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Research Paper

IMPACT OF CLIMATE CHANGE ON INCIDENCE OF DENGUE FEVER

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ABSTRACT

This paper deals with impact of climate change on incidence of dengue fever. It outlines the symptoms of dengue fever and concentration of dengue cases in India. This paper makes a special note on temperature and vector ecology, climate, habitat and vector ecology, precipitation and vector ecology, temperature and mosquitoes breeding cycle, disease occurrence due to climate change and dengue fever control measures. This paper depicts the interstate disparity in the incidence of dengue cases and dengue deaths in India. This paper concludes with some interesting findings along with policy suggestions.

KEYWORDS: *mosquitoes, dengue fever, climate change, temperature, population growth, urbanization*

INTRODUCTION

Dengue viruses are transmitted by Aedes mosquitoes, which are highly sensitive to environmental conditions. Temperature, precipitation, and humidity are critical to mosquito survival, reproduction, and development and can influence mosquito presence and abundance. Additionally, higher temperatures reduce the time required for the virus to replicate and disseminate in the mosquito. This process, referred to as the “extrinsic incubation period”, must occur before the virus can reach the mosquitoes salivary glands and be transmitted to humans. If the mosquito becomes infectious faster because temperatures are warmer, it has a greater chance of infecting a human before it dies.

Globally, the reported incidence of dengue has been increasing. Although climate may play a role in changing dengue incidence and distribution, it is one of many factors; given its poor correlation with historical changes in incidence, its role may be minor. Other important factors potentially contributing to global changes in dengue incidence and distribution include population growth, urbanization, lack of sanitation, increased long-distance travel, ineffective mosquito control, and increased reporting capacity.

ROLE OF TEMPERATURE IN VECTOR ECOLOGY

Mosquitoes of the genus Aedes, primarily Ae. aegypti, are the vectors for dengue virus; therefore, the ecology of the virus is intrinsically tied to the ecology of these mosquitoes. As per the report by Scott et al. (2000), temperature can exert considerable influence on mosquito population dynamics. Christophers (1960), notes that egg and immature mosquito development, ovarian development, and survival at all stages of the mosquito life cycle are governed in part by temperature. In the laboratory setting, Rueda et al. (1990) found that immature Ae. Aegypti development rates generally increased with incubation temperatures to 34°C and then slowed. Survival through all developmental phases peaked at approximately 90% (27°C) with cooler temperatures being especially detrimental to survival. Tun-Lin et al. (2000) reported that Ae. aegypti egg, larvae, and pupae development rates increased at higher incubation temperatures and ceased at < 8.3°C. Tun-Lin et al. (2000) estimated the survival rates with the ideal range for survival through all phases of development (88–93%) occurring between 20–30°C. The laboratory studies discussed above yielded consistent results with little variation between trials, in the field portion of their study, It is evident from the work of Tun-Lin et al. (2000), that development rates accelerated in warmer water, but development was often slower and more variable in field trials than in their laboratory trials at comparative temperatures.

ROLE OF CLIMATE CHANGE ON VECTOR HABITAT AND ECOLOGY

Christophers (1960) notes that precipitation and temperature work interdependently: Increased temperatures accelerate evaporation rates and limit standing water as a potential habitat source for immature mosquitoes, although the eggs are resistant to desiccation over extended time periods and thus climate effects on immature vector survival are a complex balance between precipitation and evaporation. Higher rates of precipitation combined with higher temperatures also result in increased humidity. Higher humidity is associated with increased Ae. aegypti feeding activity, survival, and egg development. It is evident from the work of Nagao et al. (2003) that daily minimum temperature and an increase in precipitation from the previous month were both associated with increased larval abundances. Within water habitats, competition for space and nutrients is a key determinant of population levels. As the water in containers evaporates, the density of immature mosquitoes may increase, enhancing competition and deterring potential egg laying.

