Chapter 4

Variables that May Affect the Transmission of Dengue – A Case Study for Health Management in Asia

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Additional information is available at the end of the chapter

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1. Introduction

Dengue, an emergent viral infection, has increased exponentially since the 1960s [1]. In spite of the alarming escalation of cases reported, the WHO still believes the disease is significantly underreported [2]. The effects of climate change are expected to dramatically increase the global incidence and geographic locations of dengue. According to the WHO, the number of countries reporting dengue cases has increased from nine countries before 1960 to more than 64 countries in 2007 [2]. Dengue cases continue to climb despite numerous interventions globally to halt the progression. Climate change allows the primary dengue vectors to thrive in more geographical locations; increased population, urbanization and deforestation have also provided favorable conditions for vectors. In areas with poor or nonexistent infrastructure, sanitation, and unreliable water supplies, water storage systems provide ideal breeding grounds for mosquitos. These issues are compounded by intercontinental commerce, specifically the transport of tires, which harbor rainwater and mosquito larvae, allowing introduction of non-native mosquitos to other countries.

No cure currently exists for dengue and vaccine development has been fraught with difficulties. Dengue should be categorized as one of the most imperative global health issues in need of effective solutions. Drastic changes need to occur in public health approaches and health management policies for dengue. Without serious and immediate attention to the escalation of dengue the global burden of disease will significantly intensify.

2. Background

Dengue is believed to be an ancient disease, one with unclear origins. Early Chinese medical records first describe a dengue-like outbreak as early as 400 AD, and later historical documentation in Asia, Africa, and North America made record of a dengue-like epidemic in the seventeenth century. Dengue has often been referred to as "break bone fever"; it was given this name due to the onset of high fever accompanied by agonizing bone and joint pain. The word "Dengue" was first recorded in the nineteenth century derived from the Spanish word meaning "fastidious" possibly to describe the way infected individuals carefully walked while experiencing horrendous bone pain [3].

Dengue is an infection passed from person to person by vector transmission. The predominant vectors for dengue are *Aedes aegypti* and *Aedes albopictus*. The vectors become infected after the female mosquito takes a blood meal from an infected human. Once the mosquito has been infected the virus incubates inside the mosquito host for approximately 8-10 days [4]. Upon completion of the incubation period the infected mosquito is capable of transmitting dengue to any human that it feeds on, for the remainder of its life. Four primary serotypes of dengue exist, DEN-1, DEN-2, DEN-3, DEN-4. Recently the Center for Infectious Disease and Research Policy reported a fifth serotype [5].

The most severe manifestations of the disease are dengue shock syndrome, and dengue hemorrhagic fever. Infection with one serotype does not impart complete or lasting immunity to other serotypes of dengue. Following recuperation from dengue infection, of a specific serotype, an individual has immunity from that serotype however immunity to other serotypes transitory and incomplete leaving individuals at a significantly increased risk of infection with a more severe serotype of dengue [2]. Unlike other vector-transmitted diseases, concurrent dengue infections increase an individual's susceptibility to a more life threatening serotype of dengue. Some cases of dengue are asymptomatic, however the classic symptoms include malaise, severe muscle and joint pain all accompanied with a high fever. The only treatment option currently administered for dengue infection is fluid replacement and rest. More severe cases of dengue cause capillaries in the body to leak blood plasma. This can progress to internal hemorrhaging, organ failure, and death [2].

According to estimates from the Centers for Disease Control and Prevention (CDC) three billion people globally are at risk of contracting dengue [4]. Although accurate assessments of dengue are difficult to ascertain, one undeniable observation is that Asia bears an unequal burden of dengue cases, with an approximate seventy percent of cases arising in Asian countries [6]. Findings from a recent study reveal that dengue is universal throughout tropical regions. Researchers estimate that there are 390 million dengue infections annually, all around the globe [6]. This is more than triple the WHO's most recent estimates of 100 million infections each year [2]. Another 16 million infections are attributed to Africa's burden of disease, which rivals that of the Americas and is significantly larger than previously predicted [6]. It is assumed that these numbers still underestimate the true incidence of dengue. Several factors likely add to the underreporting of dengue. Many tropical regions have various other diseases with symptomatically similar illnesses, which people may not seek treatment for or, if treatment is sought, misdiagnosis can occur. There are also potential economic impacts of reporting dengue for both individuals and countries as a whole.

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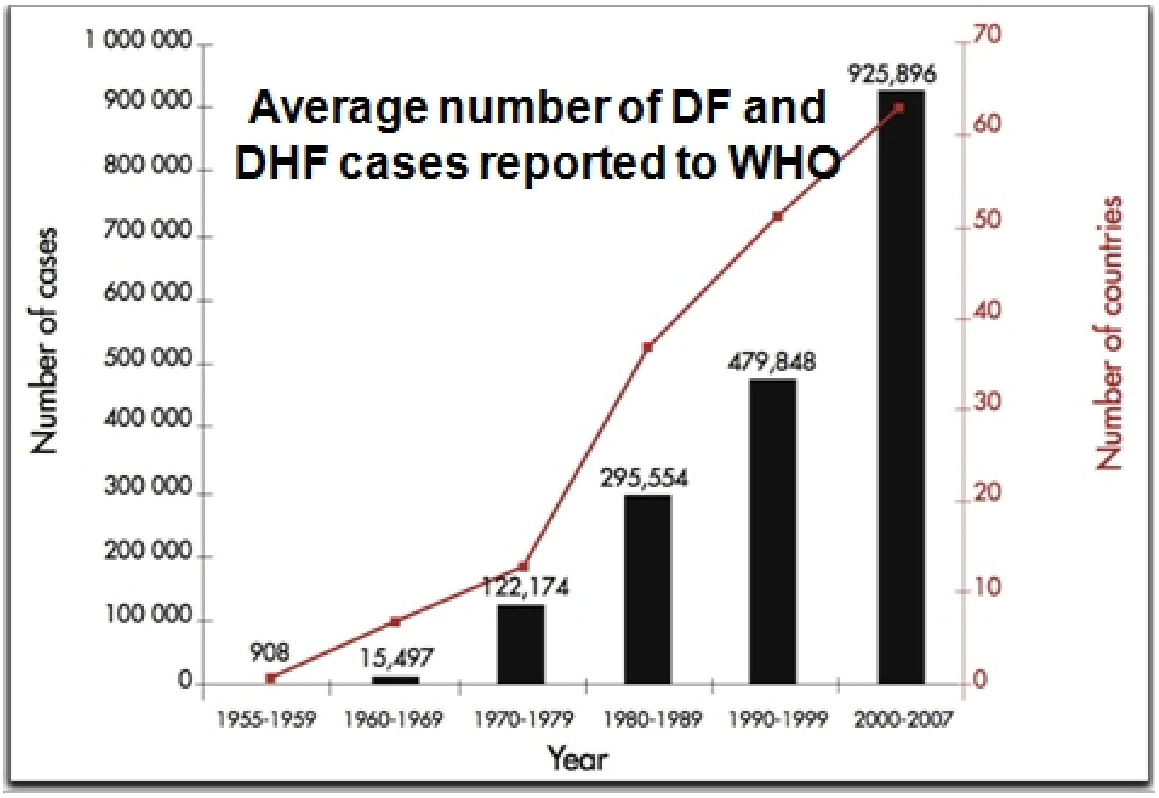

http://www.who.int/entity/csr/disease/dengue/dengue2008.jpg

Figure 1. World Health Organization

Climate and population growth are important factors for predicting the current risk of dengue around the world. With population explosion, globalization, and constant urbanization, dramatic shifts in the distribution of the disease are anticipated. The virus may be introduced to areas that previously were not at risk, and those, that are currently affected, may experience enormous increases in the number of cases. Endemic transmission in Africa and the Americas, recent outbreaks in Portugal, and the ever-increasing incidence in Asia are proof of the challenges that plague an effective dengue control and the issues surrounding vector control [6]. This is a pivotal moment in the fields of global health and health management systems. Efforts to combat dengue appear stuck. However, recent vaccine developments appear to be more effective at delivering a more feasible vaccine Strategies for tackling dengue need to be rethought in order to maximize the value and cost-effectiveness of health management systems, by indicating where resources can be targeted to achieve maximum and sustainable impact.

Humans have known for a long time that climatic conditions affect epidemic diseases. Today there is a worldwide increase in many infectious diseases and this reflects the combined impacts of rapid demographic changes, as well as social and environmental changes in human living conditions. Important determinants of vector-transmitted disease include: vector survival, reproduction, and the vector's biting habits. Vectors can survive and reproduce within a range of optimal climatic conditions, which include factors such as temperature, rainfall, proximity to large bodies of water, amount of daylight and elevation. There is a large body of evidence demonstrating associations between climatic conditions and infectious diseases. Dengue is of great public health concern and may be very sensitive to long term climate change. Dengue varies seasonally in highly endemic areas. Excessive rainfall and high humidity are major contributing factors to enhancing mosquito breeding sites and thus overall mosquito populations. Mathematical modeling methods have been used to demonstrate the relationship between climatic variables and biological parameters such as breeding, survival, and biting rates. Landscape modeling is also used because climate also influences habitats. Combining climate bases models with spatial analytical methods to study the effects of both climatic and environmental factors are beginning to be used to predict how climate induce changes would affect mosquito populations.

http://www.who.int/entity/csr/disease/dengue/dehngueemergence.jpg

Figure 2. World Health Organization

3. Burden of Disease

The burden of disease due to dengue started in Asia after the commencement of World War II [7]. Major factors contributing to the post war dengue proliferation include: worldwide rapid population expansion, urbanization, and globalization of markets. These factors coupled with new modes of human transportation could have facilitated the dissemination of both people and disease [7].

