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MOSQUITO CONTROL AND SCRAP TIRES: SAME OLD PROBLEM, NO RELIABLE STRATEGIES

Control de mosquitos y neumáticos usados: el mismo viejo problema, sin estrategias fiables

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ABSTRACT

Artificial breeding sites in urban areas have favored the domestication of mosquito vectors. Scrap tires are an important breeding source for mosquito larvae. Few efforts have been made to establish appropriate management measures for used tires, which poses a challenge for larval control activities. Here we mention the inconveniences of tire disposal and the physical and chemical control alternatives. We also note the available methods of larvicide application against larvae in tires and the advantages and disadvantages of each method. The possible effect of overdose/underdose on the development of resistance is considered. Finally, we mention that the actions of vector control programs, the local or state government policies, and active community participation must be interconnected to develop effective tire management.

Keywords: *Aedes* spp, community participation, larval control, used tires.

RESUMEN

Los criaderos artificiales de las zonas urbanas han favorecido la domesticación de los mosquitos vectores. Los neumáticos usados son una importante fuente de cría para las larvas de mosquitos. Se han realizado pocos esfuerzos para establecer medidas de gestión adecuadas para los neumáticos usados, lo que supone un reto para las actividades de control larvario. Aquí mencionamos los inconvenientes para la eliminación de los neumáticos y las alternativas de control físico y químico. También mencionamos los métodos disponibles de aplicación de larvicidas contra las larvas en los neumáticos y las ventajas y desventajas de cada método. Se considera el posible efecto de la sobredosis/subdosis en el desarrollo de resistencia. Finalmente, mencionamos que las acciones de los programas de control de vectores, las políticas del gobierno local o estatal y la participación activa de la comunidad deben estar interconectadas para desarrollar una gestión efectiva de los neumáticos usados.

Palabras clave: *Aedes* spp, participación comunitaria, control de larvas, neumáticos usados.

INTRODUCTION

Aedes aegypti and *Ae. albopictus* domestication has been favored by the vast diversity and the high number of non-natural breeding containers in urban and periurban areas (Powell and Tabachnick, 2013). Recklessly discarded scrap tires or used tires stored in residential or commercial areas are of special interest, as they have shown high productivity of immature stages of mosquitoes, approximately 4000 larvae per tire per month (Malla et al., 2020), and have contributed to the rapid spread of species to a large number of locations in Asia, Europe, and America (Reiter and Sprenger, 1987; Higa et al., 2010; Scholte et al., 2010; Bennett et al., 2019). These containers are closely associated with human settlements and can be commonly found in the yards and roofs of houses, as well as in streets and uninhabited lots.

The importance of used tires as productive breeding sites has been documented for the past century (see Reiter and Sprenger, 1987). Currently, there is much information regarding their impact on larval productivity, ecological factors (e.g., species replacement), and the risk of mosquito-borne diseases (MBDs) epidemics (see Yee, 2008). In theory, proper disposal and the use of larvicides should be enough to control used tires; however, the problem persists. Progress has yet to be made in establishing efficient management measures, creating a great challenge for operative procedures within mosquito vector control programs. This paper discusses the current control strategies (advantages and limitations) and available methods of larvicide application in tires. We expose the limitations to properly managing used tires. Finally, we also discuss the possible effect of larvicide over an underdosing on the evolution of resistance.

LARVAE CONTROL METHODS

In Mexico and other countries, health workers visit each household searching for potential breeding sites and treat them depending on their capacity (liters) and the associated type of use (Villegas-Trejo et al., 2011; CENAPRECE, 2016). For containers with large amounts of water storage (> 100 liters), the use of natural or synthetic formulations is the primary method. The use of lids, if possible, is highly recommended. For containers with volumes < 20 liters, such as used tires, buckets, vases, fountains, domestic animal water bowls, etc., the preferred procedure is water management (i.e., physical control). This is done by drilling, turning over, covering, emptying, scrubbing, and/or placing containers in roofed areas. For small containers as cans, bottles, glass jars, pots or any item without any use but can become an outdoor still-water container, physical control by source reduction, including removal, destruction, and/or perforation, is mandatory. Larval control activities are carried out by health personnel inside and outside the house with the consent of the resident. All these activities are performed during the pre- and post-epidemic period, associated with the dry season and low cases of MBDs, and intensified in the epidemic period associated with the rainy season, whit an increase in mosquito population density and MBDs.

