Dengue transmission in the Asia-Pacific region: impact of climate change and socio-environmental factors

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Summary

OBJECTIVE To review the scientific evidence about the impact of climate change and socio-environmental factors on dengue transmission, particularly in the Asia-Pacific region.

METHODS Search of the published literature on PubMed, ISI web of Knowledge and Google Scholar. Articles were included if an association between climate or socio-environmental factors and dengue transmission was assessed in any country of the Asia-Pacific region.

RESULTS Twenty-two studies met the inclusion criteria. The weight of the evidence indicates that global climate change is likely to affect the seasonal and geographical distribution of dengue fever (DF) in the Asia-Pacific region. However, empirical evidence linking DF to climate change is inconsistent across geographical locations and absent in some countries where dengue is endemic.

CONCLUSION Even though climate change may play an increasing role in the transmission of DF, no clear evidence shows that such impact has already occurred. More research is needed across countries to better understand the relationship between climate change and dengue transmission. Future research should also consider and adjust for the influence of important socio-environmental factors in the assessment of the climate change-related effects on dengue transmission.

KEYWORDS dengue transmission, climate change, socio-environmental factors, the Asia-Pacific

Introduction

Global climate is changing rapidly, due primarily to anthropogenic greenhouse gas emissions (IPCC 2007). Global mean temperature is projected to increase between 1.1–6.4 °C by the end of this century relative to 1980–1999. There is growing evidence that climate change has already affected and will increasingly impact on human health (Epstein 2005; Haines et al. 2006; McMichael et al. 2006; Costello et al. 2009). The changes in global temperature, precipitation and humidity that are expected to occur because of projected climate change will affect the biology and ecology of vectors and consequently the risk of vector-borne disease transmission (Gubler et al. 2001; Tong et al. 2008; Shuman 2010). Dengue fever (DF) is the most important arboviral disease in the world (Gubler 2002a; WHO 2006). About 2.5 billion people live in endemic areas and an additional 120 million people travel to affected areas every year. The annual number of dengue infections is estimated to be 50–100 million. Case fatality rates vary between 0.5 and 3.5% in Asian countries (Guzman & Kouri 2002; Halstead 2007; Suaya et al. 2009). Cases reported to the World Health Organization (WHO) over the past four decades show an upward trend, especially in urban areas (WHO 2006).

Climate variability, lack of effective vector control programmes, uncontrolled urbanization and increased international travel are suggested to be the important risk factors for increased activity of dengue (Gubler 2002a; Sutherst 2004). Temperature, rainfall and relative humidity are thought as important climatic factors contributing towards the growth and dispersion of the mosquito vector and potential of dengue outbreaks (Patz et al. 2005). Temperature is also capable of affecting pathogen replication, maturation and period of infectivity (Patz et al. 1998).

As global temperatures continue to increase, it has predicted that the endemic range of DF will expand geographically (Githiko et al. 2000; Hopp & Foley 2001; Woodruff & McMichael 2004). Warmer temperatures will also allow for increased reproduction and activity and decreased incubation time of larvae, resulting in an increased capacity for producing offspring. Thus, an increase in the transmission potential and prevalence of DF seems likely (Jetten & Focks 1997; Barbazan et al. 2010). The increasing temperatures could also increase DF transmission by extending the season in which transmission...
occurs (Patz & Reisen 2001). Lengthy drought conditions in endemic areas without a stable drinking water supply may encourage the storage of drinking water, thereby increasing the number of breeding sites for the mosquito vector *Aedes aegypti* (Beebe et al. 2009). Conversely, high rainfall will ensure that small artificial containers used as larval mosquito habitat would remain flooded, thereby expanding adult mosquito population (Patz et al. 1998). Moreover, climate change associated with El Niño-Southern Oscillation (ENSO) may trigger outbreak of DF in populated areas where the disease is endemic (Hales et al. 1999; Johansson et al. 2009b).

