effective against larvae and may be used on any of the larval growth stages.

With its neurotoxic mode of action different from other larvicides, it can be used in rotation with other larvicides to prevent the development of resistance. There are slow-release formulations that can provide control for 30 days or more. Since some aquatic invertebrates may be highly susceptible to the chemical, it must be used carefully so that non-target fauna may not be adversely affected.

5) Larvicidal oil

Larvicidal oil is a highly refined petroleum distillate designed especially for mosquito control. It can be applied to mosquito habitat where the water cannot be drained. As it spreads into a thin film over the water surface, only a small amount is needed.

Larvicidal oil can provide effective control on both larvae and pupae as it basically kills by suffocating them. As the oil can be degraded rapidly by light and microorganisms into harmless components, it should not pose much environmental risk. When it is used in highly sensitive areas, it is necessary to exercise more care to avoid causing adverse impact to other non-target organisms.

6) Monomolecular film

The active ingredient of monomolecular film (MMF) is Iso-alcohol ethoxylate. It is a degradable surfactant with a mode of action similar to that of larvicidal oil. It forms a very thin monomolecular film on the water surface to which it is applied and causes suffocation of larvae and pupae. MMF, an environmentally friendly pesticide, has very little adverse impact on fish and plants.

III) Adulticides

It may be necessary to resort to adulticides when larvicide application cannot provide adequate and satisfactory control and the mosquito population reaches an annoying level and there is a threat of mosquito-borne diseases.

A list of registered pesticides that can be used as mosquito adulticides is presented in Table 2. For specific rates and safety precautions on the use of adulticides, always follow the directions on the product's label.

