ISSN XXXX XXXX © 2018 IJESC

Research Article Volume 8 Issue No.4

Human Intervention in Causing Mosquito Extinction a Review

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Abstract:
Mosquitoes are termed as the world's most lethal organism. They cause millions of deaths worldwide and they are a vector for fatal diseases like arboviruses, malaria, chikungunya, yellow fever, dengue, and Zika virus. All of these diseases altogether cause more deaths than wars. For all these diseases, the vector control is the most powerful combative tool which is not being used to its full potential. Massive use of insecticides in the 1960's and 70's successfully brought down vector populations dramatically and only nine countries had cases of dengue. But, these diseases have remerged some being resistant to certain chemicals and now pose an even greater threat. [1]. Thus, eradicating these diseases would save millions of lives and eliminate sufferings of many people. The potential of the diseases to spread quickly on a global scale, changes in the environment, changes in ecology, the rapid movement of people and goods is threatening more than half of the world's population for these diseases. Thus more research needs to be done to control the mosquitoes. Along with this increasing potent danger of mosquitoes, there exists a serious concern over increasing insecticide resistance. So, if the existing class of insecticides looses their effectiveness, Human population is at risk. Due to the technological advancements, now, it is possible to cause their mass extinction. But are all mosquitoes bad? Do we kill all of them? No.

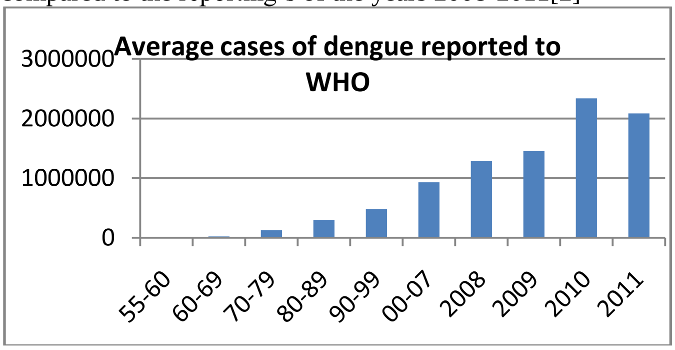
Keywords: Dengue; Malaria; Yellow fever; control measures; entomology; chemical control; Mechanical control; Biological control.

I. INTRODUCTION:

Vector borne infectious diseases, such as malaria, dengue, chikungunya, yellow fever cause a seriously huge fraction of all the infectious diseases caused worldwide. Nearly half of the world's population is infected with at least one type of vector borne pathogen[2]. These vectors thrive in conditions where hygiene is poor, water is stagnant and environments are filthy. These diseases affect person infected with HIV, children, pregnant women and unhygienic people the most.

Mosquitoes.	Diseases.
Aedes aegypti	Dengue, Yellow fever, Zika virus, Chikungunya.
Aedes albopictus	Chikungunya, Dengue, West Nile virus.
Culex quincefasciatus	Lymphatic Filariasis.
Anopheles	Malaria.
Haemagogus	Yellow fever.

The following figures highlight the danger posed by the mosquito in transmission of diseases over the decade. The figures show the average number of cases of dengue and severe dengue reported to the WHO during 1997-2007 as compared to the reporting's of the years 2008-2011[2]



The Diseases and the mosquitoes-

Malaria.
It is a parasitic disease that triggers flu like symptoms and chills. Symptoms usually appear after a period of seven days. Currently the best treatment offered is ACT (Artemisinin-based combination therapy). No vaccine is available in the market for malaria. Malaria is caused by Plasmodium parasite and five parasite species cause diseases in humans. Anopheline mosquitoes are the ONLY vectors for malaria transmission.[3]

Dengue
Dengue is a severe flu like illness having symptoms like severe headaches, joint pains, and blood in vomit, swollen glands and rash. There are four known stereotypes of dengue virus (DEN1to4). Recovery from one gives lifelong immunity for the rest. More than 40% of the world's population is now at risk of Dengue. The mosquito Aedes aegypti is the primary vector and once infected the mosquito can transmit the virus for lifetime.[4]

Chikungunya
The symptoms of Chikungunya are fever, severe joint pain, fatigue and sometimes a rash. Most patients recover fully but, joint pain may persist for years. There is no specific treatment for chikungunya. Symptomatic treatment by paracetamol or acetaminophen to relieve fever and anti-inflammatory medicine for joint pain. Aedes, Culex and Mansonsia species transmit this disease.[5]