THE STRUGGLE OF USED TIRE DISPOSAL

Accordingly, used tires should be managed through physical control (Fig. 1). Among residents, the health personnel recommend covering, removing, and drilling used tires. However, people often consider that used tires will be useful or valuable in the future, making tires difficult to discard or drill. Additionally, there is a lack of motivation for the proper management of stored tires; this is attributed to (1) low-risk perception associated with a lack of knowledge that discarded tires provide ideal breeding sites for mosquito larvae; (2) householders argue that they have already gone through any MBDs, so there is no need to dispose or drill; (3) householder get used to the assistance of health personnel in the disposal, avoiding activities themselves (e.g., putting them under cover, brushing and draining) (Toledo-Romaní, 2006; Chuc, 2013; Nathan, 1993); (4) annoyance of householder by the access of health personnel to their property.

In addition, scrap tires are not accepted as curbside garbage; consequently, regular waste collection services do not pick up used tires from residences, or businesses, or dumped at wastelands, streets, or roadways. Residents must return discarded or unwanted tires to retailers or certified disposal facilities. However, they are often unaware of proper discarding procedures or reluctant to transport tires to authorized landfills or recycling facilities and/or to pay disposal fees. People can drop off tires during special cleanup events sponsored by the local government or non-profit organizations (Fig. 1C). Unfortunately, inefficient cooperation between public/government and private companies (see Uriarte-Miranda et al., 2018), the lack of specialized infrastructure for disposal and recycling and insufficient promotion, limit the number of collection events.

CHEMICAL CONTROL

Where physical control is not possible, the use of larvicides and/or growth regulators is necessary. Temephos,

Figure 1. Control of used tires. a) Covering. b) Helping residents to dispose tires. c) Special cleanup event. d) Health staff removing and/or larvicide or IGR application in tires from an inhabited lot.

a synthetic organophosphate larvicide, has been widely used for a long time because of its simplicity of application (spoon-based), specific activity against mosquito larvae in non-natural breeding sites, and relatively harmlessness to non-target fauna (George, 2015). However, the emergence of resistance has limited its use (Rodríguez et al., 2007). Therefore, the use of environmentally sustainable larvicides or insect growth regulators (IGR) (i.e., biorational products) formulations has increased over the last years (e.g., Braga et al., 2005; Singh et al., 2013; Becker et al., 2018; Marcombe et al., 2018).

Product application and limitations

Different techniques have been developed to apply larvicides or IGRs to tires. Direct manual application of sand granules or liquid formulations into water storage containers using a calibrated scoop or spoon has been one of the most employed methods (Fernández-Salas et al., 2015, de Araújo et al., 2019). Manual or battery hand pumps or compression sprayers (i.e., backpack) have been used to apply liquid, granules, or pellets to small breeding sites, manual and backpack applications areas useful in areas that cannot be reached by vehicle (Sun et al., 2014; Harwood et al., 2015). However, manual or backpack spraying applications can be time-consuming and are limited when the access to the domicile is restricted because access is denied, residents are not home, or in the presence of vacant lots, abandoned and/or locked properties (see Unlu and Farajollahi, 2012).

