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Proposing Solutions for the Control of Dengue Fever Virus Carrying Mosquitoes (Diptera: Culicidae) *Aedes aegypti* (Linnaeus) and *Aedes albopictus* (Skuse).

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ABSTRACT

Over the past some years, there has been an impressive globalize increase in the frequency and epidemic of dengue fever. Biologically dengue virus belonging to the genus Flavivirus has four closely related but antigenically distinct serotypes, which are highly adapted and maintained to their *Aedes* mosquito species responsible for their transmission. Presently, due to the nonexistence of an effectual tetravalent vaccine or drug, the only strategic options available to reduce dengue viral transmission are case management to prevent human death and vector control. Because dengue is a global concern, based on extensive research, the new worldwide strategy for its prevention and control is to reduce the burden of dengue that solely depends on effective vector control measures. The purpose of this article is to provide specific guidelines and standardized procedures for the control of dengue fever virus carrying mosquitoes *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae). This strategy supports an integrated approach to vector management, sustained control measures and coordinated action among multi-sectoral partners at all levels. Present document provides directions at household, small-scale and large-scale field levels to determine the application and operational feasibility for the control of dengue fever vectors.

INTRODUCTION

As an introduction, man has undergone from the activities of mosquito since ancient time and this insect is ranked as most important agent which tends to promote diseases transmission. Mosquitoes belonging to the genus *Aedes* are the vectors for pathogens of different diseases including dengue fever virus. Dengue has been stated as the fastest emerging and most common insect-borne viral disease of humans, imposing a heavy economic and health burden on states, families and individual patients. Throughout tropical and sub-tropical regions of the world, dengue is a major public-health concern and most rapidly spreading mosquito-borne viral disease. The dengue virus is transmitted to humans through the bite of an infected mosquito and mosquito species *Aedes aegypti* and *Aedes albopictus* (Diptera: Culicidae) are vectors for the dengue virus, and transovarial transmission of all four dengue serotypes hah been determined. The spread of both mosquito vectors and viruses has led to the resurgence of epidemic dengue fever (a self-limited flu-like syndrome) and the emergence of dengue hemorrhagic fever (severe dengue with bleeding abnormalities) [1, 2].

Overall, the global strategy for the control of dengue fever stresses many new opportunities opened by various experiences and also recent research on vaccines, that can be held to reduce morbidity (implementing improved outbreak prediction and detection through coordinated epidemiological and entomological surveillance, promoting the principles of integrated vector management and deploying locally-adapted vector control measures) and mortality (implementing early case detection and appropriate management of severe cases, reorienting health services to identify early cases and manage dengue outbreaks effectively and training health personnel), rationalize the disease response, and build capacities that increase toughness to future outbreaks. Its leading rule is to synchronize prevention, entomological and epidemiological surveillance, and case management within existing health systems, making sure that efforts to control disease are coherent, ecologically sound, cost-effective and sustainable [3].

Integrated Strategy for Dengue Management

The implementation of dengue vector management is an important aspect of dengue prevention. The advocacy and resource mobilization, partnership, coordination and collaboration, communication to achieve behavioral outcomes, capacity building, and a strong monitoring and evaluation system are of great importance. In attempts to control dengue disease, it should also keep in mind its significant social and economic implications, which are matters of deep concern. These implications are not less important than its medical impact. Cost-efficiency and cost-effectiveness in dengue prevention and control should be considered in both social and economic terms in addition to medical aspects of dengue. To meet this priority objective for its social impact, a country can draw a public health program based on four phases: - preparatory, attack, consolidation and maintenance. To this end epidemiological data are gathered, entomological survey of the vectors is performed in each area of the country, as well as the training of staff involving in this campaign.

The integrated strategy for dengue management is a model designed to strengthen national programs, with a focus on reducing morbidity, mortality and the societal and economic burdens produced by outbreaks and epidemics. Currently, 11 of the countries in the American region have developed a plan for implementing a national strategy and in addition, a sub-regional plan has been developed. The integrated strategy for dengue is expected to produce a qualitative leap forward in prevention and control through stronger partnerships among the state, its various ministries, and governing bodies at all levels, private companies, and the range of community and civil groups. This strategy, once implemented will reduce risk factors for dengue transmission, establish an integrated epidemiological surveillance system, decrease of *A. aegypti* mosquito populations, prepare laboratories to better detect and identify the virus, and optimize diagnosis and treatment. As a result, there can be decrease in frequency, severity and magnitude of dengue outbreaks and epidemics [4].