Yellow fever
It is a viral hemorrhagic fever and was one of the most lethal diseases before vaccine invention. A single dose of the vaccine provides lifelong immunity but during recent times reports of these diseases are resurfacing due to the declining immunity towards the infection. Every year there are about 200000 cases

of illness and around 30000 deaths. This disease is transmitted by Haemagogus and Aedes species.[6]

Some of the harmful mosquitoes:

1. Aedes aegypti or yellow fever mosquito:

It is a vector of several viral pathogens that cause disease in humans. Diseases of concern include Dengue Fever, Chikungunya and Zika. The species is classed as a possible vector of WNV, confirmed by the isolation of West Nile virus from field-collected mosquitoes. (Turell et al. 2005).Aedes aegypti can be identified by the white bands on the hind legs and distinct white lyre-shaped markings on the top of the thorax (back). It is a species that lives in close association with humans, even breeding indoors. Unlike Culex mosquitoes, Aedes aegypti does not disperse far from breeding sites. Females typically lay their eggs water containers such as old tires, flower pots, barrels, cans, and various containers that hold a limited quantity of water (Bennett et al. 2003). Eggs are laid singly on a moist surface just above the water line, and hatch when water level is raised by rain. Its eggs are very resilient. They can withstand dry conditions for several months and under ideal conditions, up to a year, resuming development when water becomes available (Womack 1993). Once they hatch, the larvae develop in a relatively short time depending on the temperature. Adult females often bite around the ankles throughout the day, especially early evening.

2. Western malaria mosquito, Anopheles hermsi

Anopheles hermsi is a vector of the malaria parasite. The mosquito has also been implicated in the transmission of avian malaria to birds, and the Myxomatosis virus to rabbits. Larvae of this species prefer clear, fresh seepage water in sunlit or partially shaded pools. Roadside ditches and grassy fields provide overwintering sites for adults. The Western malaria mosquito feeds aggressively on humans.

3. The Asian tiger mosquito: Aedes albopictus

Aedes albopictus is characterized by its black and white striped legs, and a distinct median dorsal white stripe. It has become a significant pest in many countries. Aedes albopictus is a more aggressive daytime feeder compared with Aedes aegypti and is more cold tolerant, so may become established in the colder areas of the state. The mosquito feeds mainly during the day but also during evening and morning hours. Aedes albopictus is a competent vector of several viral pathogens, including Yellow Fever, Zika, Dengue Fever and Chikungunya, as well as several filarial nematodes.

The Ecological Niche of Mosquitoes:

● **The Larvae:**

The mosquito larvae eat detritus and some microbes present in the water. But so do other non vector organisms. The larvae are a food for many species of larvivorous fishes (e.g. Fishes of genus Gambusia and poecilia. A number of copepods prey on the larvae e.g. Cyclops vernalis, Megacyclops formosanus, Mesocyclops aspericornis, Mesocyclops edax, Mesocyclops thermocyclopoides. However, these fishes are not a control measure for the mosquitoes as, these fishes prefer planktons and algae for their foods, and eat mosquitoes only when there is no other food source. They show stunted growth when they eat mosquito larvae only. The only useful mosquito larvae are the Toxorhynchites which resort to cannibalism in larval stage and don't bite humans in adult stage.

● **The Adult:**

These are a food for higher animals and insects but, still they are a last resort. The insects that eat mosquitoes are the dragon fly, the damsel fly, and their aquatic nymphs. Insectivorous plants like the Venus fly trap, Drosera also eat mosquitoes. Frogs and tadpoles eat mosquitoes and so does the bird Progne subis. Bats also eat mosquitoes but only in unavailability of other food. That indicates that the mosquito overall has no significant role in the tropical and temperate food chains. However in the arctic food chain the adult mosquito plays an important role. The numbers of mosquito present in the cold ecosystems of the arctic are huge. So, the birds will lose a critical part of their diet if all the mosquitoes are wiped out. Fortunately, the dominant mosquito species is Aedes impiger and Aedes nigripes, both of which are non vectors and do not feed on human.