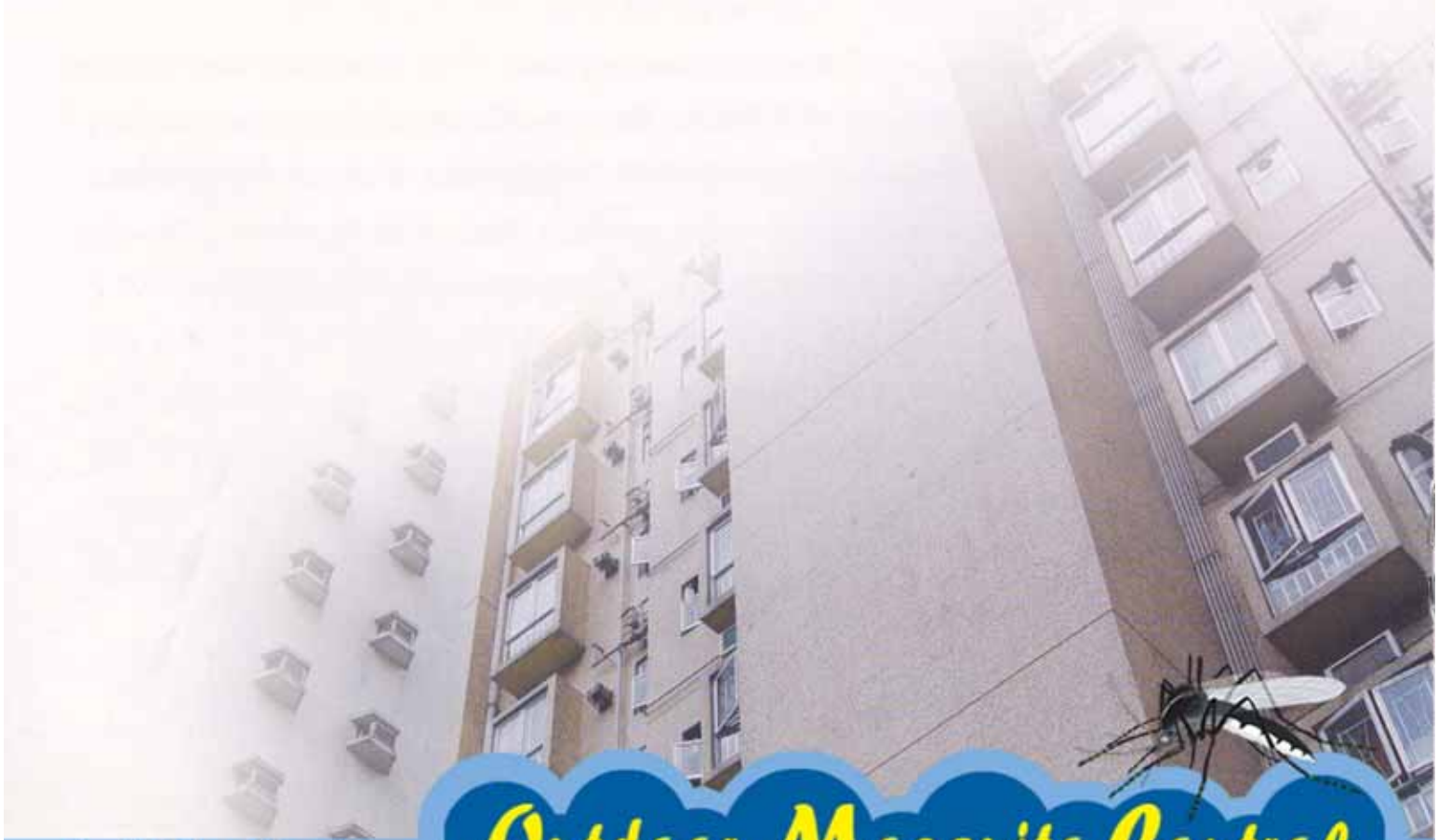


Table 2: Registered mosquito adulticides in Hong Kong and their characteristics

Active ingredient(s) [Registration No.]	Methods of application (refer to label for details)	Characteristics
Pyrethroids		
Cypermethrin [2P62]	• Cold fog (ULV) • Residual spray	• Toxic to fish and aquatic organisms • Short residual activity
alpha-Cypermethrin [2P195]	• Cold fog (ULV) • Residual spray	
beta-Cypermethrin [2P278]	• Cold fog (ULV) • Residual spray	
Cyfluthrin [2P57]	• Cold fog (ULV) • Residual spray	
Etofenprox [2P254]	• Thermal fog • Cold fog (ULV) • Residual spray	
Permethrin [2P149]	• Thermal fog • Cold fog (ULV) • Residual spray	
Pyrethroids plus Synergist		
S-Bioallethrin/Permethrin/PBO [2P24]	• Thermal fog • Cold fog (ULV)	• Synergist increases efficacy • Toxic to fish and aquatic organisms • Short residual activity
Esbiothrin/Permethrin/PBO [2P280]	• Thermal fog • Cold fog (ULV)	
Permethrin/PBO [2P284]	• Thermal fog • Cold fog (ULV)	
d-Phenothrin/PBO [2P286]	• Thermal fog • Cold fog (ULV)	
Resmethrin/PBO [2P285]	• Cold fog (ULV)	
Natural Pyrethrins plus Synergist		
Pyrethrins/PBO [2P169]	• Cold fog (ULV)	• Synergist increases efficacy • Toxic to fish and aquatic organisms • Very short residual activity
Organophosphates		
Chlorpyrifos [2P48]	• Residual spray	• Relatively high toxicity • Longer residual activity
Malathion [2P125]	• Residual spray	

1) Natural Pyrethrins and Pyrethroids

Natural Pyrethrins is a botanical insecticide made from extracts of Chrysanthemum flowers while Pyrethroids such as S-Bioallethrin, Cypermethrin, Permethrin, Etofenprox and Cyfluthrin are its synthetic chemical analogues. These chemicals are broad-spectrum contact insecticides that provide rapid knockdown effects on insects but with only little residual activity. To increase their effectiveness, a synergist - Piperonyl butoxide (PBO) is often added to the formulations.

Pyrethrins and pyrethroids are usually applied as space spray i.e. by fogging to kill mosquitoes in contact. There are also some specially formulated pyrethroid products with extended residual activity that can be applied as residual sprays. As they are generally toxic to fish and other aquatic organisms, they must be used carefully so as not to contaminate water bodies.

2) Organophosphates

Organophosphates are broad-spectrum contact insecticides with relatively higher toxicity and longer residual activities. Many organophosphates such as Chlorpyrifos and Malathion can be used as outdoor residual sprays for mosquito control.

Organophosphates generally provide good residual effects from a few days up to several weeks depending on the formulated products. However, the ability may be reduced by environmental factors such as rain, high temperature or exposure to strong sunlight. Many organophosphates, in particular Chlorpyrifos, are highly toxic to fish. It is necessary to exercise extreme care and caution not to contaminate fish bearing water bodies.