Ultralow-volume (ULV) ground spray application with truck-mounted sprayers has been used for adult control in preventive actions or during dengue outbreaks. Studies have shown that area-wide ULV applications of larvicides could be an effective method to control used tires in certain urban areas (Lucia et al., 2009; Jacups et al., 2013; Doud et al., 2014; Unlu et al., 2019; Burtis et al., 2022). On the other hand, thermal fogging is a method that generates ultra-fine droplets (1-50μm), driving the particles deep inside tiny cracks, crevices, and pores of surfaces or different types of containers. It has proven useful for applying adulticides for area-wide control. Fogging has been shown to be effective against larvae in containers (Sulaiman et al., 2000; Chung et al., 2001; Knapp et al., 2018). Nevertheless, more studies on the efficacy of thermal fogging in tires are needed. Space treatments such as ULV or thermal fogging might lack effectiveness on tires stored inside and outside dwellings with high walls (Fig. 2) or roofed yards. Reduced residual effect or the need for multiple and frequent applications has also been observed (e.g., Wilke et al., 2021).

Aerial application of mosquito larvicide has been used to rapidly treat large areas or areas unable to be treated on foot (such as lakes, woodland pools, tidal waters, marshes, swamps, catch basins, and salt marshes) (e.g., Jamnback et al., 1970; Russell et al., 2009; de Little et al., 2012; Pruszynski et al., 2017). For this method, it has been observed that granular formulations can penetrate vegetation; there is low drift and diminished evaporation (Feng and Sidhu, 1985). For aerial application, inevitable uneven application or underdose has been observed; however, effective control has been achieved (Russell et al., 2009; Pruszynski, 2017).

For truck mounted ULV, thermal fogging and aerial spraying, spray drift, droplet size, and possible underdose are the major concerns for health services programs. Moreover, residents must leave tires uncovered during the spraying/fogging operations. It has been proposed that resistance development could appear because of the spraying of underdose (Mariappan and Tyagi, 2018). Related, underdose could lead to suboptimal or decreased residual effects of larvicides or IGR on the larvae population (Jacups

Figure 2. Architecture of dwellings in dengue risk areas with regular ULV adulticide application. Despite the effectiveness observed for adult control, the efficacy of the truck-mounted sprayer larvicide application method could be limited in urban areas with high concrete block walls or with presence of tree canopy.

et al., 2013; Wilke et al., 2021). However, information on these issues must be included; further studies are required.

Manual application. The Mexican experience

Urban and semi-urban areas in Mexico are the most common risk areas for MBDs. When necessary, larvicides or IGR are applied to tires. Backpack, ULV, and aerial application have not been used mainly because these methods are costly and the architecture of dwellings may limit product application (Fig. 2). Direct manual application of larvicides or IGRs by health workers has become the standard method during the last decades (Fig. 3). This method allows recording the number of treated tires, to estimate product usage, and managing the amount of product applied with a reduced environmental impact and budget costs. Since resources and personnel to revisit properties and treat containers at frequent intervals are limited, formulations with longer residual efficacy (2-3 months) are used.

The amount of product required for tire control will depend on the used product type. For example, the quantity of temephos, Bti, Spinosad, and pyriproxyfen used is 20 gr, 1 gr, 4 gr, and 0.4 gr, respectively. Therefore, calibrated spoons are used and occasionally provided by the formulation manufacturer. Since larvicide and IGR formulations are usually intended to be applied in larger containers or to treat wide areas, there are no specific formulations/dosages or scoops for tire treatment; therefore, overdosing due to manual application is possible. Nevertheless, overdosing of some formulations has been observed to provide residual control for several months, even in dry containers (Ritchie et al., 2010; Farajollahi, 2013). In addition, focal manual application in tires avoids the potentially toxic effects of overdosing on non-target organisms.

Because the mode of action of biorational products (e.g., Bti, spinosad, methoprene, etc.) selection for resistance has been neglected; however, resistance to some of these products has been observed (Sparks et al., 2012; Su and Cheng, 2014; Paul et al., 2015; Haddi et al., 2020). Under sublethal doses of botanical insecticides, increased activity of detoxifying enzymes, related to resistance, has been reported for aphids and lepidopteran (Wei et al., 2015; Czerniewicz et al., 2018). Consequently, the health Ministry of the country constantly monitors the efficacy of biorational products, like "traditional" insecticides: pyrethroids, carbamates, and organophosphates.