Control Measures:

1. Mechanical measures.
2. Chemical measures.
3. Biological measures.

1. Mechanical measures.

The Mechanical measures involve the use of indoor repellents in the form of aerosol spray, mosquito repellents, Mosquito repellent net, and indoor residual sprays, etc. All of these are traditional measures and have been proven useful from time to time because of their cheap application rates and long lasting potency. The Bednets, a most common mechanical measure, also protects from sandflies and triatomine bugs. Nets need to be checked from time to time for holes in them. Indoor residual spraying with insecticides also is a potent method as they can last for 3-4 months. Various companies sell mosquito repellent sprays and balms which can be applied on the skin (they act as mosquito repellents). Other insect repellents in the form of coils, vaporizers, and insecticide impregnated curtains are an effective method for mosquito control. Insecticides having synthetic pyrethyroids are generally used.

2. The Chemical Measures:

The WHO prequalified chemicals and mosquitocides are sold in the market in the form of indoor as well as outdoor residual spray. Both are effective in killing mosquitoes. This list contains vector control products that have been assessed by WHO and found to be acceptable, in principle, for procurement by UN and other international agencies and countries [7]

Product name	Reference no.	Applicant	prequalification date
SumiShield 50WG	001-001	Sumimoto chemical co, Ltd	25/10/2017
Sumilarv	001-002	Sumimoto chemical co, Ltd	7/12/2017
OLYSET	001-004	Sumimoto chemical co, Ltd	7/12/2017
Sumilarv 2MR	001-006	Sumimoto chemical co, Ltd	7/12/2017
Royal sentry	003-001	Disease Control Technology, LLC	7/12/2017
RUBI 250WG-SB	004-005	Tagros chemicals India, pvt. Ltd	7/12/2017
LIMITOR-5GR	004-001	Tagros chemicals India, pvt. Ltd	7/12/2017
Duranet LLIN	006-001	Shobikaa Impex Pvt.Ltd	7/12/2017
Gokilat-S5 EC	001-003	Sumimoto chemical co, Ltd	8/12/2017

The Biological control of Mosquitoes [8]:

1. Bacillus thuringiensis

Bacillus thuringiensis is a pathogen of lepidopterous larvae B.t. products are widely used for the Biological control of lepidopteran pests on various food crops and forest trees (Rowe & Margaritis 1987; Jutsum 1988). More recently, strains of B.t. with toxicity towards Diptera (mosquitoes and black flies; Goldberg & Margalit 1977; Margarlit & Dean 1985) and Coleoptera (various beetles; Krieg et al. 1983; Herrnstadt et al. 1986)have been isolated thus widening the scope of biological control with this bacterium. Taxonomy of Bacillus thuringiensis B.t. is a large, rod-shaped bacterium that under appropriate conditions differentiates into an ellipsoidal spore. B.t. is closely related to B. anthracis and B. cereus to the extent that in the absence of pathogenicity they would be considered a single species. Other approaches such as enzyme electrophoresis (Zahner et al. 1989) and numerical phenetics (Priest et al. 1988) have failed to provide good evidence for separation of these taxa although pyrolysis GC showed some potential (O'Donnell et al. 1980) B.t. has been divided into at least 34 serotypes or serovars on the basis of flagellar (H) antigens (de Barjac & Frachon 1990). The majority of crystal protein genes are plasmid encoded. Mosquitocidal strains of B.t. are commonly associated with serotype 14 (subsp. isruelensis (B.ti.); de Barjac 1978) For example, since the original isolation of B.ti. by Goldberg & Margalit (1977), mosquitocidal strains identified as serotype 14 have been isolated from Egypt (Abdel Hameed et al. 1990a), India (Balaraman et al. 1981), China (Zhang et al.1984) and Israel (Brownbridge & Margalit 1986). It may be that the prevalence of mosquito toxicity in serotype 14 indicates that this variety may be closely associated with dipteran breeding grounds. Genes specifying crystal protein synthesis in B.ti. are located on plasmids. Hymen et al. (1985) screened numerous strains of B.ti. and showed that toxicity was invariably associated with the presence of a large (ca 70 mD) plasmid although numerous smaller and one larger plasmid were present in both crystalliferous and acrystalliferous B.ti. strains.

2. B. Sphaericus

Isolation of mosquito pathogenic strains of B. sphaericus (B.s.) predated the isolation of B.ti. by some 10 years (Kellen et al. 1965) but these early strains showed low toxicity. Following an intensive isolation and screening proprogramme organized by WHO, more highly toxic strains were recovered and these, together with several recently isolated strains, have considerable potential as control agents (reviewed by Singer 1988. B.s. strains are non-toxic towards Simulium larvae but are toxic towards many mosquito larvae, in particular, those of the genus Culex. Toxicity against Anopheles, Mansonia and Psorophora is variable depending on species and against Aedes larvae is generally very low. Important attributes of B.s. seem to be its persistence in the environment following application and activity in heavily polluted areas which have promoted its use as a biocontrol agent.