INFLUENCE OF PRECIPITATION ON VECTOR ECOLOGY

It could be noted that temperature has a direct biophysical influence on viral replication and on vector development and survival, precipitation provides essential habitat for the aquatic stages of the mosquito life cycle. Containers, common in urban environments, are often an important habitat. Southwood et al. (1972) and Hoeck et al. (2003) studied vector abundances related to climate in Tucson, Arizona, an urban area inhabited by Ae. aegypti and in close proximity to dengue virus-endemic areas, but where dengue fever does not occur, in neighborhoods near San Juan, Puerto Rico, Barrera et al. (2011) reported from their study that higher precipitation was associated with increased Ae. aegypti populations, and that man-made containers were the most important pupae habitat for producing adult mosquitoes. Intense rainfall, however, may wash out breeding sites and thus have a negative effect on vector populations. Precipitation is often required to create and maintain breeding sites and has a strong influence on vector distributions. Kolivras (2010) estimated intraannual climate-induced range changes of Ae. albopictus in Hawaii using a geographic information system (GIS), climate data, and the known habitat of the mosquito. They concluded that mosquito ranges expand during La Niña conditions (generally wetter) and decrease during El Niño conditions (generally drier).

INFLUENCE OF TEMPERATURE ON MOSQUITOES' BREEDING CYCLE

As per the report by Christophers (1960), the female mosquito's reproductive cycle is also governed by ambient temperature. At < 20°C, fertilization decreases. De Garin et al. (2000) established the fact that increased minimum temperatures resulted in accelerated oviposition cycles and egg laying. Female Ae. aegypti require a blood meal for ovarian development, and feeding behavior is also influenced by temperature. Feeding activity is limited or ceases at temperatures < 15°C and can also be limited at temperatures > 36°C. Multiplicity of feeding, that is, the taking of blood meals from multiple hosts during a single gonotrophic cycle has been associated with higher levels of dengue virus transmission Scott and Takken (2012) and Scott et al. (2000) found that higher temperatures were associated with higher incidences of multiple blood feedings in Thailand. Scott et al. (2000) note that female size was also negatively correlated with temperature and smaller females exhibited increased multiplicity of feeding in.

The effect of temperature on the ability of the mosquito to reproduce has consequences for population dynamics and range limits. There is evidence of selection of breeding containers based on temperature and sun exposure. It is evident from the work of Barrera et al. (2006) that Ae. aegypti preferred shaded containers and cooler water temperatures for egg laying in Puerto Rico. However, Wong et al. (2011) identified that containers with more sun exposure were more likely to be inhabited in Iquitos, Peru. This may be because obtaining optimal water temperature for the mosquito required heating from direct sun exposure in one location and protection from the sun in another. In both cases, however, water temperature was important for mosquito reproduction. Barrera et al. (2006) also found the presence of trees to be associated with Ae. aegypti pupal productivity; they suggested that although dense vegetation may promote growth by contributing organic material to the habitat, it can also influence water temperature and evaporation by creating shade. This highlights how land-cover and land-use characteristics can influence microclimates and, consequently, mosquito populations. Using a statistical population model with known temperature limits and ecological parameters of the mosquito, Otero et al. (2006) calculated the limits of Ae. aegypti habitat range to be along the 15°C average annual temperature isotherm. Landau and van Leeuwen (2012) note that an examination of the spatial distribution of adult Ae. aegypti with remotely sensed land use and land cover indicated that Ae. aegypti were more likely to be present in areas with structures and medium height trees than in areas with bare earth. Although there are similarities in the thermal characteristics of many of the variables associated with vector and viral development, the critical limiting values are not the same. Integrating all these variables together in one temperature-driven model can enable simulation of very complex dynamics.

IMPACT OF CLIMATE CHANGE ON DENGUE OCCURRENCE

Numerous methods of statistical analysis have been used to estimate associations between climate variables and dengue fever incidence, including cross correlations; Poisson, logistic, and multivariate regression; autoregression; and wavelet analysis. Arcari et al. 2007 and Lu et al. (2009) have been successful in identifying climate– dengue virus relationships and creating predictive models of dengue fever incidence based on climate associations. Variables that predict the intensity and timing of outbreaks include minimum, maximum, and mean temperature as well as relative humidity and wind velocity, whereas the seasonal timing of epidemics is predicted by precipitation. Often these variables are predictive at specific time lags.