As climate change may have a significant impact on the transmission and incidence of DF, it is essential to examine the association between climatic variables and DF epidemic. Recently, a few studies have explored the impact of climate variability and climate change on dengue transmission (Hales et al. 2002; Johansson et al. 2009a). Others assessed the influence of socio-ecological factors on dengue epidemics (McBride et al. 1998; Bohra & Andrianasolo 2001; Thammapalao et al. 2005a; Cummings et al. 2009; Johansson et al. 2009b). However, the link between dengue and climate change remains inconclusive because the potential influence of socio-demographic factors on dengue transmission has rarely been considered seriously in previous research (Patz et al. 1998; Retter 2001; Semenza & Menne 2009). In this paper, we review the reported effects of climate change and other socio-environmental factors on dengue transmission in the Asia-Pacific region to draw attention to the methodological challenges in this area. Additionally, we provided recommendations for future research directions.

### Methods

A literature search using PubMed, ISI Web of Knowledge and Google scholar was conducted in December 2009. Keywords such as ‘Dengue’, ‘Dengue fever’, ‘Dengue hemorrhagic fever’, ‘climate change*’, ‘climate variability’, ‘climate model*’, ‘Risk factors’ and ‘socio-environmental factors’ were used in different combinations to identify potential articles and references. Search terms included MeSH terms and free text terms. Limits were set for language (English) and publication year (1990–2009). In Google Scholar, we limited our search by subject (Biology, Life Science and Environmental science) as it gives huge number of irrelevant references. However, we searched all fields for PubMed and Web of Science. Table 1 shows the search results from each database. The initial search generated 1931 references including duplicates. All titles and 466 abstracts were reviewed to identify potential epidemiological studies. Then, 290 full-text articles were retrieved based on abstracts reviewed and critically analysed by the first author.

<table>
<thead>
<tr>
<th>Search terms</th>
<th>PubMed</th>
<th>ISI web of knowledge</th>
<th>Google Scholar</th>
<th>Total (including duplicates)</th>
</tr>
</thead>
<tbody>
<tr>
<td># 1 (‘Dengue’ OR ‘Dengue fever’ OR ‘Dengue Hemorrhagic fever’) AND (‘climate change*’ OR ‘climate variability’ OR ‘climate model’)</td>
<td>310</td>
<td>134</td>
<td>167</td>
<td>611</td>
</tr>
<tr>
<td># 2 (‘Dengue’ OR ‘Dengue fever’ OR ‘Dengue Hemorrhagic fever’) AND (‘Risk factors’ OR ‘Socio-environmental factors’)</td>
<td>325</td>
<td>216</td>
<td>584</td>
<td>1125</td>
</tr>
<tr>
<td>#1 AND #2 (‘Dengue’ OR ‘Dengue fever’ OR ‘Dengue Hemorrhagic fever’) AND (‘climate change*’ OR ‘climate variability’ OR ‘climate model*’) AND (‘Risk factors’ OR ‘Socio-environmental factors’)</td>
<td>47</td>
<td>19</td>
<td>129</td>
<td>195</td>
</tr>
<tr>
<td>Total (including duplicates)</td>
<td></td>
<td></td>
<td></td>
<td>1931</td>
</tr>
</tbody>
</table>
Inclusion criteria

Articles were included in the review if they (i) evaluated the effects of climate variability or the influence of other socio-environmental factors on dengue transmission (ii) conducted in countries of the Asia-Pacific region and (iii) used an epidemiological study design. Only studies conducted in the Asia-Pacific region were included because many countries of this region are prone to dengue transmission but no systematic review has focused on this region in the literature yet. Epidemiological study designs included time series analysis, spatial or spatio-temporal analysis and descriptive study which applied to identify the influence of climate variables (temperature, humidity, precipitation, wind speed and El Niño events) and socio-environmental factors (population density, urbanization, housing, family income, transport and vector control) on dengue transmission. Figure 1 illustrates article inclusion process.

Results

Of 290 full-text articles, 22 articles met the inclusion criteria and the major findings of these studies were reviewed and summarized in Tables 2 and 3. All articles included in this
### Table 2 Characteristics of studies on the association between climatic variables and dengue transmission