Taxonomy of Bacillus sphaericus

Virtually all mesophilic, aerobic rod-shaped bacteria that differentiate into spherical endospores are placed in the species B. sphaericus. The groundwork of B.s. systematics were established by Krych et al. (1980) who allocated 62 strains to five homology groups using DNA reassociation. The insect pathogens were divided into two groups one contained strains pathogenic to mosquitoes, and the other group comprised non-toxic strains. Despite variations in phage- and serotype, all these strains have the same spectrum of activity with high toxicity towards Culex and low toxicity towards Aedes larvae.

Comparison of Biological control of mosquitoes over chemical control method[9]:

1) The encouragement to augment or replace chemical insecticides with biological types will come from two directions:

1. The ever increasing resistance towards chemicals among the targeted species.
2. The reduced ecological impact of biological control programs.

But, considering the impact of previously used insecticides like DDT, several aspects must be taken into consideration before biological insecticides are accepted as a control method for mosquito population. B.ti. is more toxic than B.s. and kills Aedes species along with the mosquitoes like midges and blackflies. B.s., on the other hand, is more active against Anopheles species. Genetic engineering offers an attractive alternative to strain improvement and strains of B.s. that contain and express the B.ti. 130 kD toxin gene show high toxicity towards 2 Ae. aegypti (Trisrisook et al. 1990). Beyond mosquitoes and blackflies, there may be important new areas in the control of midges and houseflies where biological insecticides could replace chemicals. For example, B.ti. has proved very effective for the control of Chironomidae (non-biting midges), Psychodidae (moth flies) and the nuisance fly Syluicola fenestralis in sewage filter beds in the UK (Coombs et al. 1091). Flies of agricultural importance such as the Tipulids also comprise an important application of bacterial control.

(2) Persistence and recycling.

The B.ti. is lost from a place after some time of application this time period changes with place and temperature. Attempts to overcome this have involved expressing the B.ti. toxin gene in B.s. (Trisrisook et al. 1990). It is not clear at present how quickly the repeated or continual use of a biological mosquito control agent will lead to resistance but laboratory and field studies suggest that it could be far more rapid than first suspected. In one case, C. guinguefasciatus, have developed resistant populations against applied organophosphates which then quickly become established worldwide, presumably in conjunction with air travel (Raymond et al. 1991).

(3) Formulations.

"Bacterial insecticides are not equally effective under all environmental situations. Environmental locations such as saline habitats require new agents and products frequently. Inactivation by sunlight, pH and chemical composition of the water are additional factors that must be considered. One of the differences between bacterial and chemical formulations is that the former must be presented in an ingestible form. The ultimate is therefore to include the toxin in the larval food and to this end the B.s. toxin gene has been cloned into a cyanobacterium (Tandeau de Marsac et al. 1987) which is widely distributed in both mosquito and blackfly larval habitats and is an important food source for these insects."

(4) Cost.

Finally, implementation of bacterial insecticides will only occur if the cost of treatment is equal to or less than the chemical alternatives. There are many opportunities in the realms of strain improvement and fermentation development to reduce the cost of production of both B.ti. and B.s. Effective products at a realistic price will assure a bright future for bacterial insecticides.

Discussion:

According to the literature available and studies, there exist no useful species of mosquitoes except the non-vectors of the arctic. No ecosystem depends on any mosquito to the point that it would collapse if they were to disappear. But, we are unsure