The manual application of larvicides or IGR needs many personnel with the necessary skills to communicate easily with residents, apply the correct amount of the product, and perform physical control of any container, including tires. For this reason, health authorities in each State provide constant training courses to its personnel as a way to improve their performance and competence.

Novel control methods

The control of larvae and adults is carried out by employing a variety of strategies to attain an integrated vector management (IVM) approach. IVM is a decision-making process for the management of vector populations integrating all available measures, whether chemical by targeted application of insecticides, biological through the use of natural predators and reduction of breeding sources, such as tire removal (OPS 2013)

Traditional control methods have proven effective to a certain extent, but novel strategies are essential to overcome challenges such as insecticide resistance, ecological concerns, and the need for sustainable solutions. New insights such as: (1) Sterile Insect Technique (SIT), involve mass-rearing mosquitoes, sterilizing them, and releasing them into the wild to mate with their wild counterparts (Alphey et al 2010). The resultant infertile eggs will decrease the target population over successive generations. (2) Release of Insects Carrying a Dominant Lethal Gene (RIDL) entails the release of genetically modified mosquitoes carrying a gene that results in the death of offspring before reaching adulthood. This approach relies on the dominance of the lethal gene, ensuring that even heterozygous individuals will not be able to reproduce (Alphey et al 2013). (3) Release of Wolbachia-Infected Male Mosquitoes (RWM), which involves releasing male mosquitoes infected with Wolbachia (intracellular bacteria that can influence mosquito reproduction and pathogen transmission), which when mated with wild females, leads to inviable eggs or reduced pathogen transmission (Ogunlade et al 2021).

SIT and RIDL can have minimal environmental impact due to the temporary nature of releases, while RWM impact depends on the strain of Wolbachia used and its interactions with local ecosystems. All three strategies aim for self-sustaining population suppression, but challenges like evolving resistance, maintaining genetic modifications and ensuring consistent releases must be addressed. These

Figure 3. a) Spoons used for the manual application of larvicides or IGR. b-d) Larvicides or IGR application in used/stored tires. e) The white asterisk indicates that the tire has been treated with larvicides or IGRs.

novel methods can complement traditional approaches and enhance overall control efforts.

CONCLUSION

The problem of used tires as breeding sites must be addressed from several sectors. Operational vector control programs should continue with the physical/chemical control of tires. It is their responsibility to ensure proper dosing of larvicides in tires that cannot be physically controlled and to constantly monitor susceptibility/resistance to products used for chemical control. State or local governments should make a thorough effort to ensure that tire collections become routine. Despite the limited budget, backpack, ULV, and aerial application tests must be performed in field conditions. This is necessary for each government to choose the most effective application method during the pre-, post, and epidemic periods.

To facilitate chemical control, product manufacturers must consider tires and design standardized product dispensers. Develop novel application techniques to avoid under or overdosing, which can lead to formulation resistance or excessive operational costs.

Finally, and most complicated and important for an integrated vector control management vector control, is active community involvement. A successful integrated management approach to mosquito control begins with the understanding that each breeding site is unique and larvae control does not only depend on health authorities alone. This is a challenging task, but it can be achieved through constant awareness-raising, sensitization, and education campaigns on mosquito control.

AUTHORS PARTICIPATION

W. Eduardo Quezada-Yaguachi: Conceptualization, Writing - Original Draft, Visualization, Investigation. Miriam Alquisira-Domínguez: Data Curation, Visualization, Writing - Original Draft. Miriam J. Vázquez-Anzúres: Data Curation, Visualization, Writing - Original Draft. Dania Rebollo-Salinas: Data Curation, Visualization, Writing - Original Draft. L. Dalila Rescalvo-Luna: Data Curation, Visualization, Writing - Original Draft. Fabián Correa-Morales: Conceptualization, Writing - Original Draft, Project administration, Supervision. Cassandra González-Acosta: Conceptualization, Writing - Original Draft, Supervision. Miguel Moreno-García: Conceptualization, Writing - Original Draft, Writing - Review & Editing, Visualization, Investigation.

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CONFLICT OF INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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