In order to initiate successful health management policies and programs it is important to understand the economic impact of dengue on Southeast Asia. Several articles have been published about this topic as well as assessments from the WHO. The overwhelming consensus

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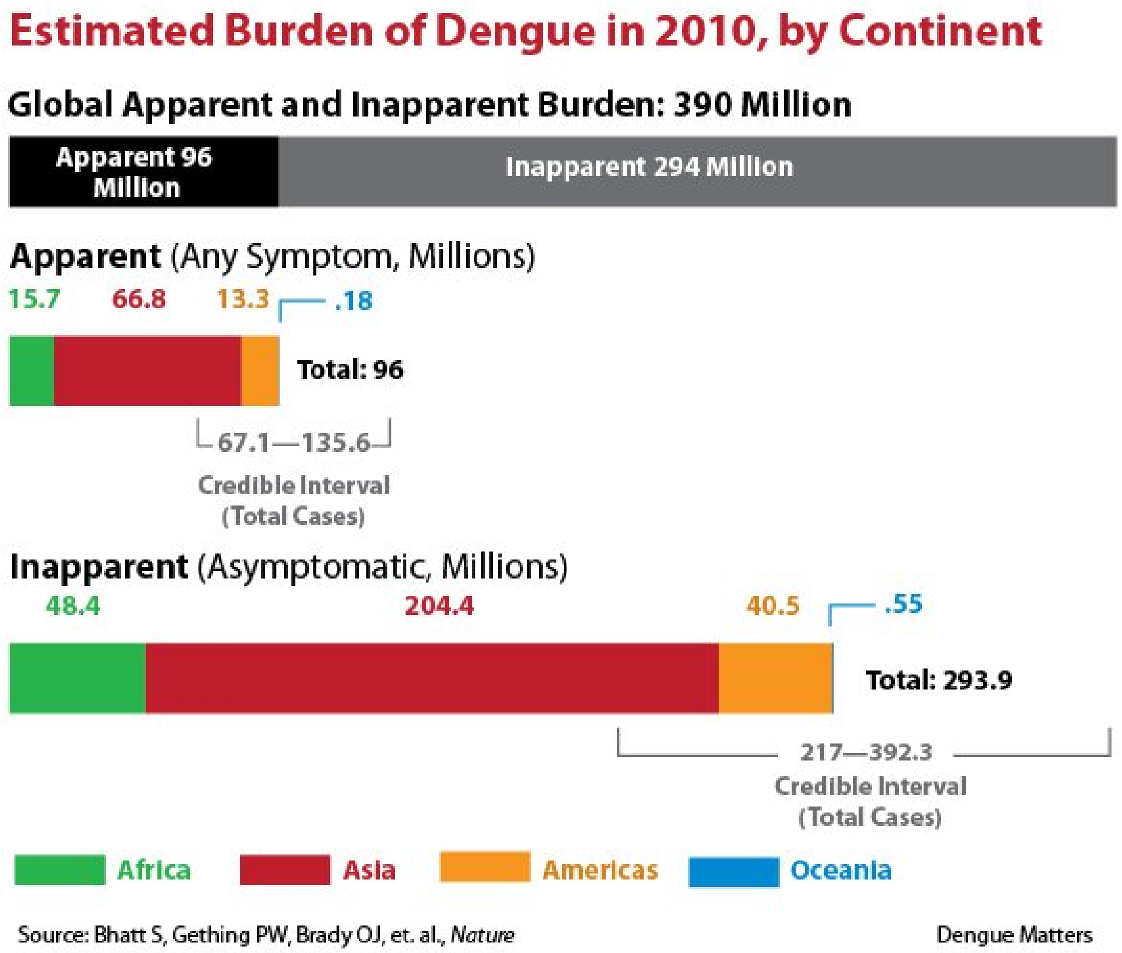

http://www.denguematters.info/content/issue-14-dengue-updates-december-2013

Figure 3. Dengue matters

reports that dengue is one of the most critical infectious diseases in tropical and subtropical regions. Dengue represents a monumental burden in Southeast Asia where it is endemic. Studies conducted from 2001 – 2005 have reported dengue specific cases in Cambodia to be three million dollars annually, Malaysia at forty-two million dollars annually, and Thailand fifty-three million dollars annually [8]. Another study estimated annual costs for Cambodia to be eight million dollars [9]. In 2009 the officially reported dengue cases were estimated to cost Malaysia one hundred million dollars [10]. The estimates of SEA burden of disease due to dengue are available only for a fraction of countries in the region. Estimates vary depending on methodology of studies and variance in officially reported cases. Although dengue is a reportable disease there is a considerable amount of underreporting [11, 12]. The total number of dengue related cases is difficult to ascertain due to inconsistency in surveillance methods and unreliability of surveillance reporting. Unreliability is due to a variety of factors including method and certainty of diagnosis as well as when and where the data were collected. To better illustrate the current estimates for the burden of disease the following graphs from Dengue Matters are provided: figure 3 and figure 4.

http://denguematters.info/content/issue-15-spotlight-dengue-southeast-asia

Figure 4. 'Dengue Matters'

The rapid urbanization and development of Asian cities has a drastic effect on the transmission of infectious disease. Currently, millions of people inhabit several cities in Asia. This coupled with a lack of wastewater infrastructure, insufficient housing, and unhygienic societal conditions promote the propagation of dengue infection. These factors are some of the major contributors to the proliferation of dengue in Asia [87].

Various global issues impact the delicate balance between environment and development. This balance has serious ramifications for controlling vector-transmitted diseases. The most profound impact on the encroachment of the environment is the explosion in human population. According to the United States Census Bureau, the world population is currently seven billion individuals. A human population that continues to grow will have a number of impacts on the surrounding environment and mosquito ecology including depletion of natural resources, opportunistic breeding sites, decreased biodiversity.

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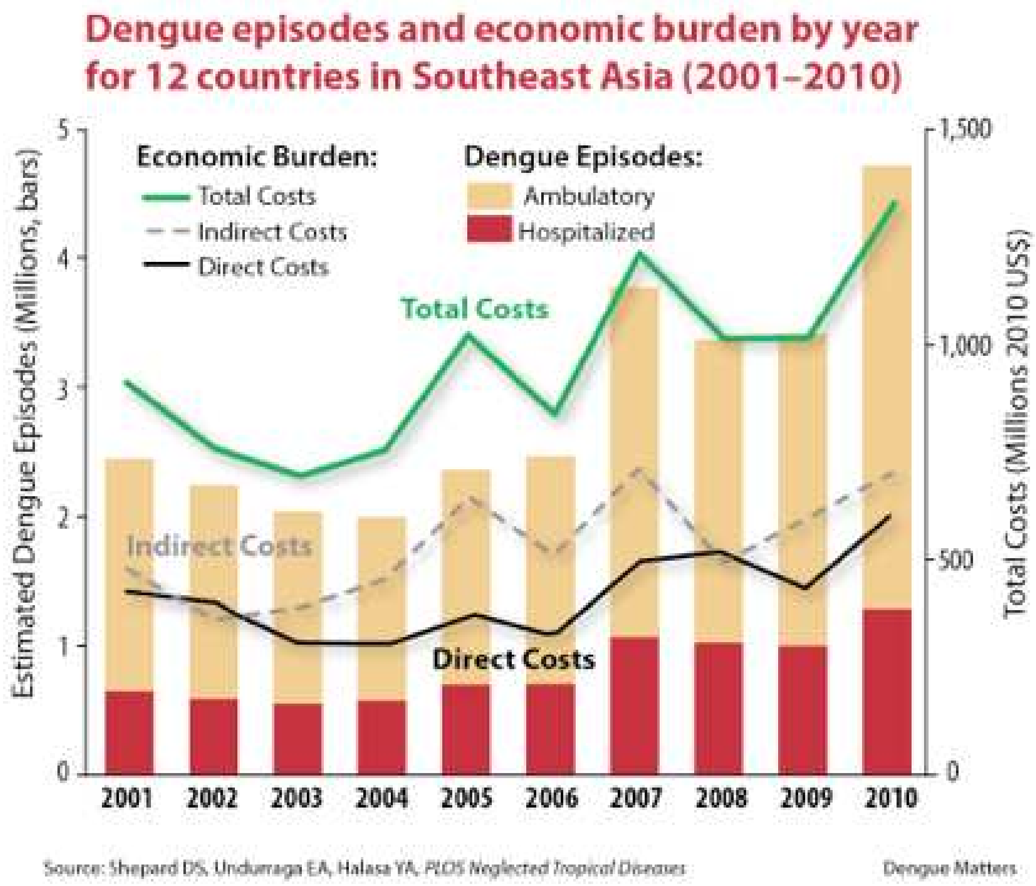


http://denguematters.info/content/issue-15-spotlight-dengue-southeast-asia

Figure 5. 'Dengue Matters'

The perpetual demand for commercial goods, food, and energy compels nations to develop vast quantities of land and water resources for agricultural and energy harvesting purposes. In the process of land development, deforestation and soil degradation decimate the natural habitats of mosquito populations. These processes are then compounded by man-made water reservoirs and irrigation systems designed to facilitate land development. Such large stagnant bodies of water may be providing generous breeding grounds for vector populations. Mitigation of such ecological impacts may be addressed by allowing cooperative consultation during construction planning phases. Construction plans can be coupled with adequate health risk assessment plans to facilitate improved environmental safeguards to prevent future vector ecological problems and health concerns. Areas developed for their natural resources undergo significant alterations in human population living conditions and density, which correlate to the incidence of infectious diseases [13]. Land development tends to create population migration due to potential economic opportunities and the need for seasonal labor. Settlement of individuals in a new area without competent infrastructure of water systems can introduce new unexposed individuals into a high-risk situation that has the potential to spread vector-transmitted illnesses rapidly. Living conditions may also degrade the overall health of the population and promote the spread of viral variations [13].

Expeditious urbanization entices rural individuals to relocate to urban environments based on potential economic opportunities. As this occurs urban settings tend to be ill prepared for the increased demand of basic water services. Sewage, sanitation and drinking water supplies rarely match the populations' needs and consequently result in increased incidence of infectious diseases. Historical patterns of rapid urbanization coupled with observable correlations of increased infectious disease, specifically vector-transmitted diseases, highlight the dramatic need for resources in urban settings.