of all the ways culicidans interact in the ecosystem. Therefore, only on-target extinction is required. The worst scenario is one vector mosquito species will replace another, and the most likely scenario is mosquitoes will be replaced by midges. They also have aquatic larvae and the females also blood-feed on humans. The combination of fewer mosquito competitors and possibly fewer predators of mosquitoes could mean an explosion of midge populations. On the other hand, the predators now reliant on mosquitoes may eat more midges instead, causing the populations to reach a stable equilibrium after a while. Midges in the family Chironomidae don't harm humans, but those in the family Ceratopogonidae do, a few do vector human and animal diseases. "Another surprising way mosquitoes can affect the ecosystem comes, again, from the arctic. Mosquitoes control the migrations of woodland caribou (Rangifer tarandus caribou). Their massive herds in Canada are always on the move to find food, but in the summer they travel a lot more, covering greater distances and moving to higher ground, sometimes avoiding the best feeding sites, because they are trying to avoid the gigantic swarms of mosquitoes that plague the Arctic regions in the summer. All the time spent running and not eating means they build up less fat that they would need for the cold winters, which can often mean death. Killing off these mosquitoes would change the historic caribou historical migration routes, with unpredictable consequences."
Scientists have eradicated many malaria mosquitoes from many parts of the world without any ecological imbalance, but so any extinction of complete mosquito population may have unforeseen risks. Arboviruses and malaria currently are killing or affecting millions, to not eradicate the vector mosquitoes responsible could only be justified if the expected environmental effects would be similarly damaging. But, how do we affect only the mosquito populations of the world? Pesticides are not an option they have non-target effects and may lead to bio-magnification. Aerial sprays won't hit the mosquitoes that like to bite indoors, and putting oils or insecticides in breeding sites won't catch the many, many tiny breeding sites in peoples' properties: everything from a tree hollow to a bit of rainwater sitting in a discarded plastic bag is a potential mosquito breeding site. Even if a single population isolated from our activities survives, the whole mosquito menance can re-emerge So, if we are going to eradicate mosquitoes worldwide, we need a species specific method. And we have been able to construct such methods and they have been proven to be useful on initial implementation. Now, there is a need to implement them globally.

II. CONCLUSION:

There exists tremendous need to eradicate the mosquitoes on a global scale. For this, the genetic autocide method is the best. It will ensure that only the mosquitoes will die but not any other organism. The use of genetics to control mosquitoes has been used before and it gave fruitful results. Following ways will help in controlling mosquito populations:

1. GSS- Genetic sexing strain:

"Using genetic sexing strains (GSS), an old technique in which a dominant selectable marker—a gene that makes its possessor able to survive an otherwise lethal challenge— is attached to the male sex chromosome. A successful example is the aptly named MACHO: a strain of An. albimanus with an insecticide-resistance gene attached to the male chromosome (mosquitoes mostly have an XY sex-determination system like humans do, where only males have a Y-chromosome). Treating a batch of MACHO eggs with insecticide will kill 99.9% of all females, allowing a million mosquitoes per day to be released when it was used to control mosquitoes in El Salvador in the late '70's. In case you are wondering, the eradication almost worked, until the mosquito immigrated back in from another country. Whatever technique we choose, it would need to be global, and in any case GSS doesn't solve the problem that irradiation can make many mosquitoes weak competitors."[10]

2. Use of RIDL technique

RIDL, or, the Release of Insects carrying Dominant Lethals, invented by entomologist Luke Alphey, is a technique in which the males are not irradiated but carry a lethal gene that causes their larval offspring to die before reaching adulthood. The RIDL technique which is being used now involves a gene called tTAV (tetracycline repressible activator variant), which makes a nontoxic protein that clogs up the insect's cell machinery so no other genes are activated which causes death before reaching adulthood. The system only works in the mosquitoes' own cells, and the protein is degraded when eaten, so there is no effect to animals that eat the modified mosquitoes or their larvae: It is a completely nontoxic system. RIDL is currently being used to fight mosquitoes in the southern US and South America, where they have already caused massive declines in dengue mosquitoes, and are now being deployed to stop the Zika epidemic in Brazil. And also, this method ensures that the chances of mating increase as compared to the SIT technique males, as the males here remain healthy.

3. Using Wolbachia to infect the mosquitoes.

Wolbachia is a symbiotic bacteria which was firstly reported in Drosophila, which was then transferred into the Aedes aegypti. It blocked the transmission of dengue and zika viruses. The mechanism behind this was reported to be "Cytoplasmic incompatibility. A recent paper has reported large-scale releases of Wolbachia-infected Ae. aegypti in the city of Cairns, Australia. Wolbachia was introduced in males and it invaded and spread through the populations due to a sperm–egg incompatibility (cytoplasmic incompatibility). Over a period of 2 years, a wave of Wolbachia infection slowly spread out from 2 release sites. In line with theoretical predictions, Wolbachia infection at a third, smaller release site collapsed due to the immigration of Wolbachia-free mosquitoes from surrounding areas. The Wolbachia completely blocks the Dengue transmission in at least 37.5%. These results highlight the potential usefulness of Wolbachia based strategies to protect the population from Dengue fever.

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