Entomological Surveillance

In support of entomological surveillance and integrated control of *A. aegypti*, it is emphasized the existence of detailed surveillance data before, during and after the dengue epidemic that can offer a unique opportunity to analyze entomologic information at different geographic levels. Entomologic data related to immature stages are collected through the basic sampling of house or premise, and 4 indices that are commonly used include House index (HI): percentage of houses infected with larvae and or pupae, Container Index (CI): percentage of water holding containers infected with larvae or pupae, Breteau Index (BI): number of positive containers per 100 houses inspected, and Pupae Index (PI): number of pupae per 100 houses. Based on extensive research during the study, the incidence of dengue fever has been found significantly associated with the following factors: - higher household index, higher container index, and higher Breteau index. Adult vector surveillance is done through landing/ biting collection, resting collection and oviposition traps. It is necessary to monitor vectors regularly for disease prevention activities to determine at which growth stage the mosquitoes are and is helpful in deciding whether vector control is necessary [5].

Monitoring Ecological and Biological Factors

The ecological studies of *A. aegypti* and *A. albopictus*, which are principal mosquito vectors of dengue viruses is very crucial. Eggs of *A. aegypti* can survive unfavorable conditions, while, larvae and pupae breed into natural or artificial containers, the last being the most important. Artificial breeding-sites are mostly water storage containers and discarded containers. The adult females of *A. aegypti* are mostly diurnal and indoor feeder. Active dispersion of females is weak, one female can usually visit one or two houses in its life, and at the opposite, passive dispersion is extreme. The *A. albopictus* is a tree-hole mosquito, and so its breeding places in nature are small, restricted, shaded bodies of water surrounded by vegetation, and it inhabits densely vegetated rural areas. It may reproduce in cemetery flower pots, bird baths, soda cans, abandoned containers and water recipients, and decaying leaves. Tires are particularly useful for mosquito reproduction as they are often stored outdoors and can effectively collect and retain rain water for a long time. Comparisons of sampling methods for immatures in drums revealed that net sweeping was better than ladle dipping; the % recovery for fourth stage was the highest when sampled from the top (compared to the other stages) and with the decrease in the water temperature recovery from the top by net sweeping became less after the second sweep.

The most common positive container types found during field studies are tires, buckets, plant pot bases, rain water tanks and ice cream containers. It has been determined that certain rain water tanks and wells produced high numbers of *A. aegypti* immatures and adults and thereby indicating that key containers exist. On the aspect of bio-ecology of dengue vectors, the factors influencing dengue vector densities and ultimately viral transmission are ecological and biological which tend to promote disease transmission or inhibit efforts of vector control. Vector breeding and the production of adult *A. aegypti* are influenced by a complex interplay of factors. Natural factors include climate (temperature, humidity and rainfall), and development of urban settlements and agriculture also have profound impacts. Biological factors relate to the behavior of the dengue vector, *A. aegypti* and the transmission dynamics of the disease. In the ecological model, dengue risk is related to households situated in the ecotope of residential mixed with commercial and densely populated urban residential areas, high historical dengue risk area, and presence of household window screens [6, 7].

Accounting for variations in dengue transmission dynamic and mosquito vector populations, it will improve dengue surveillance and prevention. The seasonality and short term cross-protection are key factors for explaining dengue dynamics. The impact of demographic changes by considering a sudden change in the population growth rate for both the human and mosquito populations have been explored. Doubling the population growth rate of both host and vector led to a higher frequency of outbreaks. When population growth is set to zero, the dengue incidence decreased. A sudden reduction in the size of the vector population, such as that caused by the implementation of a vector control program, reduces the disease incidence in the short term, but does not alter the long-term dynamics of transmission. Stopping the vector population growth, while allowing the human population to continue growing, eliminated the circulation of dengue. Even though the intense efforts are under way to develop a vaccine, there is neither a vaccine to prevent dengue nor there are any effective anti-viral drugs to treat the disease. So, the countries should strengthen their vector control program including individuals, families and community participation to have the best chances of success [8].

Biological Control

Biological control is the deliberate use of natural enemies to reduce the number of vector organisms. Existing vector control tools have several limitations in terms of cost, delivery and long-term sustainability. However, there are several new innovative tools in the pipeline. These include Release of Insects Carrying a Dominant Lethal system and an endosymbiotic bacterium *Wolbachia*, to inhibit dengue virus in the vector. In addition, the use of biological control agents such as larvivorous fish in combination with community education have potential to dengue management. Despite recently heightened awareness for dengue prevention, various challenges still exist. These include inadequate funding and resources, and the lack of a sound strategy to respond to the increasing problem of dengue outbreaks in various geographical areas.