In a study by Yu et al. (2011) in southern Taiwan, report that mean and maximum temperature were negatively associated with dengue fever cases, which seems counterintuitive until the generally high temperatures in this region which can often reach levels that damage mosquitoes and thus limit virus transmission > 30°C are considered. In contrast, in other regions low temperatures may be the limiting factor. Similarly, Pinto et al. (2011) did not find a high correlation between precipitation and dengue fever incidence in Singapore because rain occurs there throughout the year, and thus it is not a significant limiting factor for mosquitoes. In Taiwan, Wu et al. (2009) found relative humidity to be negatively associated with dengue fever incidence. They hypothesized that although mosquitoes generally survive longer in humid conditions, they may bite more when water-stressed, thus increasing dengue virus transmission at lower humidity. These studies highlight the multiple avenues through which climate variables can influence dengue virus transmission.

IMPACT OF CLIMATE CHANGE ON DENGUE FEVER INCIDENCE

The impact of climate change on dengue fever has also been examined. The studies conducted concerning climate, vectors, and the virus; suggest that suitable climatic conditions are required for mosquito population development and subsequent infections. It follows, therefore, that changes in climate will alter the spatial and temporal dynamics of dengue virus ecology, potentially increasing vector ranges, lengthening the duration of vector activity, and increasing the mosquito's infectious period by shortening the extrinsic incubation period. Conversely, increased temperatures in already warm locations may have negative effects on the range of virus transmission through decreased vector survival, reproduction, and immature habitat.

Jetten and Focks (1997) published one of the earliest papers connecting climate and future dengue virus transmission risk. They used a modified vectorial capacity equation to estimate the vector population required to maintain dengue virus transmission. The equation included climate dependent variables such as the early incubation period, daily mosquito mortality, mosquito size, and the length of the gonotrophic cycle. The Intergovernmental Panel on Climate Change–projected temperature increases of 2–4°C were applied to weekly-averaged data from weather stations in cities across the tropics. Jetten and Focks (1997) suggested that climate change would lead to an increase in the latitudinal and elevational extent of the disease, and a longer season of viral transmission.

Patz et al. (1998) used a similar vectorial capacity equation that was modified to estimate epidemic potential. The model used projected climate change data from a general circulation model at 250 km × 250 km resolution to project future dengue fever risk across the world, focusing on five climatologically contrasting cities. The model predicted large increases in the geographic extent of dengue fever and a longer disease season, especially in temperate regions at the fringes of the virus' range. Jetten and Focks (1997) and Patz et al. (1998) both provided a good framework for future research on climate and dengue fever risk, but estimates should be updated based on current general circulation model projections with improved resolution that are based on standardized approaches.

Hales et al. (2002), conducted an early study using logistic regression to model disease range based on the statistical association of dengue fever presence with water vapor and other climate variables. According to Hales et al. (2002), general circulation model projections and human population demographics, the authors predicted that the magnitude and distribution of dengue fever would increase and encompass a larger total population and percent of the population. Caution should be used when modeling dengue fever incidence using statistical relationships with climate variables because the statistical model is trained with present climate data that may differ greatly from projected future climate regimes. The boundaries of statistical model predictions are limited to climate variable combinations that have already been experienced, and extrapolating outside those bounds may lead to inaccuracies.

Some studies suggest that climate change will not necessarily result in significant changes in the range and incidence of dengue fever, especially in developed countries. Reiter et al. (2003) compared dengue fever incidence levels on either side of the Texas–Mexico border and concluded that although mosquito levels were similar, the risk of dengue virus transmission was far lower in Texas than in Mexico because human–vector contact was reduced due to the prevalence of well-sealed air-conditioned buildings, less outdoor exposure, and socioeconomic factors. The potential importance of socioeconomic factors should not be underestimated; clearly, these factors can have significant effects. In addition, one can recognize that both mosquitoes and dengue virus may adapt to climate change in ways we cannot currently predict. However, the literature from other disease models suggests that the magnitude of these influences may vary by the intensity and types of climatic changes that occur in a given location. As per the report by Artzy-Randrup et al. (2010), Liu et al. (2011), Randolph and Rogers (2002) and Rottschaefer et al. 2011) the magnitude of changes may occur due to direct influences on the evolution of the vector and infectious agent but may also be related to changes in viral diversity associated with increasing or decreasing levels of dengue virus transmission.