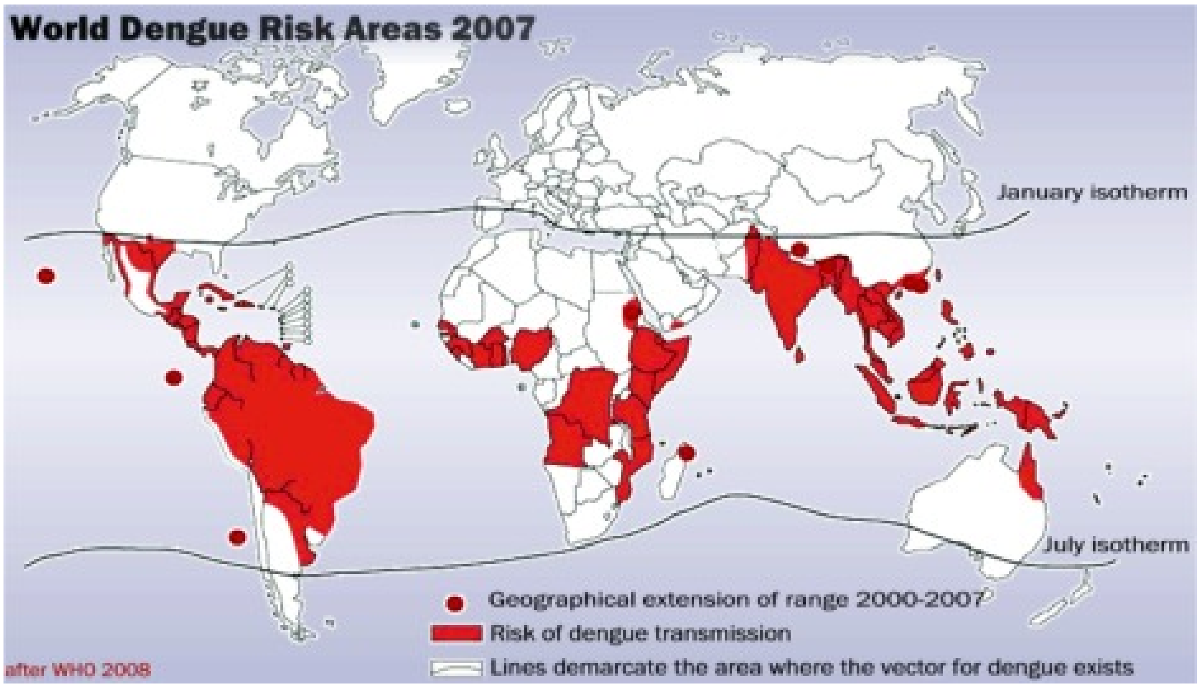
Vector transmitted diseases such as dengue increase as biodiversity decreases. When natural habitats are destroyed by land development projects, habitats become simplified. The breakdown of habitats facilitates the growth of mosquito populations over their natural predators. Exacerbating the situation is the excessive use of pesticides, which can select for mutations, and lead to insecticide resistant mosquitos. Of particular concern are the agricultural applications of indiscriminate pesticide application that can release chemical residue into the environment affecting a wide variety of other insects. Natural predators of mosquitos, like dragonflies, tend be unintended victims of pesticide overuse and in turn lead to the acceleration of insecticide resistance.

The effects of climate change on global disease patterns and geographical expansion are still speculative. By reflecting on the observable patterns in the last few decades, some trends become apparent. A few of the global climate change issues have the potential for impacting vector ecology and thus vector transmitted diseases. Increased temperatures may expand the geographical endemic areas for infectious diseases. Warmer temperatures may also allow vector migration to occur at higher altitudes. Shifts in global wind patterns may impact the passive migration of vectors. Increased rainfall introduces stagnant water issues to new areas and plays an important role in the life cycle of a mosquito. Most dengue transmitting vectors breed in small pools of water. The existence of potential vector breeding grounds depends not only upon rainfall but also on evaporation. The patterns, frequency, and amounts of rainfall globally are expected to change and will impact temperature, evaporation and humidity thereby making clear predictions regarding vector migrations complex. Increased temperatures are anticipated to increase sea levels, natural disasters, and rainfall all of which could lead to greater vector breading site opportunities Climate change is predicted to increase the quantity and intensity of natural disasters. Natural disaster areas are ideal sites for the dissemination of infectious disease and give ample opportunities for vectors to propagate.

Various time series studies explore the relationship between average temperatures in conjunction with rainfall rates. It has been hypothesized that increasing temperatures could be part of the reason why dengue can now survive in a greater range of areas. Many other confounding factors, however, could be causing the increase in dengue in these areas. Further investigations into whether climate change could drive the geographical spread of the disease and produce an increase in incidence would be beneficial. Other studies consider the impact temperature and deforestation have on vector transmitted diseases. Assessing the biological significance of the warming trend on mosquito populations some scientists suggest that the observed temperature changes will be significantly amplify the mosquito population. The effects of climate change on the health of human societies are already evident however these effects are expected to increase. Direct assessment of climate related effects are difficult to definitively ascertain due to the complexity of interrelated variables. Challenges arise when attempting to distinguish which variables most directly affect climate change but a few influences are clear. Human population explosion, the use and development of land, and naturally occurring variability are some of the most influential factors in climate change. Current data can be used to influence future policy and public information. Many agree that climate change exacerbates weather related issues, droughts from a dearth of rainfall or once manageable seasonable rainfall causing widespread flooding conditions [88]. Affects suffered as a result of climate change would include weather-related disasters. Condition can be temporary or permanent, ranging from short-term displacement from a natural disaster to living with severe water scarcity. Currently the best estimates of the level of impact of climate on health trends are just predictions based on possibilities. Gradual environmental degradation due to climate change also affects long-term water quality and quantity in various parts of the world. Water related issues could trigger increases in vector-transmitted diseases such as dengue. Environmental degradation is a contributing factor to poverty, and can expel people from their homes. Individuals affected by water scarcity, poverty, disease, or displacement also tends to have worse health outcomes. Climate change can be expected to disproportionally affect developing countries. Effects brought on by climate change could further reduce health outcomes and increase food and water insecurity leading to more displacement and greater proportions of populations subjected to poverty and disease. Increases in poverty would result in competition for scarce resources and greater burdens on economically limited governments. Deteriorating conditions could ultimately lead to increases in conflicts. Therefore, health outcomes are employed as a foundation for climate change associated influences [88]. Employing this tactic, WHO assesses the global burden of disease related to climate change factors to have longitudinal effects on millions of individuals currently [1]. Climate change is anticipated to significantly increase food and water quality and insecurity [1]. Climate change is expected to produce an increase in chronic diseases, respiratory diseases, and vector-transmitted diseases, all of which could overburden the current public health system. A warmer and more variable climate leads to increased levels of air pollutants and increased transmission of diseases through unclean water. It compromises agricultural production and it increases the hazards of weather-related disasters. Climate change together with the changes vector habitats as well as water supplies can increase the incidence of many diseases particularly dengue.

Dengue incidence, particularly dengue epidemics, has been currently associated with rainy season. Despite the number of studies, convincing data or models supporting this hypothesis is limited in small countries [14]. A study in Thailand found that climatic factors play a role in transmission cycle of DHF, but relative importance of these factors varied with geographical areas [15]. Ecological studies related to *Aedes aegypti* have shown that *Aedes aegypti* is a humidity loving species and is governed by the conditions to which it has adapted. It avails all available opportunities in the peridomestic domain during this rainy season when temperature falls down and humidity increases. The association between flooding caused by precipitation and an increase in vector breeding sites is multifaceted. It is generally believed that increased rainfall will increase the number of breeding sites particularly for mosquitos

[16]. Flooding is typically followed by an immediate dip in vector populations, due to excess water clearing out existing breeding sites, however as waters recede mosquito populations tend to bounce back in areas where the water pools [17]. The relationship between dengue and increased precipitation is not always proportional because transmission of dengue requires the disease be prevalent in the population for vectors to be able to transmit the disease [16]. Although increased precipitation can cause more areas of pooled water, which can increase mosquito population density or increase exposure to mosquito populations through housing damage. Increased rainfall or flooding situations do not always affect the incidence of dengue infections in populations [18]. It is postulated that with an increase of mosquitos the incidence of potential dengue transmission is increased [18]. Typically after a natural disaster occurs an increase in infectious disease follows, this can occur for several reasons: lack of access to clean water, crowding living conditions, disruptions in vector elimination programs, and increase in time spent outdoors which increases the exposure to vectors [18]. Addressing some of the known risk factors and bolstering public health infrastructure can mitigate potentially preventable vector transmitted disease. Particular attention should be paid to post natural disaster situations. When individuals travel to avoid the effects of natural disasters it can lead to congregations in areas without proper water supply or sewage infrastructure both of which can rapidly increase the incidence of infectious disease [19]. Another consideration of a shift in human settlements is the potential upsurge in stress and mental illness, and human struggle, which can aggravate infectious diseases like dengue [20].



http://www.who.int/entity/csr/disease/dengue/dengue2006.jpg

Figure 6. World Health Organization

Although dengue is currently a global concern, approximately seventy-five percent of individuals living in Asia have been exposed to dengue [21, 22]. More than one billion high-risk individuals, like children, live in a dengue endemic country in Southeast. In SEA the leading cause of child hospitalizations and child mortality are attributed to dengue [22, 23]. The WHO has a clear documentation of the development of dengue in the last few decades. Eight SEA countries reported dengue related illnesses in 2003; within six years all SEA countries reported endemic dengue [21, 22]. The number of dengue cases in SEA continues to climb in quantity and severity. Currently eight SEA countries are categorized as hyper-endemic, meaning all four stains of dengue exist simultaneously [22].