IV) Application of adulticides

There are basically three kinds of methods for the application of adulticides, namely thermal fogging, cold fogging (ULV treatment) and residual spraying. As the same chemical active ingredient may be formulated into different products for different treatments, it is very important to select the right formulated products as well as the appropriate application equipment. Since adulticides may indiscriminately kill other non-target insects or organisms, they should only be used when the mosquito population reaches an annoying level and when there is a threat of mosquito-borne diseases. To ensure effective control and minimize its adverse impact, the use of adulticides should always involve the careful consideration of the biology of the target mosquitoes as well as the use of the proper application methods.

1) Thermal fogging

Thermal fogging is a space treatment against adult mosquitoes. The fog is produced by a device (thermal fogger) that uses heat to break up the chemical into very small droplets (usually in 5-30 micron diameter range) which will disperse in the air. When the chemical (usually diluted with oil-based carrier) is heated, it is vaporized in a combustion chamber and then expelled via an outlet tube to form a dense fog cloud when it condenses on contact with cool ambient air. It can even reach air spaces in areas obstructed by dense vegetation or other objects. When the mosquitoes in flight come into contact with the droplets, they will be knocked down and killed.

Thermal fogging can quickly reduce the number of biting mosquitoes but does not have lasting residual effects. As adult mosquitoes must come into contact with the pesticide, the timing of application is critical. While different mosquito species are active during different periods of the day, it is essential to fog at the right time to get effective control of the target species.

Thermal fogging is very susceptible to wind and thermal air currents. If applied during unfavorable conditions, such as during a hot day, the fog may be carried up and over the target places and the application will become ineffective. If applied in a very windy day, the fog will drift out of the area that you want to treat. Application should therefore be carried out when the air is calm and the temperature is not too high, such as during the evening or at night or early in the morning when the fog is more likely to be held close to the ground.

Thermal fogging should only be conducted by experienced and trained pest control personnel. Each application must be carefully planned with all the precautionary measures put in place. It may be necessary to give advance notice and warning to those in the immediate neighborhoods if they will be affected. As a dense thick smoke is produced, it is also necessary to ensure that the operation does not create visibility hazard to passing motorists. The applicator should wear appropriate personal protective equipment including respiratory protection to prevent inhaling the chemical. Other necessary safeguards to prevent fire and explosion and burn by heated parts of the thermal fogger must also be taken. For proper use of the fogger, it is essential to follow the instructions in the operation manual that comes along with the machine.

Thermal fogger

2) Cold fogging (ULV treatment)

Cold fogging is a space treatment against adult mosquitoes. The cold fog is produced by a special device (cold fogger) that breaks up the chemical into microscopic droplets by mechanical means, basically with a high-pressure pump and an extreme fine nozzle.

The cold fogger may dispense formulations in a very concentrated form and generate the droplets (usually in the 5-30 micron diameter range) in a precise manner. When the mosquitoes in flight come into contact with the chemical droplets floating in the air, they will be killed. However, its ability to penetrate dense foliage or obstacles is not as good as that of the thermal fogging. Cold fogging is sometimes called Ultra Low Volume (ULV) treatment as it allows the utilization of only a very small amount of chemical for coverage of a large area.

Although cold fogging can quickly reduce the number of biting mosquitoes, it does not have lasting residual effects. It is, therefore, essential to carry out fogging at the time when the mosquitoes are most active to hit them direct. Similar to thermal fogging, cold fogging must be conducted by experienced and trained pest control personnel under favorable weather conditions for it to be efficient and effective. If the application is carried out on a windy day or in the heat of the day, the fog will drift away or volatilize and go upward out of the target area.

For proper use of the cold fogger, it is essential to follow the instructions in the operation manual that comes along with the machine. Regarding precautionary measures, it is similar to those for thermal fogging except that it does not cause visibility hazard for motorists.

Cold fogger (ULV treatment)

3) Comparisons between thermal fogging and cold fogging

Thermal fogging	Cold fogging (ULV treatment)
• Usually diluted with oil-based carrier • Break up the chemical into very small droplets by heat • Can penetrate areas with dense vegetation • Easy to monitor movement • May create visibility hazards to motorists	• Usually in very concentrated forms • Utilize only very small amount of chemical • Break up the chemical into very small droplets by mechanical means • Difficult to monitor movement
• Mainly Pyrethroids (such as S-Bioallethrin and Permethrin) plus synergist • Use in outdoor and large areas • Very small chemical droplets which can be suspended in the air for long period of time • Can be affected by wind and temperature • Should be applied when air is calm and temperature is not too high, like early in the morning or evening • Should be applied when mosquitoes are actively in flight • Quick knockdown effects • Little residual effects • Pose risks to non-target organisms	