SYMPTOMS OF DENGUE FEVER

Dengue fever causes a high fever — 104 F degrees — and at least two of the following symptoms: headache, muscle, bone and joint pain, nausea, vomiting, pain behind the eyes, swollen glands and rash. Most people recover within a week or so. In some cases, symptoms worsen and can become life-threatening. Blood vessels often become damaged and leaky. And the number of clot-forming cells (platelets) in bloodstream drops. This can cause a severe form of dengue fever, called dengue hemorrhagic fever, severe dengue or dengue shock syndrome. Signs and symptoms of dengue hemorrhagic fever or severe dengue — a life-threatening emergency — include: severe abdominal pain, persistent vomiting, bleeding from gums or nose, lood in urine, stools or vomit, bleeding under the skin, which might look like bruising, difficult or rapid breathing, cold or clammy skin, fatigue and irritability or restlessness.

Table 1 presents data on the dengue cases in India since 2010. It could be noted that India reported the 28292 dengue infected persons in 2010 and it rose to 521523 by the 2017 October status. The growth of dengue cases indicates the 64.05 per cent increase during the period 2010 to 2017. It could be noted that the dengue cases incidence shows interstate disparity in India. The growth of dengue cases is highest in A& N Islands. A more than 80 per cent of the growth in dengue cases has been observed in Chattisgarh, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Meghalaya, Maharashtra, Manipur, Odisha, Sikkim, Tamil Nadu, Tripura and D&N Haveli during the period 2010 to 2017. The growth of dengue cases has become negative in Goa, Gujarat, Punjab, Delhi and Daman & Diu during the period 2010 to 2017. In absolute number a more than 20000 cases of dengue infection has been observed in Gujarat, Karnataka, Kerala, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Delhi during the period 2010 to 2017. It is clear that growth of dengue case in India is outcome of climate change and poor hygienic and health care practices among the states in India.

Table 1: Dengue Cases in India since 2010

Affected States/UTs	Dengue Cases								Total	Growth Rate
	2010	2011	2012	2013	2014	2015	2016	2017		
Andhra Pradesh	776	1209	2299	910	1262	3159	3417	2335	15367	66.77
Arunachal Pradesh	0	0	346	0	27	1933	13	5	2324	-6820.00
Assam	237	0	1058	4526	85	1076	6157	1159	14298	79.55
Bihar	510	21	872	1246	297	1771	1912	655	7284	22.14
Chattisgarh	4	313	45	83	440	384	356	106	1731	96.23
Goa	242	26	39	198	168	293	150	164	1280	-47.56
Gujarat	2568	1693	3067	6272	2320	5590	8028	2127	31665	-20.73
Haryana	866	267	768	1784	214	9921	2493	628	16941	-37.90
Himachal Pradesh	3	0	73	89	2	19	322	116	624	97.41
J & K	0	3	17	1837	1	153	79	6	2096	50.00
Jharkhand	27	36	42	161	36	102	414	531	1349	94.92
Karnataka	2285	405	3924	6408	3358	5077	6083	13016	40556	82.44
Kerala	2597	1304	4172	7938	2575	4075	7439	18727	48827	86.13
Madhya Pradesh	175	50	239	1255	2131	2108	3150	697	9805	74.89
Meghalaya	1	0	27	43	0	13	172	20	276	95.00
Maharashtra	1489	1138	2931	5610	8573	4936	6792	2948	34417	49.49
Manipur	7	220	6	9	0	52	51	170	515	95.88
Mizoram	0	0	6	7	19	43	580	64	719	90.63
Nagaland	0	3	0	0	0	21	142	12	178	75.00
Odisha	29	1816	2255	7132	6433	2450	8380	2303	30798	98.74
Punjab	4012	3921	770	4117	472	14128	10439	2678	40537	-49.81
Rajasthan	1823	1072	1295	4413	1243	4043	5292	826	20007	-120.70
Sikkim	0	2	2	38	5	21	82	96	246	97.92
Tamil Nadu	2051	2501	12826	6122	2804	4535	2531	11552	44922	82.25
Tripura	0	0	9	8	6	40	102	77	242	88.31
Telangana	0	0	0	0	704	1831	4037	1674	8246	57.95
Uttar Pradesh	960	155	342	1414	200	2892	15033	1461	22457	34.29
Uttrakhand	178	454	110	54	106	1655	2146	312	5015	42.95
West Bengal	805	510	6456	5920	3934	8516	22865	5389	54395	85.06
A& N Island	25	6	24	67	139	153	92	9	515	-177.78
Chandigarh	221	73	351	107	13	966	1246	734	3711	69.89
Delhi	6259	1131	2093	5574	995	15867	4431	4545	40895	-37.71
D&N Haveli	46	68	156	190	641	1154	4161	1219	7635	96.23
Daman & Diu	0	0	96	61	46	165	89	59	516	-62.71
Puduchery	96	463	3506	2215	1322	771	490	2271	11134	95.77
Total	28292	18860	50222	75808	40571	99913	129166	78691	521523	64.05