Dengue infections in children aged 5 years or younger, mostly in developing countries could see a sharp increase in incidence. Other severely affected population groups could include women, the elderly and people living in small islands, and other coastal regions. These groups are the most affected due to social factors such as immune susceptibility and geographic areas of high risk. Immune susceptibility affects the very young and the very old while geographical high-risk areas are those prone to natural disasters and areas lacking water and sewage infrastructure. Southeast Asia disproportionally experiences a great burden of disease due to these factors [88]. Overall, the per capita mortality rate from vector borne diseases is exponentially greater in developing nations than in developed regions.

There is increasing incidence of dengue incidence in older age groups, and this age shift has been reported in Singapore, Indonesia, Bangladesh and Thailand [24, 25]. Thailand, cases of dengue in small infants as young as 1-2 months and in adults have been reported with increasing frequency [26]. During the first known outbreak in Nepal the majority of the cases occurred between the age of 16 and 45 years [27]. The first recorded outbreak in Bangladesh affected the age group of 18-33 years were the most affected [28]. Sri Lanka with chronological overview shows that modal age group affected by dengue has shifted from less than 15 years of age to 15-34 years of age. It has been hypothesized that the time interval between two sequential infections could be the reason to explain this phenomenon [29, 30]. There are many studies from South-East Asia region that suggest higher ratio of males than females in dengue hospitalized and only few studies suggest no difference in sexes [24, 26, 28]. However, almost all of these studies were hospital-based suggesting they represent those who had access healthcare rather than the infected population [29]. Gender bias is still abundant in many countries and health-seeking behavior is linked to this issue. Further research into determining the sex differences both in infection and severity of the disease is needed to understand the biological and cultural factors that drive disease pattern in communities.

4. Objective

Explore the potential for cooperative health management policy to effectively combat the eminent threat of dengue epidemics due to climate change. In order to measure and evaluate past interventions and current health management system responses, a review of dengue literature was performed. Along with reporting successful and non-successful interventions, insight into response and treatment options available for dengue outbreaks in Asia was also assessed. All evaluations were performed with the intention of highlighting areas of health management in critical need of change to attain progress in the battle against vector-transmitted disease in Asia.

5. Methodology

A systematic review of dengue history, transmission, prevention, diagnosis, treatment, control, surveillance, response, intervention outcomes and vaccine development was performed. The purpose was to explore the potential complex causal links of effective health management strategies to combat the occurrence of dengue pandemics due to global climate change. Through the use of evidence-based literature the following paper will discuss current challenges of dengue prevention, transmission, control and vaccine development; successful and unsuccessful interventions in endemic areas, future predictions of dengue endemic areas due to climate change, and future role of health management policies globally. The research issues we address in this paper include prior intervention methods and their effectiveness, treatments, and implications on health management policies. This paper is divided into subsections with the purpose of addressing each of the research questions. A variety of intervention methods including some unconventional approaches are explained. The treatment subsection brings to light the lack of treatments available. Implications of health management and policy examine the methods of surveillance, existing infrastructure, potential sustainable approaches, and technological developments. Through the conclusion section we provide a summation and identify gaps in current public health management approaches. Although data from other sources has been used the majority of the articles focus on responses in Southeast Asia. This paper is limited to a public health management approach rather than a site management or medical management approach

6. Interventions

When assessing the dengue vector control methods in Asia the predominant types included chemical, environmental, and biological. Most interventions focused on evaluating their effectiveness based on reduction of adult vector population rather than decreased incidence of disease. Although adult vector control reduces the mosquito populations, it often does not appear to reduce the rate of dengue infections. Vector control must also be continually maintained which can cause imposition to the human population and additional costs to governments. Chemical means of vector control seem to have a better effect, when compared to other methods, for control of outbreak situations. Insecticide treated netting (ITN), or curtains, seem to be less sustainable predominantly due to non-use or improper use of ITN by indigenous populations. Bed nets used while sleeping, provide some protection but are not as effective against dengue vectors like they are in malaria; this is because the mosquitoes that transmit the dengue virus often bite during the day rather than at night. Insecticide resistance to chemical means of vector control is a problematic issue that has arisen and must be factored into any future chemical campaigns to control vector populations. Dengue is believed to be a primarily urban disease as the vectors are well adapted to human habitation. The urbanization of South East Asia that started after World War II for economic purpose has led to population growth that contributes to the increase of susceptible hosts. However, dengue has spread into rural areas from where it had not been reported before. During the first half of the 21st century, piped water supply was restricted to urban towns, and now that supply system has been introduced into rural areas, water storage practices have changed. Modern transport system has also connected the rural areas better, and, finally, solid waste disposal also became a consequence from all this development. These are most cited reasons for rural dengue spread [30, 31]. In Singapore, successful vector control programs have brought down dengue incidence between 1974 and 1985. However, there was a major resurgence of dengue with more adult cases being reported. Serological studies indicated changes in the transmission sites and that the transmission was occurring in work sites rather than in residential houses [32].

Resistance to insecticides, specifically dichlorodiphenyltrichlorethane (DDT), presents a significant challenge to the control of dengue vectors. DDT was first introduced during World War II to protect troops and control vector- borne disease, such as malaria. After World War II, the indiscriminant agricultural use of DDT greatly increased vector resistance. The World Health Organization launched a program to eradicate malaria in 1955. This program, based partially on the use of DDT was initially successful; however, the success was not sustained in lower socioeconomic areas. Today indoor residual spraying (IRS) is used to control vector populations [33]. IRS is the application of DDT to the internal walls of domiciles to repel or eliminate mosquitos. This method is effective, long lasting, and reduces both DDT resistances in vector populations as well as diminishes environmental destruction due to DDT contamination [34].

Health education to control dengue ensures that community members understand the process of dengue infection and the critical behaviors that need to be altered to prevent transmission and decrease the incidence of morbidity and mortality.

Interventions with a primary focus on behavior modification, through educational means, seem to have better, long lasting effects on the incidence of dengue. Educational campaigns involving the community are well received and sustainable. The cost is comparatively low compared to vector control measures. These programs allow for community involvement and ownership, which are the proven foundation to any successful intervention. Appointment of a community leader, with involvement from inception through the intervention, compared with communities without involvement prior to commencement of the intervention had better reduction of dengue vectors and dengue infection rates [35]. The most highly involved communities reported the most intervention success [36, 37]. Requiring the involved communities to take and maintain ownership of the interventions seems to play a significant role in intervention effectiveness [38, 39]. Additional benefits to high levels of community involvement included increased community efficacy, community pride, and an overall increase in well being [36].

Educational programs delivered through schools seemed to have the greatest impact on behavioral changes to reduce vector populations [35, 39, 40, 41, 42]. These interventions suggest educational programs delivered through schools are more effective than other methods of distributing educational information. In Colima, Mexico a study highlighted the effectiveness of a combined approach with a focus on uninterrupted health education to reduce the breeding sites of vectors [43]. The aforementioned study demonstrated community targeted health education combined with larvicide treatment had a greater impact on decreasing mosquito habitats than larvicide treatment alone. [43] This combined approach is not universally accepted. (Some argue that too much variation occurs between the acquisition of knowledge and implantation [44, 45]. Individuals with sound comprehension of preventive measures were most often successful in incorporating new behaviors to prevent dengue disease and transmission [50]. It is important to understand that in cultures where the indigenous people lacked sufficient understanding of disease transmission, changes to their personal and household behaviors were met with resistance. Their resistance stemmed from a belief that vector control should be a governmental responsibility rather than a personal responsibility [52, 52]. Education programs based in schools enhance community education programs because of the transference of information and utility from classrooms to domicile. A main factor for the success of school based education programs stems from the fact that dengue predominantly affects children; therefore, education directed at the young population can help maintain changes in attitudes and behaviors [53]. In Thailand, [54, 55], school based education programs have demonstrated children's increase in understanding and prevention of dengue. Although knowledge of mosquitos and habitat reduction methods are beneficial, they must be incorporated into a health belief and behavioral change model to ensure success. The incorporation of behavioral change models to introduce educational information is pivotal to community acceptance and participation [56]. Current gaps in research insufficiently explain the best mode of delivery and most effective length of continuous education program. Educational programs' variance is dependent upon adequate funding, convenient health care centers, human capacity, political involvement, and availability of additional resources.

In Cambodia, the National Dengue Control Program provides dengue education in the school system and at local health centers [52]. Although these programs can be effective they are not given financial priority nor are they routinely evaluated for effectiveness. Materials provided for educational purposes can be complicated and therefore misunderstood. The individuals tasked to oversee the distribution of educational material are teachers and health care workers [52]. These workers are often inadequately trained and lack guidelines that recommend practical and effective methods of preventing vector bites. Insufficient funding for new and updated educational materials leads to a culture of familiarity and lapse into old behaviors and habits that propagate dengue infections. Community involvement in the control and prevention of dengue is essential, but will not be substantially effective until proper resources are consistently allocated [52].

Some of the environmental interventions discussed in this article include the use of natural predators as vector control. Dragonfly larvae used in an experiment to reduce the abundance of *A. aegypti* mosquitos, in Myanmar, showed positive results [57]. Virtually all A. *aegypti* *larvae* disappeared immediately after two dragonflies were placed in each container, and the density of adult mosquitos declined within six weeks [57]. The use of Copepods, natural mosquito larvae predators, in an intervention in Viet Nam proved to be inexpensive and community- accepted [58]. Environmental interventions are best suited for large communal water storage containers. The use of predators may be useful in reducing vector populations, particularly where communities lack water and sewage infrastructure. Global warming is said to affect the disease pattern, and it is essential for epidemiologists to understand such patterns in relation to biodiversity. Such an approach can have a dramatic impact on the public health strategies for disease prevention and control. Climate change may have variable effects on different diseases; some diseases may be sensitive to climatic changes, while others may be less responsive [59]. Climate change may actually expand the range of vector borne diseases from the tropical zone, where the species diversity of hosts is comparatively high in contrast to the temperate climatic zone, where species diversity is very low [60, 61]. It is too early to predict the impact of biodiversity and global warming on the propagation of vector borne disease as the vector behavior and transmission mechanisms of the host differ [62]. It is also necessary to initiate innovative research and systematic monitoring programs to obtain first hand information about the patterns of disease occurrence and relate it with biodiversity.