<table>
<thead>
<tr>
<th>Study</th>
<th>Location (study period)</th>
<th>Statistical method</th>
<th>Risk factors</th>
<th>Major findings</th>
<th>Comments</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johansson et al. 2009a</td>
<td>Thailand (1983–1996)</td>
<td>Wavelet analysis</td>
<td>ENSO, Precipitation &amp; temperature</td>
<td>The direct relationship between ENSO and dengue was non-stationary and ENSO appeared to be associated with local temperature and precipitation</td>
<td>Further research is needed to explain the non-stationarity in ENSO and dengue incidence</td>
<td></td>
</tr>
<tr>
<td>Tipayamongkholgul et al. 2009</td>
<td>Thailand (1996–2005)</td>
<td>Poisson regression</td>
<td>ENSO, Temperature, Relative humidity, Wind speed</td>
<td>The effects of El Niño on dengue transmission were varied according to geographical location within Thailand</td>
<td>Only southern coastal and northern inland regions were included</td>
<td></td>
</tr>
<tr>
<td>Cazelles et al. 2005</td>
<td>Thailand (1983–1997)</td>
<td>Wavelet analysis</td>
<td>ENSO</td>
<td>The dynamics of El Niño were strongly associated with dengue incidence but non-stationary existed in this relation which might influenced by the synchrony of previous dengue epidemic</td>
<td>The magnitude of the El Niño and dengue relationship needs to be viewed within a wider context of socio-environmental variability</td>
<td></td>
</tr>
<tr>
<td>Nakhapakorn &amp; Tripathi 2005</td>
<td>Thailand (1997–2001)</td>
<td>Multiple regression</td>
<td>Rainfall, Temperature, Humidity, Land use</td>
<td>Built-up area had highest risk of dengue incidence and temperature, rainfall and humidity were likely to be key determinants of DF</td>
<td>Only one province was included</td>
<td></td>
</tr>
<tr>
<td>Thammapalo et al. 2005b</td>
<td>Thailand (1978–1997)</td>
<td>Linear least square regression</td>
<td>Monthly total rainfall, Rain days, Daily temperature, Daily relative humidity</td>
<td>Increased temperature was positively associated with dengue incidence in central and northern parts of Thailand where in increased rainfall was negatively associated in southern Thailand</td>
<td>Spatial variation was not examined</td>
<td></td>
</tr>
<tr>
<td>Nagao et al. 2003</td>
<td>Thailand (1992–1996)</td>
<td>Multiple regression</td>
<td>Temperature, Rainfall, Water wells, Tin houses</td>
<td>Larval abundance of Aedes mosquito was positively associated with house conditions, water supply and transport services. In increased rainfall in 2 months earlier and temperature were also correlated with larval indices</td>
<td>Only 18 province of Northern Thailand were included</td>
<td></td>
</tr>
<tr>
<td>Hsieh &amp; Chen 2009</td>
<td>Taiwan (2007)</td>
<td>Richards model Distributed lag model</td>
<td>Typhoon, Temperature, Precipitation</td>
<td>The multiwave dengue outbreak in Taiwan in 2007 was appeared to be influenced by rainfall and temperature variation as a consequence of two consecutive typhoons</td>
<td>Further research is required to explore the relationship between extreme weather events and dengue transmission</td>
<td></td>
</tr>
<tr>
<td>Wu et al. 2007</td>
<td>Taiwan (1998–2003)</td>
<td>ARIMA model</td>
<td>Temperature, Relative humidity, Vector density</td>
<td>The incidence of DF was negatively associated with monthly temperature variation and reversely with relative humidity at lags of 2 months</td>
<td>Only one metropolitan city was included</td>
<td></td>
</tr>
</tbody>
</table>
### Table 2 (Continued)