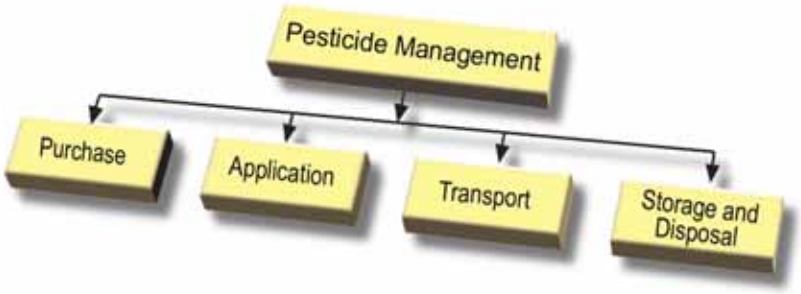
4) Residual spraying

Residual spraying is usually carried out in the form of a fine spray made to the surface where mosquitoes may come into contact. As the droplets of the spray are much larger, they settle very quickly on the surface of treated areas. Residual effects usually last from a few days to about a week to several weeks depending on the product used. Mosquitoes rest or land in treated areas may be killed.

Equipment used for spraying can range from a small hand-held compression sprayer to a gas-powered backpack sprayer to a hydraulic mist blower. Residual spraying should only be conducted when the mosquito population reaches an annoying level and there is a threat of mosquito-borne diseases. When it is applied in areas to where the general public may have access, it is necessary to post warning notices so that passersby will not touch the treated areas inadvertently.

V) Good practice in pesticide management

When circumstances necessitate the use of pesticides for mosquito control, extreme caution and care must always be exercised. Pest control operators have the responsibility to ensure the adoption of good pesticide management practice to protect themselves, the public and the environment. Good pesticide management practice can be generally divided into the following aspects, namely purchase, application, transport, storage and disposal.



1) Purchase

- Buy only registered pesticides
- Pesticides should be in proper packaging
- Pesticides should display a proper label in both English and Chinese
- Pick the right product for the target pest
- Choose the least hazardous pesticides that can have an effective treatment
- Rotate different pesticides to avoid the development of resistance
- Purchase no more than what is necessary for operational needs

2) Application

- Allow only those who have the proper training to handle pesticides
- Follow all label instructions closely
- Mix and dilute the required pesticides in a precise manner
- Adopt the appropriate treatment method and use the proper application equipment
- Wear appropriate protective clothing and equipment
- Take all the necessary safety procedures and precautionary measures before, during and after each application
- Post warning signs with all the relevant information in appropriate areas
- Notify the client and/or through the client to other affected parties the scheduled application well in advance and provide them with information on the spray activities and all necessary safety precautions
- Maintain comprehensive records of all pesticide application for a period of at least two years
- Provide proper calibration and regular maintenance to all application equipment

3) Transport

- Avoid transporting pesticides together with food and drinks
- Always load pesticides with care
- Make sure all pesticides are secured when the vehicle is in motion
- Keep cloth, sand, empty containers and cleaning agents in vehicle for immediate handling of minor spillage
- Bring along Material Safety Data Sheet (MSDS)
- Always keep vehicle locked when no one is guarding
- Pesticides which are also classified as dangerous goods must be transported in accordance with requirements laid down by the Fire Services Department

4) Storage and disposal

- Do not store with food, feed or absorbent
- Store under lock and key
- Only allow authorized personnel to access
- Check inventory regularly and keep an updated inventory of all pesticides
- Store along with Material Safety Data Sheet (MSDS)
- Do not reuse empty containers for any other purposes
- Keep cloth, sand, empty containers and cleaning agents in hand for immediate handling of minor spillage
- Pesticides which are also classified as dangerous goods must be stored in accordance with requirements laid down by the Fire Services Department
- Dispose obsolete or unwanted pesticides properly in accordance with requirements laid down by the Environmental Protection Department

Enquiries:

Agriculture, Fisheries and Conservation Department
Plant and Pesticides Regulatory Division

5/F, Cheung Sha Wan Government Offices,

303 Cheung Sha Wan Road, Kowloon, Hong Kong.

Tel.: (852) 2150 7010 Fax: (852) 2314 2622

Interactive voice response system: (852) 2708 8885

e-mail: mailbox@afcd.gov.hk Web-site: http://www.afcd.gov.hk

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