Biodiversity plays an important role in the transmission of diseases. However, the mechanism by which the biodiversity disease relationship is controlled is still ambiguous, as biodiversity and disease pattern show varied degrees of complexities, which need to be, addressed in future studies. Extensive studies on biodiversity–disease relationships in different ecological zones would be helpful in order to demystify the associations with this relationship. The task is not easy for ecologists as the dynamic nature of ecosystems poses difficulties in understanding various eco-based relationships. The need for increased precision in estimates presents an opportunity for investment in research on the social implications of climate change.

7. Immunizations

Currently no vaccine exists to protect against dengue. Specific challenges in vaccine development are due to three major factors. The first difficulty arises from the fact that dengue has four distinct serotypes each with the ability to cause disease. The second and more challenging obstacle is each infection increases an individual's risk of contracting a more severe strain of dengue. Therefore an effective vaccine must protect against all serotypes simultaneously. Lastly, there are no known animal hosts for dengue. Without an animal host, the only viable candidates for vaccine trials are human beings themselves. Testing the effectiveness of a trial vaccine poses serious ethical issues.

8. Implications on health management policy

Increased burning of fossil fuels by the world's developed nations and the continued course of industrialization and development are attributed with great impacts to the world's climate.

Developing nations will face an unequal burden of disease caused by climate change. Individuals in impoverished areas have enormous morbidity and mortality rates in relation to infectious diseases when compared with developed nations [88]. More concretely, both climate change and disease affect human vulnerability. In addition to the known factors of dengue, such as variation in seasonal weather, vector control programs, and socioeconomic status, climate change is extremely likely to influence current vector-borne disease epidemiology. While the effects could manifest in several ways ranging from, an increase in short term epidemics to a gradual change in long term disease tendencies. Currently there are limited amounts of published articles that provide information containing predictions. There is currently a dearth of substantiated information regarding the exact percentage of climate change influenced infectious disease. This can prove challenging to making new public health policies [18]. Clear indications of climate change on dengue, will be easier to detect than overall climate change, due to the slow rate of transformation. Climate change variability will depend on the level of health infrastructure in the affected areas. The cost and efficacy of prevention and potential cures or vaccines will be essential to disease management.

Making headway in the fight against vector-transmitted diseases ideally will incorporate a multidisciplinary approach. Working together with mosquito experts to understand mosquito attraction and control vector populations, future development that considers ecological balance and mitigates human impact on the environment, unified and structured rapid disease identification surveillance reporting and treatment of diseases, well-funded and continually evolving community education programs are all vital parts of a holistic approach.

High-risk populations for contraction of the more serious forms of dengue, dengue hemorrhagic fever and dengue shock syndrome, are individuals who have recently been infected with a less severe stain of dengue. Children in impoverished areas are at particularly elevated risk. They often become infected early with less severe stains of dengue, which puts them at a much higher risk of contracting a more severe type of dengue and thus more likely to die. Little to no research has been completed to assess the ability to transmit the dengue through breast milk. This could potentially shed new light on transmission risk factors.

Surveillance of disease is one of the most critical factors for assessing and responding to disease outbreaks. Once surveillance indicates an emerging infectious disease, treatment, containment, and prevention of new cases becomes the focus of effective health management. The existing surveillance systems in Asia are woefully inadequate to address the urgency of dengue. Lack of emerging disease surveillance, in Asia, must be given greater priority. The use of surveillance to forecast the risk of vector borne disease more accurately could greatly alter the impact of emerging disease. Traditional health management resources are insufficiently funded; focused efforts to develop more effective, and more accurate tools could greatly aid early detection of increased infection rates.

Strong health systems are also important to maintain. Dengue outbreaks can be worsened when health systems are not strong enough to adequately respond to the increased demands of epidemics. Viruses are continually evolving to outwit control measures. Public health and health systems must be ever vigilant in maintaining set priorities to tackle infectious diseases, such as dengue. Training of community- based individuals in assessing; treating, reporting,

http://dx.doi.org/10.5772/59983

and containing outbreaks of dengue are of great importance. There is an imperative need for point of care testing. Many areas of Asia with endemic dengue lack access to proper laboratory testing. Even in the presence of laboratory facilities testing for dengue can be time consuming. Point of care (POC) testing would allow health care workers in the communities to rapidly assess and accurately diagnose dengue infections. One of the major challenges to preventing the spread of dengue infections is the amount of time needed to confirm the presence of antibodies in the host system; however, with POC testing this could be significantly mitigated.

The need for sustainable development in sanitation and water availability is pivotal to alleviating the burden of disease in Asia. The establishment of a consistent water supply to homes would decrease the need for water storage and thus decrease available breeding sites for vectors, bacteria, and other pathogens. The WHO conducted a cost benefit analysis of establishing such systems in developing countries. The outcome of the analysis discussed the financial gain that could be achieved. The report suggests a minimal return of 3 to 1 for each dollar invested, and up to thirty-four times the return on investment [63]. This would also directly reduce the burden of various diseases and drastically reduce the need for economic funding to combat preventable diseases. Although exact funding estimates are variable depending on regions, the application of new ideas or innovations to tackling the engineering obstacles could prove financially profitable [63]. In addition to potential profitability, establishing or improving sanitation and water supply could reduce the average days lost due to illness. There would also be a decrease in money spent by patients seeking treatment. The benefits to improving and establishing these systems would behoove nations globally. The increase in production of developing countries coupled with more consistent attendance in schools would also allow these countries to establish and maintain ownership of high health management improvements at a cost significantly less than the current burden of disease [63].

Public health principals are rooted in the idea of community involvement. This involvement has been proven effective for sustainable interventions. Communities that do not understand, support, or have a clear understanding of the importance of the intervention undermine intervention success. Community health and well-being are multifactorial and equally affect individuals quality of life. Community based changes should be made to the current system with the intention of improving the health of the entire community and should be evidence based. Approaching these changes from a community level and paying acute attention all aspects of the social, political, and economic factors of each community in an effort to reduce health disparities [89].This is important to eliminate or reduce factors that contribute to health problems or introduce new elements that promote better health.

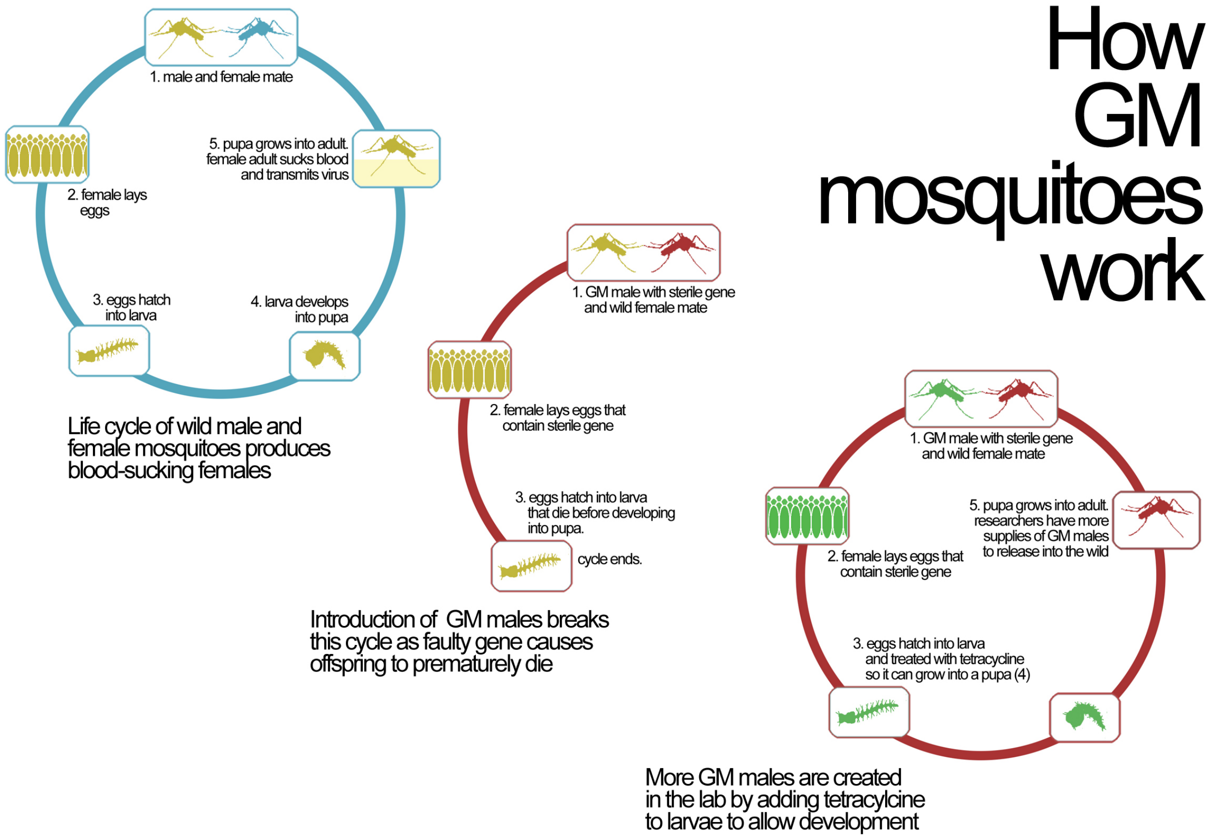
Mosquitos can fly distances equivalent to about thirty miles; this includes open ocean distances, like those found between islands and mainland. They can smell humans from a distance of fifty yards. Mosquito eradication would significantly decrease the global burden of disease;, however the magnitude and complexity of such a project would not only be impractical but potentially have unintended consequences on global ecology. Scientists are however, employing innovative techniques to battle vector transmitted diseases, and some of the most groundbreaking processes can be found in the fight against malaria. Malaria research is developing new ways to combat vector populations: genetically altered mosquitos, mosquito attraction and repulsion factors, the use of animals to detect mosquito breeding sites, and human pharmaceutical interventions for exterminating adult mosquitos.