Rapid urbanization, lack of basic sanitation, increased mobility of populations and international travels have compounded the problem in some countries and areas, and there is no promising solution for sustainable control of dengue vectors. Knowing the complexity of dengue vector control at national level, a well-organized dengue control program should be established to collaborate with different sectors, ministries, agencies and partners to plan, implement and facilitate these activities [9].

Based on research, good formulates of *Bacillus sphaericus* and *B. thuringienis* subsp. *israelensis* to control larval populations at accessible costs and with no risk of pollution as threat to human and his environment, can produce short term efforts of vector control. The *Toxorhynchites* mosquitoes are good larval predators, but high numbers of *Aedes* larvae are required to produce sufficient adults that need to be used in inundative releases. Copepods are the group with the most potential to control larvae and they are very cheap to yield as biolarvicides. Actually copepods show a great potential to be used in the integrated Vector Management (IVM) control programs against *A. aegypti* worldwide. Finally another promising group is formed by the fungi Ascomycetes *Metarhizium anisopliae* and *Beauveria bassiana*. They are effective to control immatures and adults mosquito. These fungi can be cheaply produced by using natural substrates like rice, sorghum, etc. in plastic bags in laboratory, to have a low cost production in an IVM control program [10].

Chemical Control

The most effective mosquito vectors control methods include a variety of insecticidal tools that target adults or immatures. In the early campaigns against the *Aedes* vectors, larval habitats have been treated with oil and houses remained fumigated with pyrethrins. Later on the insecticide DDT became a principal method of *A. aegypti* eradication, and when resistance developed to it, organophosphate insecticides, including fenthion, malathion and fenitrothion are used for adult control and temephos as a larvicide. Current methods for applying insecticides include larvicide application and space spraying. There are three insecticides that can be used for treating containers that hold drinking water. One percent temephos sand granules are applied to containers using a calibrated plastic spoon to manage a dosage of 1 ppm which has been found to be effective for 8-12 weeks. Insect growth regulators like methoprene interfere with the development of the immature stages of the mosquito by interference of chitin synthesis during the molting process in larvae or disrupt pupal and adult transformation processes. Generally, there are two forms of space-spray that have been used, namely thermal fogs and cold fogs. Thermal fogging formulations can be oil-based (diesel) or water-based.

The ultra-low volume, aerosols (cold fogs) and mist involve the application of a small quantity of concentrated liquid insecticides. It has been demonstrated the control strategy that exploits adult mosquitoes as vehicles of insecticide transfer by harnessing their fundamental behaviors to disseminate a juvenile hormone analogue between resting and oviposition sites. A series of field trials undertaken showed that more than control, overall reductions in adult emergence of 42-98% have been achieved during the trials.

Another recommendation of the international organizations is to use essential oils for *A. agypti* control as component of programs to combat larvae. Essential oils from plants have been considered important natural resources to act as insecticides in controlling several species of mosquitoes. Efficacy of essential oils screened against *A. aegypti* indicated that mentha oil and calamus oil are the most promising larvicides, and orange oil has potent knockdown effect against the tested mosquito species. Repellence of the oil *Lavandula gibsoni* provided 100% protection for more than 7 h at a concentration of 2.0 mg/ cm^2. The most active essential oils are those of *Guarea humaitensis* branches (LC50 48.6 µg/ mL), *G. scabra* leaves (LC50 98.6 µg/ mL) and *G. silvatica* (LC50 117.9 µg/ mL) due to differences in qualitative and quantitative variations of the components, therefore the larvicidal effect may be due to higher amount of the sesquiterpenes with caryophyllane skeleton.

The *Cymbopogon citratus* exhibited high efficiency for the protection time and the percentage of biting deterrent against all of three different mosquitoes. The percentage repellency increased with increase in the concentration of essential oils or biting rates decreased when the concentration of oils increased. These oils could be used to develop a new formulation to control mosquitoes [11, 12, 13].