Source: National Vector Borne Disease Control Programme, Directorate General of Health Services, Ministry of Health and Family Welfare: nvbdcp.gov.in/den-cd, html

Table 2: Dengue Deaths in India since 2010

Affected States/UTs	Dengue Deaths								Total	Growth rate
	2010	2011	2012	2013	2014	2015	2016	2017		
Andhra Pradesh	3	6	2	1	5	2	2	0	21	-50
Arunachal Pradesh	0	0	0	0	00	1	0	0	1	-
Assam	2	0	5	2	0	1	4	2	16	-
Bihar	0	0	3	5	0	0	0	0	8	40
Chattisgarh	0	11	0	2	9	1	0	0	23	-1000
Goa	0	0	0	2	1	0	0	0	3	-100
Gujarat	1	9	6	15	3	9	14	2	59	50
Haryana	20	3	2	5	2	13	0	1	46	-1900
Himachal Pradesh	0	0	0	2	0	1	0	0	3	-100
J & K	0	0	1	3	0	0	1	0	5	-
Jharkhand	0	0	0	0	0	0	1	1	2	-
Karnataka	7	5	21	12	2	9	8	5	69	-40
Kerala	17	10	15	29	11	25	13	35	155	52.00
Madhya Pradesh	1	0	6	9	13	8	12	4	53	75.00
Meghalaya	0	0	2	0	0	0	0	0	2	-
Maharashtra	5	25	59	48	54	23	33	8	255	34.50

Manipur	0	0	0	0	0	0	1	1	2	-
Mizoram	0	0	0	0	0	0	0	0	0	-
Nagaland	0	0	0	0	0	1	0	0	1	-
Odisha	5	33	6	6	9	2	11	5	77	-
Punjab	15	33	9	25	8	18	15	0	123	-
Rajasthan	9	4	10	10	7	7	16	1	64	-800.00
Sikkim	0	0	0	0	0	0	0	0	0	-
Tamil Nadu	8	9	66	0	3	12	5	18	121	55.56
Tripura	0	0	0	0	0	0	0	0	0	-
Telangana	0	0	0	0	1	2	4	0	7	
Uttar Pradesh	8	5	4	5	0	9	42	23	96	
Uttrakhand	0	5	2	0	0	1	4	0	12	75.00
West Bengal	1	0	11	6	4	14	45	13	94	92.31
A& N Island	0	0	0	0	0	0	0	0	0	-
Chandigarh	0	0	2	0	0	1	0	0	3	-100.00
Delhi	8	8	4	6	3	60	10	1	100	-700.00
D&N Haveli	0	0	1	0	1	0	2	0	4	50.00
Daman & Diu	0	0	0	0	0	0	0	0	0	-
Puduchery	0	3	5	0	1	0	2	2	13	-50.00
Total	110	169	242	193	137	220	245	122	1438	9.84

Source: National Vector Borne Disease Control Programme, Directorate General of Health Services, Ministry of Health and Family Welfare: nvbdcp.gov.in/den-cd, html

Table 2 presents data on the Dengue Deaths in India since 2010. It could be observed that in India 110 people died consequent upon climate change induced dengue fever and it increased to 1438 by the end of the October 2017, indicating a growth of 9.84 per cent during the period 2010 to 2017. The dengue death cases are more than 100 in Kerala, Maharashtra, Odisha, Tamil Nadu and Delhi during the period 2010 to 2017. The dengue death cases are not reported in Mizoram state, Sikkim, Tripura, A& N Islands.