There are hundreds of scientists whose entire lives and careers have been devoted to working on the problems caused by mosquitoes. They follow their breeding habits, study them to understanding their sense of smell, and decipherer their DNA. Bart Knols, a malariologist, is a leader in the fight against mosquito-transmitted disease. Although insecticides are making a comeback, new modern and radical versions are in the forefront of this battle. Genetically altered mosquitos offer a potential middle ground to complete mosquito eradication. The normal process inside mosquitos involves the release of a repressor chemical to prevent protein (tTA) from binding to the complementary site [64]. Genetic modification alters this process by removing the repressor and allowing the tTA to bind to the tetO-binding site. This binding process triggers more tTA proteins to be released and bond to tetO creating a continuous cycle [64]. The tTA protein damages the normal mosquito cells and causes larvae to die [64]. The following image illustrates the aforementioned process. This genetic alteration does not allow the larvae to survive to adulthood. Male and female mosquito genes are necessary for successful breeding of genetically altered offspring, but only male mosquitoes are released after the modification process is complete. Release of only the male mosquitos is done to prevent any genetically altered mosquitoes from biting humans, thereby eliminating the potential of genetically altered genes being transferred to humans. Careful consideration has been given to ethical and safety concerns where genetic modification techniques are applied. Advocates for genetically modified mosquitos argue that mosquito transmitted disease could be drastically lowered with very little disruption in the ecology. Others have suggested that the so-called Asian tiger mosquito, which also carries dengue, could fill the vacuum left by the Aedes aegypti.

Mosquito traps are another potential low cost high impact innovation that may impact the number of dengue related illnesses. Traps specifically designed for this purpose have been developed with a variety of users in mind: researcher, private consumers, and commercial consumers. Through a combination of light and dark contrasting color combinations these traps visual simulate objects that naturally attract mosquitos. The traps also are made with chemical compounds meant give off an odor similar to human skin. Some traps additionally have CO2, which is another attractant for mosquitos. These traps reduce adult mosquito populations without the need for insecticides or pesticides [65].

Smartphones may help increase the ability to halt outbreaks of dengue fever. Mobile phones are increasingly being used across the developing world to collect data and improve health outcomes. Mobile phones have penetrated the majority of markets worldwide and South East Asia is one of the mobile phones fastest growing markets.

The potential of integrated mobile services could better serve rural communities by providing the ability to communicate health related information. Rural communities tend to face unnecessary health related hardships that could be greatly mitigated with mobile access to health experts and necessary information services. Mobile connectedness would also allow for more accurate assessments of the prevalence of diseases [87]. A range of educational services could be provided via mobile phones for health education in remote villages and communities.



https://oneinsevenpeople.wordpress.com/tag/dengue/

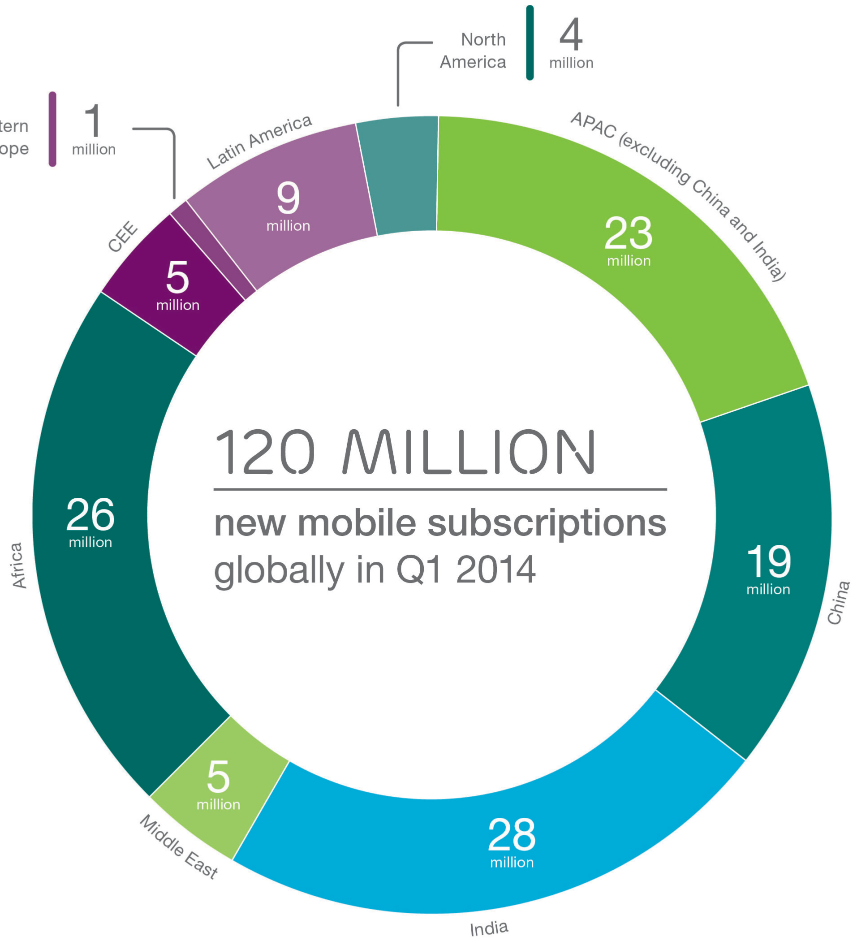
Figure 7. How GM mosquitos work

Mobile phone can be used to collect and analyze data regarding disease outbreaks faster, which would allow for faster response time and containment. This is particularly important for communities that have been displaced due to a natural disasters or conflict.

In Sri Lanka in a brief experiment morning and evening newspapers were printed using ink infused with citronella, a natural insect repellent. The experiment began by handing out newspapers on World Health Day and although no long lasting effects were expected. This type of approach may be more cost effective than other approaches and may serve as a bridge while waiting for an effective vaccine to be developed. Another possible use of such a low-tech approach may allow for dissemination of health related educational pamphlets or newspapers treated with natural insect repellant [66].

9. Conclusion

The first step in effective dengue prevention and control should be recognizing it as a priority and understanding its characteristics.[67] Factors that may have contributed to rapid changing epidemiology of dengue in South East Asia region are the challenges that need to be addressed



http://www.ericsson.com/news/1790097

Figure 8. Ericsson Mobile

in designing operational research and implementation strategies. Operational research is needed to answer research questions on how the efficacy, cost-effectiveness, sustainability and scaling-up of existing and promising new control methods can be enhanced. Complementary to basic research, operational and implementation research are important in achieving progress. Dengue is a rising threat globally and requires actions of prevention and control in an urgent manner. Some of the major factors influencing changes in dengue epidemiology include: viral subtypes with increased virulence, lack of information on vector ecology in microclimatic conditions, time interval in sequential infection. Greater resources and efforts will be essential to containing the expected changes in disease epidemiology. Climate variability has the potential to produce multiple disease epidemics simultaneously. Climate change has extensive consequences that reach well beyond health concerns. Human health and survival is contingent upon the effects of climate change. Future health policies are related to climate change and therefore policy changes for both should be interwoven. The complex relationship of socioeconomic status, climate changes and the proliferation of infectious disease like dengue should be addressed as a global issue. Climate change is expected to affect vector breeding sites and global dissemination in addition to human immunology, migration, and behavior. Impoverished areas have heightened environmental risk and decreased resources to prevent or manage dengue infection [88]. Community based interventions employing education and natural predators may be of particular use in rural and urban areas. However for long lasting declines in infectious disease major infrastructure must be undertaken. Changes in water security and wastewater are integral for public health programs to wholly address the propagation of dengue [88]. Most of the structural improvements could reduce the incidence of other infectious diseases.

Resources and knowledge must be harnessed at a community level through integrated programs. Having aid workers trained in effective responses and prevention for dengue infections is paramount and will make a substantial contribution toward reducing dengue related illness. Much needed behavior changes can only come about by empowering communities with critical knowledge concerning hygiene, sanitation, and the environment. Funding and continual training needs to be given priority this will allow community health workers to identify and treat suspected dengue cases. Integration of community needs and aspirations with overall health outcomes will improve the overall community-based surveillance.

Economic growth opportunities, of Asian countries, can be bolstered if endemic dengue infections can be tackled, treated, and effectively managed. Opportunities exist for stakeholders and financial investors to better utilize their contributions by investing in holistic sustainable and innovative health management policies and public health practices. Equilibrium needs to be reached between communities, sustainability, infrastructure, technological advances, ecofriendly approaches, and effective solutions. Educational and community based programs should be a central focus on all future dengue control and prevention measures. The most effective methods of educational programs were those based out of the primary schools within communities. A means of rapid on site testing should be utilized for detection and diagnosis of dengue. Once dengue is diagnosed in a community, better reporting and surveillance must occur to prevent epidemics. Addressing the lack of accurate surveillance systems in Asia could significantly impact response time and limit the occurrence of epidemic episodes of dengue. Future innovations focused on natural deterrents to target mosquitos may have useable implications for other vector transmitted diseases. These issues are important to the field of public health and health management systems further research, analysis, and monitoring is warranted to fully understand the effects of interconnected, sustainable, innovative ways to reduce the global burden of dengue infections.

Pharmaceuticals designed to treat dengue have made progress and could potentially develop more rapidly due to the enormity of dengue's impact on a global scale. The continued increase of vector-transmitted diseases might make the drug markets for a dengue cure economically viable. Morbidity issues as they relate to economies can be drastically affected by sudden epidemics; here is where antivirals could potentially have a complementary role to vaccines for dengue. The challenges that remain with dengue pharmaceuticals are due to the need for human clinical trials.

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References

[1] Impact of Dengue. *WHO*. Retrieved May 17, 2014, from http://www.who.int/csr/disease/dengue/impact/en/

[2] World Health Organization, Retrieved May 16, 2014 from http://www.who.int/topics/dengue/en/

[3] Halstead, S. B. "Dengue: Overview and History." In Dengue: Tropical Medicine: Science and Practice, vol. 5, eds. G. Pasvol & S. L. Hoffman (London: Imperial College Press, 2008): 1–28.