<table>
<thead>
<tr>
<th>Study</th>
<th>Location (study period)</th>
<th>Statistical method</th>
<th>Risk factors</th>
<th>Major findings</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wu <em>et al.</em> 2009</td>
<td>Taiwan (1998–2002)</td>
<td>Spatial analysis Logistic regression</td>
<td>Temperature, Rainfall, Level of urbanization, Percentage of elder population, Temperature, Relative humidity</td>
<td>Number of warm months and degree of urbanization were found to be associated with increasing risk of DF incidence at township level</td>
<td>Both climatic variables and socio-demographic factors were considered</td>
</tr>
<tr>
<td>Halide &amp; Ridd 2008</td>
<td>Indonesia (1998–2005)</td>
<td>Multiple regression</td>
<td>Temperature, Rainfall, Relative humidity</td>
<td>Relative humidity at 3–4 months lags and current number of dengue cases appeared to be major determinants for prediction of DF outbreak in Indonesia</td>
<td>Only one city was included</td>
</tr>
<tr>
<td>Arcari <em>et al.</em> 2007</td>
<td>Indonesia (1992–2001)</td>
<td>Multiple regression</td>
<td>Temperature, Rainfall, Relative humidity, SOI</td>
<td>Rainfall and temperature observed as important predictor of DF transmission in Indonesia</td>
<td>Socio-environmental factors were not included</td>
</tr>
<tr>
<td>Bangs <em>et al.</em> 2006</td>
<td>Indonesia (1997 &amp; 1998)</td>
<td>Descriptive analysis</td>
<td>Temperature, Relative humidity, Rainfall, ENSO, House index</td>
<td>ENSO driven increased temperature exhibited greater impact on dengue transmission by the vector population</td>
<td>Only one city was included</td>
</tr>
<tr>
<td>Chakravarti &amp; Kumaria 2005</td>
<td>India (2003)</td>
<td>Descriptive analysis</td>
<td>Temperature, Rainfall, Relative humidity</td>
<td>Temperature, rainfall and relative humidity were major determinants for dengue transmission and outbreak coincided in post-monsoon period</td>
<td>Only one outbreak in one city was considered</td>
</tr>
<tr>
<td>Lu <em>et al.</em> 2009</td>
<td>China (2001–2006)</td>
<td>Poisson regression</td>
<td>Temperature, rain fall, Relative humidity, Wind velocity</td>
<td>Increase minimum temperature and decreased wind velocity were associated with increase dengue incidence</td>
<td>Only one province was included</td>
</tr>
<tr>
<td>Yang <em>et al.</em> 2009</td>
<td>China (July –October 2004)</td>
<td>Descriptive analysis</td>
<td>Temperature, precipitation, Humidity, Breteau index, House index</td>
<td>Dengue incidence seemed to have no relationship with climatic factors. However, negatively associated with vector control</td>
<td>Non-endemic nature of DF in Cixi city may biased the relationship between climate variables and DF</td>
</tr>
<tr>
<td>Hii <em>et al.</em> 2009</td>
<td>Singapore (2000–2007)</td>
<td>Poisson regression</td>
<td>Temperature, Precipitation</td>
<td>Weekly mean temperature and total precipitation were related to increased dengue incidence</td>
<td>Socio-environmental factors were not included</td>
</tr>
<tr>
<td>Hu <em>et al.</em> 2010</td>
<td>Australia (1993–2005)</td>
<td>SARIMA model</td>
<td>ENSO</td>
<td>Decreased mean of SOI at lags of 3–12 months earlier was inversely associated with dengue incidence in Queensland</td>
<td>Only SOI was considered</td>
</tr>
<tr>
<td>Bi <em>et al.</em> 2001</td>
<td>Australia (1990–1994)</td>
<td>ARIMA model</td>
<td>Temperature, Precipitation, Relative humidity</td>
<td>Monthly mean minimum temperature was the major contributor for dengue outbreak in Townsville</td>
<td>Only 4 years dataset used</td>
</tr>
</tbody>
</table>

Arranged by location of study.

ENSO, El Niño-Southern Oscillation Index; ARIMA, autoregressive integrated moving average; SARIMA, seasonal autoregressive integrated moving average; SOI, Southern Oscillation Index; DF, dengue fever.
review were published between 1998 and 2010. Eight studies from Thailand, three each from Australia, Taiwan and Indonesia, two each from China and India and one from Singapore. There was no study conducted in some countries of the Asia-Pacific region where dengue is endemic, such as, Bangladesh, Sri Lanka, and Myanmar.

**Association between climatic factors and DF**

Of the 22 published studies, 18 evaluated the relationship between climatic variables and dengue incidence (Bi et al. 2001; Nagao et al. 2003; Cazelles et al. 2005; Chakravarti & Kumaria 2005; Nakhapakorn & Tripathi 2003; Thammapaloo et al. 2005b; Bangs et al. 2006; Arcari et al. 2007; Wu et al. 2007, 2009; Halide & Ridd 2008; Hii et al. 2009; Hsieh & Chen 2009; Johansson et al. 2009a; Lu et al. 2009; Tipayamongkholgul et al. 2009; Yang et al. 2009; Hu et al. 2010). Among them, only three studies considered both climatic and social factors (Nagao et al. 2003; Nakhapakorn & Tripathi 2005; Wu et al. 2009). The main outcome variables assessed in these studies were the number of dengue cases and/ or mosquito density (Breteau index, house index and container index). Most studies collected data on temperature, amount of precipitation and relative humidity as climatic variables (Cazelles et al. 2005; Nakhapakorn & Tripathi 2005; Thammapaloo et al. 2005b; Wu et al. 2007). Several used ENSO as an independent variable (Cazelles et al. 2005; Johansson et al. 2009a; Tipayamongkholgul et al. 2009). Only one study assessed the influence of extreme weather event (Typhoon) on DF (Hsieh & Chen 2009).