The year 2017, monsoon is expected to be heavier and so, we must expect as many dengue cases. We are expecting at least a 25 percent hike in its incidence than the previous year in India."

Global incidence of dengue has drastically upped in the last few years. According to the World Health Organization (WHO), there are about 390 million cases of dengue fever worldwide, and of the total number of cases, 96 million require medical treatment. India also saw a doubling up of cases of dengue from 2014 to 2015 and the worst hit city was Delhi with over 1800 cases of the fever. 2016 isn't expected to be any better and this has become a cause of concern for the country.

Dr Sushila Kataria, Division of Internal Medicine, Medanta the Medicity warns, "This year, monsoon is expected to be heavier and so, we must expect as many dengue cases. We are expecting at least a 25 per cent hike in its incidence than the previous year." Though dengue trends have shown a more severe outbreak in alternate years, Dr Sushila believes that for past few years, the incidence has been getting worse each pass. The Tamil Nadu government had faced flak following dengue deaths in some cities, including Chennai and Coimbatore, with the opposition targeting it over the spread of the fever.

The Tamil Nadu government had faced flak following dengue deaths in some cities, including Chennai and Coimbatore, with the opposition targeting it over the spread of the fever. The government had on October 3 said it has undertaken work on a "war-footing" to address the issue and Rs 13.95 crore has been allocated for mosquito control.

CONTROL MEASURES

The primary preventative measure to reduce dengue infections is the control of mosquito populations. Because the transmission of dengue requires mosquitoes as vectors, the spread of dengue can be limited by reducing mosquito populations. What can people at risk of dengue infections do to reduce the size of mosquito populations? One practical and recommended environmental management strategy is to eliminate unnecessary container habitats that collect water such as plastic jars, bottles, cans, tires, and buckets in which Aedes aegypti can lay their eggs. This strategy is called source reduction. When container habitats are removed and water storage containers are covered with a fine mesh to prevent mosquitoes from getting inside them, mosquitoes have fewer opportunities to lay eggs and cannot develop through their aquatic life stages. Source reduction can be effective when performed regularly, especially when members of a community are mobilized and educated about vector control.

Environmental management initiatives can also include major changes in a community, such as installing water systems with direct connections to residences and replacing wells and other water-storage containers, which can be mosquito-breeding habitats. Smaller-scale environmental changes can also be effective. For example, mosquito populations can be reduced when all members of a community clear blocked gutters and street drains and keep their yards free of containers with standing water. Any open containers should be emptied and cleaned each week to eliminate mosquito eggs and larvae. These efforts can reduce the number of mosquitoes living in an area.

What other measures can members of a community take to reduce mosquito populations? Community-based approaches must go hand in hand with educational initiatives that teach people about mosquito vectors and the risks of having mosquito-breeding habitats near their homes. Educational initiatives can encourage people to take an active role in participating in source reduction. Communities that understand the need to make behavioral changes are the most effective in controlling dengue. In addition to steps that communities can take, what can individuals do to protect themselves from dengue?

Personal Actions to Reduce Contact with Mosquitoes:-

People can reduce the risk of mosquitoes entering their homes by using window and door screens or by keeping their doors and windows closed and using air conditioning to keep their homes cool. Aedes aegypti typically bite people during the day, so wearing long pants and long-sleeved shirts can reduce mosquito bites when spending time outdoors. In addition, mosquito repellents can be applied to exposed skin and clothing to lower the risk of mosquito bites. Sleeping under a mosquito net can also provide protection from being bitten, particularly in areas where people rest in the afternoon or in houses with infants. What about other methods of reducing mosquito populations?