[4] Dengue Clinical Lab. (2014, May 16). *Centers for Disease Control and Prevention*. Retrieved May 20, 2014, from http://www.cdc.gov/dengue/, http://www.cdc.gov/dengue/clinicalLab/clinical.html, http://www.cdc.gov/dengue/clinicalLab/caseDef.html

[5] Researchers identify fifth dengue subtype. *CIDRAP*. Retrieved May 15, 2014, from http://www.cidrap.umn.edu/news-perspective/2013/10/researchers-identify-fifth-dengue-subtype

[6] Dash, A., Bhatia, R., Sunyoto, T., & Mourya, D. (2013). Emerging and Reemerging arboviral diseases in Southeast Asia. *Journal of vector borne disease*, *50*(June 2013), 77-84.

[7] Ooi, E., & Gubler, D. J. (2009). Dengue in Southeast Asia: epidemiological characteristics and strategic challenges in disease prevention. *Cadernos de Saude Publica*, *25*, S115-S124.

[8] Suaya JA, Shepard DS, Siqueira JB, Martelli CT, Lum LCS, et al. (2009) Cost of dengue cases in eight countries in the Americas and Asia: A prospective study. Am J Trop Med Hyg 80: 846–855

[9] Beaute J, Vong S (2010) Cost and disease burden of dengue in Cambodia. BMC Public Health 10: 1–6

[10] Lim LH, Vasan SS, Birgelen L, Murtola TM, Gong H-F, et al. (2010) Immediate cost of dengue to Malaysia and Thailand: An estimate. Dengue Bulletin 34: 65–76

[11] Undurraga EA, Halasa YA, Shepard DS (2012) Use of expansion factors to estimate the burden of dengue in Southeast Asia: a systematic analysis. PloS Negl Trop Dis 7: e2056

[12] Undurraga EA, Halasa YA, Shepard DS (2011) Expansion factors: a key step in estimating dengue burden and costs in Southeast Asia. Am J Trop Med Hyg 85: 318.

[13] Therawiwat M, Fungladda W, Kaewkungwal J, Imamee N, Steckler A. Community-based approach for prevention and control of dengue hemorrhagic fever in Kanchanaburi Province, Thailand. *The Southeast Asian Journal Of Tropical Medicine And Public Health*. 2005;36(6):1439-1449.

[14] Hales (2002); J. A. Patz, D. Campbell-Lendrum, T Holloway, et al., "Impact of regional climate change on human health, " *Nature* (2005), pp. 310-317.

[15] Colón-González (2013); M. Hagenlocher, E. Delmelle, I. Casas et al., "Assessing socio-economic vulnerability to dengue fever in Cali, Colombia: Statistical vs expert-based modeling, " *International Journal of Health Geographics* 12/1 (2013), p. 36; M. Johansson, D. Cummings, and G. Glass, "PLOS medicine: Multiyear climate variability and Dengue—El Niño Southern Oscillation, weather, and dengue incidence in Puerto Rico, Mexico, and Thailand: A longitudinal data analysis, " *PLoS Medicine* 6/11 (2009), pp. 1-9.; M. A. Johansson, F. Dominici, and G. E. Glass. "Local and global effects of climate on dengue transmission in Puerto Rico, " *PLoS Neglected Tropical Diseases* (2009), pp. 1-5.

[16] McMichael (2006); C. P. Diman, and W. Tahir, "Potential of stagnant water due to dam flooding, " *Innovation Management and Technology Research, 2012 International Conference* (2012), pp. 609-612.; J. T. Watson, M. Gayer, and M. A. Connolly, "Epidemics after natural disasters, " *Emerging Infectious Diseases* (2007), pp. 1-5.

[17] Centers for Disease Control and Prevention, "Emergency mosquito control associated with Hurricane Andrew–Florida and Louisiana, 1992, " *Morbidity Mortality Weekly Report*. (1993), pp. 240-242.

[18] R. S. Nasci, and C. G. Moore, "Vector-borne disease surveillance and natural disasters, " *Emerging Infectious Disease* (1998), pp. 333-334.

[19] Millennium Ecosystem Assessment Report on Ecosystems and human well-being. Vol 5 (2005).

[20] McMichael., pp. 401-413.

[21] Rodhain F, Rosen L. Mosquito vectors and dengue virus-vector relationships. In: Gubler DJ, Kuno G, editors. Dengue and Dengue Hemorrhagic Fever. New York: CAB International; 1997. p. 45-60.

[22] Gubler DJ. The changing epidemiology of yellow fever and dengue, 1900 to 2003: Full circle? Comp Immunol Microbiol Infect Dis 2004;27:319-30.

[23] Nimmanutya S. Dengue haemorrhagic fever: Current issues and future research. Asia-Oceanian. J Pediatr Child Health 2002;1:1-22.

[24] Kalayanarooj S, Nimmannitya S. Guidelines for dengue hemorrhagic fever case management. Bangkok: Bangkok Medical Publisher; 2004.

[25] Chareonsook O, Foy HM, Teeraratkul A, Silarug N. Changing epidemiology of dengue haemorrhagic fever in Thailand. Epidemiol Infect 1999;122:161-6.

[26] SedhainA, Adhikari S, Bhattarai GR, Regmi S, Subedee LR, Chaudhary SK, et al. A clinicoradiological and laboratory analysis of dengue cases during an outbreak in central Nepal in 2010. Dengue Bull 2012;36:134-48.

[27] Rahman M, Rahman K, Siddque AK, Shoma S, Kamal AH, Ali KS, et al. First outbreak of dengue hemorrhagic fever in Bangladesh. Emerg Infect Dis 2002;8:738-40.

[28] Gupta E, Dar L, Kapoor G, Broor S. The changing epidemiology of dengue in Delhi, India. Virol J 2006;3:92.

[29] Guha-Sapir D, Schimmer B. Dengue fever: New paradigms for a changing epidemiology. Emerg Themes Epidemiol 2005;2:1.

[30] Ooi EE. Changing pattern of dengue transmission in Singapore. Dengue Bull 2001;25:40-4.

[31] Zargar, U.R., 2011. Proceed with caution on disease eradication. Science and Development Network. http://www.scidev.net/en/ health/health-policy/editor-letters/proceed-with-caution-on-dis- easeeradication-1.html (accessed 10/12/2014).

[32] Dobson, A., Carper, R., 1992. Global Warming and Potential Changes in Host–Parasite and Disease–Vector Relationship. Yale University Press, Connecticut, pp. 201–217.

[33] Harvell, C.D., Mitchell, C.E., Ward, J.R., Altizer, S., Dobson, A.P., et al, 2002. Ecology – climate warming and disease risks for terrestrial and marine biota. Science 296, 2158–2162.

[34] Miller, E., Huppert, A., 2013. The effects of host diversity on vector- borne disease: the conditions under which diversity will amplify or dilute the disease risk. PLoS ONE 8, e80279.

[35] Ooi EE, Gubler DJ. Dengue in South East Asia: Epidemiological

[36] World Health Organization (WHO) Global Strategy for Dengue Prevention and Control, 2012–2020. Geneva: WHO Press; 2012.

[37] WHO Regional Office for South-East Asia Comprehensive Guidelines for Prevention and Control of Dengue and Dengue Haemorrhagic Fever, Revised and Expanded Edition. New Delhi: World Health Organisation South East Asia Regional Office; 2011.

[38] Gubler DJ. Epidemic dengue/dengue hemorrhagic fever as a public health, social and economic problem in the 21st century. Trend Microbiol. 2002;10(2):100–103. [PubMed]

[39] Report of the Third Expert Group Meeting on DDT, UNEP/POPS/DDT-EG.3/3, Stockholm Convention on Persistent Organic Pollutants, November 12, 2010. http://chm.pops.int/Programmes/DDT/Meetings/DDTEG32010/tabid/1108/mctl/ViewDetails/EventModID/1421/EventID/116/xmid/4037/language/en-US/Default.aspx

[40] "Is DDT still effective and needed in malaria control?". Malaria Foundation International. Archived from the original on November 18, 2010. Retrieved March 15, 2006. http://www.webcitation.org/5uKxTzvxt

[41] Nam VS, Yen NT, Kay B, Marten GG, Reid JW. Eradication of Aedes aegypti from a village in Vietnam using copepods and community participation. *The American Journal of Tropical Medicine and Hygiene.* 1998;59:657-660.

[42] Crabtree SA, Wong CM, Mas'ud F. Community participatory approaches to Dengue prevention in Sarawak, Malaysia. *Human Organization*. 2001;60(3):281-287.

[43] Suwanbamrung C, Dumpan A, Thammapalo S, Sumrongtong R, Phedkeang P. A model of community capacity building for sustainable dengue problem solution in Southern Thailand. *Health.* 2011;3(9):584-601.

[44] Nam VS, Nguyen TY, Tran VP, Truong UN, Le QM, Le VL, et al. Elimination of dengue by community programs using Mesocyclops(Copepoda) against Aedes aegypti in central Vietnam. *The American Journal Of Tropical Medicine And Hygiene*. 2005;72(1): 67-73.

[45] Kay B, Nam VS. New strategy against Aedes aegypti in Vietnam. *Lancet*. 2005; 365(9459):613- 617.

[46] Phatumachinda B, Phanurai P, Samutrapongse W, Chareonsook OA. Studies on community participation in Aedes aegypti control at Phanus Nikhom district, Chonburi Province, Thailand. *Mosquito-Borne Diseases Bulletin*. 1985;2:1-8.

[47] Suroso H, Suroso T. Aedes aegypti, control through source reduction by community efforts in Pekalongan, Indonesia. *Mosquito-Borne Diseases Bulletin*. 1990;7:59-62.