The experience, which has accumulated larval control of *A. aegypti* mosquito has utilized the organophosphate temephos, which has selected resistant mosquito populations. Faced with this problem, there is searching for new products including those based on *B. thuringiensis israelensis* (Bti). During sporulation, many Bt strains produce crystal proteins (proteinaceous inclusions), called δ-endotoxins that have insecticide action. The work has compared the efficacy and persistence of two bioinsecticides based on Bti, growth regulator-pyriproxyfen and chemical product-temephos in susceptible and temephos resistant populations of *A. aegypti*. The results showed that the Bti products gave 100% population control for 20 days and there was no difference in susceptibility among the two mosquito populations. The products based on temephos and pyriproxyfen caused 100% larval mortality in both populations for 60 days after treatment.

However, after the 2-year storage period, Bti still provided very good efficacy against all laboratory-cultured susceptible strains of *A. aegypti* and *A. albopictus* [14, 15].

Integrated Vector Control Program

Integrated vector control program is to prevent mosquito population outbreaks associated with the seasonal increase of dengue cases by intensifying control measures in specific places at specific times. There is no specific dengue therapeutic, and its prevention is currently limited to vector control measures. The characteristic features of integrated vector management include methods based on knowledge of local vector biology, disease transmission and morbidity. use of a range of interventions often in combination and synergistically, collaboration within the health sector and with other public and private sectors that impact vector breeding, engagement with local communities and other stakeholders, and a public health regulatory and legislative framework. The key elements of IVM are advocacy, awareness generation, social mobilization and legislation, collaboration within the health sector and with other sectors, integrated approach, evidence-based decision-making, and capacity-building. The major management methods involve environmental management, personal protection, biological control, chemical control, legislative measures and health education for community mobilization and inter-sectoral convergence.

The incorporating alternative tools, such as gravid ovitraps (lethal ovitraps and sticky ovitraps) may provide greater potential for monitoring and reducing vector populations and dengue virus transmission. It has been observed that the first rainfall after the dry season, associated with the season's high temperatures promote a massive mosquito egg hatching, resulting in very high mosquito densities, which match the dengue season. The vector population boost can be prevented through egg mass collection using 4,000 control-ovitraps/ km^2. The strategy is to combine larval source reduction by eliminating, properly covering or applying Bti as a larvicide in potential larval habitats, with mass collection/ destruction of eggs. In this strategy, the use of ovitraps is essential to avoid gravid females to disperse in the search for oviposition sites and to lower the amount of available breeding sites in a house. Traditionally, IVM control programs have been based on two components, chemical control (temephos as larvicide and organophosphates and pyrethroids as adulticides applied by ultra-low volume space spraying), and the community contribution to remove the water in artificial containers.

The use of aspirators for indoor collection of adult mosquitoes has several advantages over the use of organophosphorous or pyretroids as adulticides. It is expected that the vector population is impacted by indoors mosquito captures repeated fortnightly for two consecutive months within houses containing two or three ovitraps for egg collection. It is advocated an expansion of this idea to include in the integration of vector control and vaccines. In combination with a vaccine, sustained, effective vector control becomes an operationally achievable task. When applied together, vector control and vaccines have the potential for more swift and prolonged dengue prevention than if either approach is used by itself.

For preventing any arboviral diseases, persons should avoid arthropod bites by wearing a long sleeve shirt, long pants, and a hat when going into mosquito or tick infested areas like wetlands or woods. Tuck pant legs into socks or boots and shirts into pants to keep insects on the outside of clothing. Using mosquito repellent to protect against mosquito bites to skin, Permethrin repellent for application to clothing and gear, and using mosquito bed nets are crucial. During field activities, workers and public services citizens might cover tightly water kept in tanks or buckets, and prevent the accumulation of water of air conditioning, which allows the mosquitoes to breed and multiply more easily. Monthly door-to-door visits by specialized health workers to kill mosquito larvae might be augmented to every twelve days and some neighborhoods and to every week where the illness locus has been identified.

Furthermore, citizens are being advised to visit their family doctors at the first sign of symptoms that could signal dengue including aches and pains, a spiking fever, or rash and peoples who have previously suffered from dengue should be monitored especially closely as they are at a higher risk of fever.

This document is an expanded and updated version of the guidelines for operational indoor and outdoor control of dengue fever virus carrying mosquitoes *A. aegypti* and *A. albopictus.* Here most of examples furnished are pertaining to mosquitoes, however, these guidelines with whatsoever modifications can also be utilized against other vectors of public health significance. Operational trials ought to be conducted under the approximate supervision of personnel familiar with sound scientific and experimental procedures.

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