Chemical Control of Dengue Mosquitoes:-

Chemical control can be effective in controlling mosquito populations. For instance, insecticides can be used to kill mosquito larvae or adult mosquitoes. Can insecticides be widely and routinely used? The use of insecticides is recommended in emergency situations during dengue epidemics or when there is evidence that an epidemic is emerging. On a regular basis, however, sustainable, coordinated, community-based environmental approaches are favored over chemical methods for controlling mosquitoes, and limited reliance on these chemicals is preferred. Why are environmental management approaches favored? One reason is that mosquitoes can develop resistance to insecticides. In addition, insecticides are expensive, and high doses can be toxic to humans and other species. Therefore, it is best to be cautious about applying these chemicals.

Bioinsecticides:-

One example of a bioinsecticide is Bacillus thuringiensis israelensis, which is a naturally occurring soil bacterium that can effectively kill mosquito larvae present in water. There are many strains of Bacillus thuringiensis, each having unique toxicity characteristics, and Bacillus thuringiensis israelensis is very specific for mosquitoes. Bacillus thuringiensis israelensis is available in small, slow-release bricks called "mosquito dunks" that float on the water surface and are effective in treating deep water. Other bio insecticides, such as pyriproxyfen and methoprene, act as juvenile hormone analogues that prevent mosquito larvae from metamorphosizing into adults.

Recently, researchers used mosquitoes to transfer insecticides to larval habitats. They noticed that after taking a blood meal, female Aedes aegypti enjoy resting in damp and dark areas. To take advantage of this behavior, the researchers set up dark, damp stations dusted with a bio insecticide that targets larvae. When the mosquitoes came to rest on the stations, their legs picked up the bio insecticide and transferred it to the aquatic mosquito habitats where they laid their eggs. This method was effective in killing the mosquito larvae and reducing the number of adult mosquitoes.

New genetic approaches are also being considered as ways to control mosquito populations. Researchers at the University of Oxford and Oxitec genetically engineered female mosquitoes that cannot fly. Being flightless is a huge genetic disadvantage. The flightless female mosquitoes are unable to "sing" and court with male mosquitoes using their wing oscillation "song." Predators can more easily prey on flightless female mosquitoes. The researchers theorize that these genetically engineered mosquitoes could be used to control mosquito populations and reduce dengue transmission. The same group of researchers recently genetically modified male mosquitoes to be sterile, and they released these mosquitoes in a trial in Grand Cayman, a Caribbean island, to wipe out dengue fever.

Better Environmental Management for Control of Dengue:-

New scientific insights into dengue vector ecology and disease transmission patterns, together with more targeted use of environmental management strategies, may offer improved potential for combating dengue fever, the world's fastest growing vector-borne disease. Dengue fever, together with associated dengue haemorrhagic fever (DHF), is the most important vector-borne viral disease affecting humans. Aedes aegypti, the urban yellow fever mosquito, is also the principal dengue-carrying vector. A secondary vector is Aedes albopictus. Aedes aegypti was eliminated from large areas of the Americas as part of the yellow fever mosquito eradication campaign in the 1950s and 1960s, but later reinvaded those areas. Dengue has emerged or re-emerged in Asia, the Americas and elsewhere over the past three decades, and presently occurs in nearly 100 tropical and subtropical countries. Epidemics have become progressively larger.

The Resurgence of Dengue

Social and environmental factors – including increased urbanization particularly of poor populations lacking basic health services as well as expansion of international travel and trade – are linked to the resurgence of dengue disease. Climate change also may affect transmission, as dengue mosquitoes reproduce more quickly and bite more frequently at higher temperatures. The epidemiology and ecology of dengue are complicated by the fact that there are four virus serotypes, some or all of which may be circulating in a particular endemic region at a particular time. Within any given local population, levels of immunity to each of the four serotypes may vary over time as a function of natural population growth, past population exposure to other serotypes, etc. Depending on the local level of immunity, therefore, an epidemic may erupt at higher or lower thresholds of vector density. While beginning as a flu-like illness, dengue can develop into a deadly fever (dengue haemorrhagic fever). Unlike most other diseases, sequential infection with different serotypes increases – rather than reduces – the risk of severe illness. Most cases of dengue haemorrhagic fever occur in children under the age of 15.