[48] Swaddiwudhipong W, Chaovakiratipong C, Nguntra P, Koonchote S, Khumklam P, Lerdlukanavonge P. Effect of health education on community participation in control of dengue hemorrhagic fever in an urban area of Thailand. *The Southeast Asian Journal Of Tropical Medicine And Public Health*. 1992;23(2):200-206.

[49] Espinoza-Gomez F, Hernandez-Suarez CM, Coll-Cardenas R (2002) Educational campaign versus malathion spraying for the control of Aedes aegypti in Colima, Mexico. Journal of Epidemiology and Community Health 56(2): 148–152.

[50] Lloyd L, Winch P, Ortega-Canto J, Kendall C (1992) Results of a community based Aedes aegypti control program in Merida, Yucatan, Mexico. American Journal of Tropical Medicine and Hygiene 46: 635–642.

[51] Swaddiwudhipong W, Lerdlukanavonge P, Klumklam P, Koonchote S, Nguntra P, et al. (1992) A survey of knowledge, attitudes and practice of the prevention and control of dengue hemorrhagic fever in an urban community in Thailand. Southeast Asian Journal of Tropical Medicine and Public Health 23(2): 207–211.

[52] Rosenbaum J, Nathan M, Ragoonanansingh R, Rawlins S, Gayle C (1995) Community participation in dengue prevention and control: A survey of Health Education for Dengue Control in Cambodia PLoS Neglected Tropical Diseases | www.plosntds.org 9 2007 | Volume 1 | Issue 3 | e143 knowledge, attitudes and practices in Trinidad and Tobago. The American Society of Tropical Medicine and Hygiene 53(2): 111–117.

[53] Whiteford LM (2000) Local identify, globalization and health in Cuba and the Dominican Republic. In: Whiteford LM, Manderson L, eds. Global Health Policy, Local Realities: The fallacy of a level-playing field. Boulder, CO: Lynne Rienner Publishers. pp 57–78.

[54] Perez-Guerra CL, Seda H, Garcia-Rivera EJ, Clark GG (2005) Knowledge and attitudes in Puerto Rico concerning dengue prevention. Pan-American Journal of Public Health 17(4): 243–253.

[55] Win KT, Nang SZ, Min A (2004) Community-based assessment of dengue related knowledge among caregivers. Dengue Bulletin 28: 189–195.

[56] Serufo JC, Souza AM, Avares VA (1993) Dengue in the South-Eastern Region of Brazil – Historical analysis and epidemiology. Revista de Saude Publica 27(3): 157–167.

[57] Wangroongsarb Y (1997) Dengue control in Thailand. Public Health 14: 32–38.

[58] Chau T, Fortin J, Khun S, Nguyen H (2000) Practise what is preached? Dengue health education in Muan District, Khon Kaen Province, Thailand: Primary school children's knowledge and reported practice, in Australian Centre for International & Tropical Health and Nutrition. Brisbane: The University of Queensland.

[59] Lennon J (2005) The use of health belief model in dengue health education. Dengue Bulletin 29: 217–219.

[60] Samways, M. J. (1996, May 22). Insects in the Urban Environment: Pest Pressures versus Conservation Concerns. *International Conference on Urban Pests*, pp. 129-133.

[61] Kay BH, Nam VS, Tien TV, Yen NT, Phong TV, Diep VTB, et al. Control of aedes vectors of dengue in three provinces of Vietnam by use of Mesocyclops (Copepoda) and community-based methods validated by entomologic, clinical, and serological surveillance. *The American Journal Of Tropical Medicine And Hygiene.* 2002;66(1):40-48.

[62] Costs and benefits of water and sanitation improvements at the global level (Evaluation of the). *WHO*. Retrieved May 20, 2014, from http://www.who.int/water_sanitation_health/wsh0404summary/en/

[63] Fu, G., A. A. James, D. Aw, D. Nimmo, R. S. Lees, L. Alphey, N. Jasinskiene, O. Marinotti, H. Kim Phuc, S. Scaife, H. White-Cooper, T. U. Berendonk, P. Gray, and L. Jin. "Female-specific flightless phenotype for mosquito control." *Proceedings of the National Academy of Sciences* 107.10 (2010): 4550-4554.

[64] "Mosquito Trap Product Range Helps Prevent Malaria, Dengue or Yellow Fever." *The256Com RSS*. Web. 22 July 2014. http://the256.com/mosquito-trap-product-range-helps-prevent-malaria-dengue-or-yellow-fever.html

[65] "This Sri Lankan Newspaper Repels Mosquitos While You Enjoy Reading." *Wonderful Engineering*. N.p., n.d. Web. 24 July 2014. http://wonderfulengineering.com/this-sri-lankan-newspaper-repels-mosquitos-while-you-enjoy-reading/

[66] Ang LW, Foong B, Ye T, Chow A, Chew S. Impact of 'carpet-combing' vector control operations in terminating the 2005 dengue outbreak in Singapore. *Epidemiological News Bulletin*. 2007;33(3):31-36.

[67] Beckett CG, Kosasih H, Tan R, Widjaja S, Listianingsih E, Ma'roef C, et al. Enhancing knowledge and awareness of dengue during a prospective study of dengue fever. *The Southeast Asian Journal Of Tropical Medicine And Public Health*. 2004;35(3):614-617.

[68] Butraporn P, Saelim W, Sitapura P, Tantawiwat S. Establishment of an environmental master team to control dengue haemorrhagic fever by local wisdom in Thailand. *Dengue bulletin*. 1999;23: 99-104.

[69] Eamchan P, Nisalak A, Foy HM, Chareonsook OA. Epidemiology and control of dengue virus infections in Thai villages in 1987. *The American Journal Of Tropical Medicine And Hygiene*. 1989;41(1):95-101.

[70] Hien Tran V. Application of mosquito—proof water containers in the reduction of dengue mosquito population in a dengue endemic province of Vietnam. *Asian Pacific Journal of Tropical Disease*. 2011;1(4):270-274.

[71] Igarashi A. Impact of dengue virus infection and its control. *FEMS Immunology And Medical Microbiology*. 1997;18(4):291-300.

[72] Kay BH, Tuyet Hanh TT, Le NH, Quy TM, Nam VS, Hang PVD, et al. Sustainability and cost of a community-based strategy against Aedes aegypti in northern and central Vietnam. *The American Journal Of Tropical Medicine And Hygiene*. 2010;82(5): 822-830.

[73] Kittayapong P, Yoksan S, Chansang U, Chansang C, Bhumiratana A. Suppression of dengue transmission by application of integrated vector control strategies at seropositive GIS-based foci. *The American Journal Of Tropical Medicine And Hygiene*. 2008;78(1):70-76.

[74] Madarieta SK, Salarda A, Benabaye MRS, Bacus MB, Tagle R. Use of permethrin-treated curtains for control of Aedes aegypti in the Philippines. *Dengue Bulletin*. 1999;23:51-54.

[75] Osaka K, Ha DQ, Sakakihara Y, Khiem HB, Umenai T. Control of dengue fever with active surveillance and the use of insecticidal aerosol cans. *The Southeast Asian Journal Of Tropical Medicine And Public Health*. 1999;30(3):484-488.

[76] Pengvanich V. Family leader empowerment program using participatory learning process for dengue vector control. *Journal Of The Medical Association Of Thailand = Chotmaihet Thangphaet.* 2011;94(2):235-241.

[77] Phan-Urai P, Kong-ngamsuk W, Malainual N. Field trial of Bacillus thuringiensis H-14 (Larvitab) against Aedes aegypti larvae in Amphoe Khlung, Chanthaburi Province, Thailand. *Journal of Tropical Medicine and Parasitology*. 1995;16:35-41.

[78] Suaya JA, Shepard DS, Caram M, Hoyer S, Nathan MB. Cost-effectiveness of annual targeted larviciding campaigns in Cambodia against the dengue vector Aedes aegypti. *Tropical Medicine and International Health*. 2007;12(9):1026-1036.

[79] Tan C-C. SARS in Singapore--key lessons from an epidemic. *Annals Of The Academy Of Medicine, Singapore.* 2006;35(5):345-349.

[80] Tun-Lin W, Lenhart A, Nam VS, Rebollar-Téllez E, Morrison AC, Barbazan P, et al. Reducing costs and operational constraints of dengue vector control by targeting productive breeding places: a multi-country non-inferiority cluster randomized trial. *Tropical Medicine & International Health: TM & IH*. 2009;14(9):1143-1153.

[81] Umniyati SR, Umayah SS. Evaluation of community-based Aedes control programme by source reduction in Perumnas Condong Catur, Yogyakarta, Indonesia. *Dengue Bulletin*. 2000;24:1-3.

[82] Van Kerkhove MD, Ly S, Guitian J, Holl D, San S, Mangtani P, et al. Changes in poultry handling behavior and poultry mortality reporting among rural Cambodians in areas affected by HPAI/H5N1. *Plos One*. 2009;4(7):e6466.

[83] Vanlerberghe V, Villegas E, Jirarojwatana S, Santana N, Trongtorkit Y, Jirarojwatana R, et al. Determinants of uptake, short-term and continued use of insecticide-treated curtains and jar covers for dengue control. *Tropical Medicine & International Health:* TM & IH. 2011;16(2):162-173

[84] Wolbachia. *FAQs*. Retrieved May 19, 2014, from http://www.eliminatedengue.com/faqs/index/type/wolbachia

[85] Oxitec Limited. *Dengue Fever Information Centre.* Retrieved July 26, 2014, from Oxitec: http://www.oxitec.com/our-targets/dengue-fever-and-chikungunya/

[86] United States Census Bureau. Retrieved July 20, 2014 from http://www.census.gov/popclock/

[87] Best Practices for supporting internet and development initiatives. http://www.fao.org/docrep/W6840E/w6840e06.htm

[88] United Nations. Housing the poor in Asian cities, Urbanization: The role the poor play in urban development. http://www.citiesalliance.org/sites/citiesalliance.org/files/QG1-Urbanization%5B2%5D.pdf

[89] CDC http://www.cdc.gov/phppo/pce/part1.htm