Different methods were used to evaluate the association between climatic variables and dengue incidence or mosquito density. Of the 18 studies reviewed, two used spatial analyses (Nakhapakorn & Tripathi 2005; Wu et al. 2009), 13 time series analyses (Bi et al. 2001; Nagao et al. 2003; Cazelles et al. 2005; Thammapaloo et al. 2005b; Arcari et al. 2007; Wu et al. 2007; Halide & Ridd 2008; Hii et al. 2009; Hsieh & Chen 2009; Johansson et al. 2009a; Lu et al. 2009; Tipayamongkholgul et al. 2009; Hu et al. 2010) and three descriptive analyses (Chakravarti & Kumaria 2005; Bangs et al. 2006; Yang et al. 2009).
Various multiple regressions analyses like logistic regression and Poisson regression were mostly used to analyse and predict DF transmission. These time series regression analyses provide a way to establish the relationship between changes of weather parameters, environmental factors and the occurrence of dengue cases which might be used for forecasting future dengue outbreak based on model scenarios (Wu et al. 2007). Both classical autoregressive integrated moving average (ARIMA) model and seasonal ARIMA model were also applied to link between weather variation and dengue (Bi et al. 2001; Wu et al. 2007; Hu et al. 2010). Spatial analysis of dengue occurrence was used to identify the high-risk area for dengue outbreaks (Wu et al. 2009). However, none of the previous studies included both spatial and temporal data into their models. The identification of high-risk areas through spatio-temporal modelling may assist existing surveillance and control efforts by permitting limited resources in areas where dengue outbreaks are most likely to occur.

An association between climatic factors and dengue incidence or mosquito density was reported in most studies (Bi et al. 2001; Nagao et al. 2003; Cazelles et al. 2005; Chakravarti & Kumaria 2005; Nakhapakorn & Tripathi 2005; Thammapalo et al. 2005b; Bangs et al. 2006; Arcari et al. 2007; Wu et al. 2007; Halide & Ridd 2008; Hi et al. 2009; Hsieh & Chen 2009; Johansson et al. 2009a; Lu et al. 2009; Tipayamongkholgul et al. 2009; Hu et al. 2010). However, the direction and intensity of this association varied by time and location (Thammapalo et al. 2005b; Arcari et al. 2007; Tipayamongkholgul et al. 2009). Temperature, rainfall and relative humidity were often major determinants of dengue transmission. There was no association between dengue incidence and climate variability in Cixi, China, which might be attributed to the non-endemic nature of DF in Cixi and the short study period (4 months) (Yang et al. 2009).

Several non-climatic factors, such as, urbanization, land use, vector-control programme, human movement, housing quality and population immunity, were identified as potential confounders for assessing the climate-dengue relationship. Only 1 of 18 studies reviewed was adjusted for socio-environmental factors (Nagao et al. 2003), apparently because the lack of relevant datasets makes it difficult to control these variables (Bi et al. 2001; Arcari et al. 2007; Wu et al. 2007).

Most studies examining the temperature influence on dengue transmission or mosquito density reported a positive association (Bi et al. 2001; Nagao et al. 2003; Thammapalo et al. 2005b; Arcari et al. 2007; Hi et al. 2009; Lu et al. 2009; Wu et al. 2009). Higher temperature favours virus replication, vector proliferation and feeding frequency of mosquito (Jetten & Focks 1997; Patz et al. 1998). Therefore, rising temperature may enhance dengue transmission. However, the impact of increased temperature on dengue outbreak was not immediate. Various lag times were reported for this relationship, ranging from 4 to 16 weeks (Bi et al. 2001; Arcari et al. 2007; Wu et al. 2007; Hsieh & Chen 2009; Lu et al. 2009; Hu et al. 2010). Bi et al. 2001 found that monthly mean minimum temperatures impacted on the transmission of DF through a 4-month lagged period which includes the period of replication and development of mosquito, the extrinsic incubation period (time of replication of virus within vector) and intrinsic incubation period of the virus (time of virus replication within the host)(Bi et al. 2001). Therefore, observed lags were biologically plausible.