CONCLUSION

It could be seen clearly from the above discussion that climate change has serious impact on spread of dengue fever. It has been proved by scientists' throughout the world. The raising temperature and changing climate scenario enable the growth of dengue virus vector in female Aedes aegypti. There are a lot of dengue fever control options. Despite this situation, the incidence of dengue fever is growing, indicating the inadequate mitigation measures taken by the government. It could be noted that India reported the 28292 dengue infected persons in 2010 and it rose to 521523 by the 2017 October status. The growth of dengue cases indicates the 64.05 per cent increase during the period 2010 to 2017. The reporting of dengue cases in India is due to climate change as it increases the breeding cycles of the mosquitoes and other vector bearing pathogens.

It could be noted that the dengue cases incidence shows interstate disparity in India. The growth of dengue cases is highest in A& N Islands. A more than 80 per cent of the growth in dengue cases has been observed in Chattisgarh, Himachal Pradesh, Jharkhand, Karnataka, Kerala, Meghalaya, Maharashtra, Manipur, Odisha, Sikkim, Tamil Nadu, Tripura and D&N Haveli during the period 2010 to 2017. The growth of dengue cases has become negative in Goa, Gujarat, Punjab, Delhi and Daman & Diu during the period 2010 to 2017. In absolute number a more than 20000 cases of dengue infection has been observed in Gujarat, Karnataka, Kerala, Maharashtra, Odisha, Punjab, Rajasthan, Tamil Nadu, Uttar Pradesh, West Bengal and Delhi during the period 2010 to 2017. It is clear that growth of dengue case in India is outcome of climate change and poor hygienic and health care practices among the states in India. It could be observed that in India 110 people died consequent upon climate change induced dengue fever and it increased to 1438 by the end of the October 2017, indicating a growth of 9.84 per cent during the period 2010 to 2017. The dengue death cases are more than 100 in Kerala, Maharashtra, Odisha, Tamil Nadu and Delhi during the period 2010 to 2017. The dengue death cases are not reported in Mizoram state, Sikkim, Tripura, A& N Islands.

SUGGESTION

- The prevention of dengue requires control or eradication of the mosquitoes carrying the virus that causes dengue.
- To prevent mosquito bites, wear long-sleeved shirts, long pants, socks and shoes when outdoors.
- For personal protection, use mosquito repellant sprays when visiting places where dengue is endemic.
- "Aedes" mosquitoes usually bite during the day. Therefore, special precautions should be taken during early morning hours before day break and in the late afternoon before dark.
- Eliminate stagnant water that serve as mosquito breeding sites at home, workplaces and their vicinity.
- Using mosquito nets at home and patients need to be kept under mosquito netting until the second bout of fever is over and they are no longer contagious.
- Cover overhead tank to prevent access to mosquitoes.
- Eliminate breeding ground by removing unused plastic pools, old tires, or buckets and clearing clogged gutters.
- Conducts dengue awareness programs in the apartment complex and neighborhood.
- Advise people showing symptoms of dengue to immediately go for a check-up and get treatment.

•The most effective way to prevent mosquito bite and to reduce the number of mosquitoes around homes or neighborhoods is to find and eliminate their breeding sites.

•Turn over empty pails and buckets, so that they do not collect excess water. If the container that contains water cannot be emptied, remember to cover it well when not in use.

•Remember to clean out empty flower pots and not to over water potted plants. It is advised to not have any stagnant water around as it acts as breeding ground for the mosquitoes.

•Apply mosquito repellents on all exposed areas, during the day as well as at night on a regular basis to prevent dengue. Here are some innovative ways to keep our home mosquito free.

• Make sure our window and door screens do not have any holes. If so, block those areas properly to eliminate mosquitoes.

If someone at home is ill with dengue, try to not let the mosquitoes bite them or others in the house. Always sleep under a mosquito net especially small children as they sleep during the day and hence, the chance of mosquito bite is high during this time. Using camphor as a repellent also works wonders. Light camphor in a room and close all the doors and windows. Leave it this way for about fifteen to twenty minutes to have a mosquito free environment.

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