Associations between rainfall and dengue transmission are inconsistent across geographical locations. Dengue outbreaks were usually coincided with wet season and positive associations between dengue incidence and precipitation were reported in many countries of the Asia-Pacific region (Nagao et al. 2003; Nakhapakorn & Tripathi 2005; Arcari et al. 2007). Rainfall may increase the breeding sites of *Aedes* mosquito and therefore increase dengue transmission. However, excess rainfall was found negatively associated with dengue incidence in Thailand, Indonesia and Taiwan (Thammapalo et al. 2005b; Halide & Ridd 2008; Wu et al. 2009). The plausible explanation might be the mosquito larvae washed away by heavy rainfall (Thammapalo et al. 2005b; Arcari et al. 2007).

The ENSO is a periodic variation in the atmospheric conditions and ocean surface temperatures of the tropical Pacific and hypothesized to have influence on multiyear variation in dengue incidence (Johansson et al. 2009a). Among the studies reviewed, four examined the impact of ENSO on the synchrony of dengue epidemics in Thailand and Australia (Cazelles et al. 2005; Johansson et al. 2009a; Tipayamongkholgul et al. 2009; Hu et al. 2010). They reported a significant but non-stationary influence of ENSO on dengue transmission (Cazelles et al. 2005; Johansson et al. 2009a; Tipayamongkholgul et al. 2009; Hu et al. 2010). Spatial heterogeneity and various lag effects were also apparent in this relation (Tipayamongkholgul et al. 2009; Hu et al. 2010). In Thailand, ENSO was associated with local temperature and precipitation changes. It was suggested that decreased ENSO could result in increased temperature and decreased rainfall leading to increased water storage, increased mosquito breeding sites and therefore, increased dengue transmission (Johansson et al. 2009a). Moreover, further research is necessary to explain the non-stationarity and spatial variation in the ENSO–dengue relationship to effectively support the hypothesis of inter annual variation in dengue transmission.
Association between socio-environmental factors and DF

Four studies have examined the impact of socio-environmental factors on dengue incidence in the Asia-Pacific region (Table 2) (McBride et al. 1998; Bohra & Andrianasolo 2001; Thammapalo et al. 2005a; Cummings et al. 2009). The increasing trends in population growth, uncontrolled urbanization, spread of mosquito vector and movement of virus through international travel were suggested to be the major contributing factors for the recent dengue expansion in endemic areas (Gubler et al. 2001; Campbell-Lendrum & Reithinger 2002; Kyle & Harris 2008). Influences of different socio-environmental factors on dengue transmission were illustrated in this part of the paper from a global perspective as very little evidence is available from the Asia-Pacific region.

Socio-economic condition.

Dengue transmission might be influenced by people’s socio-economic status (Gubler et al. 2001; Reiter et al. 2003). People in developed countries usually live in better houses with glazed windows, piped water, insect screening and air-conditioning than those in developing countries (Reiter 2001). These facilities may effectively reduce their contacts with vector mosquitoes and even if infected mosquitoes gain entry to these buildings, the low ambient temperature and artificially dry atmosphere may decrease their survival rate and reduce the risk of transmission (Reiter 2001). Besides these, many activities, particularly social gatherings which occur in outdoor situations such as balconies, courtyards and outdoor restaurants, might facilitate contact with vector (Gubler et al. 2001; Reiter 2001). It has been suggested that the large difference in disease incidence between United States and Mexico Border States is probably caused by differences in living standards and human behaviours (Gubler et al. 2001).

A spatial analysis of dengue in Thailand reported that the risk of DF was quite geographically homogenous and associated with housing types and poor garbage disposal (Thammapalo et al. 2007). Housing style was strongly related to the number of water jars and discarded items. Town houses and slum houses in Phuket had relatively fewer discarded wet containers than single houses on rubber plantations. Therefore, single houses had a 3–15 times higher risk of dengue, because these dwelling types have sufficient open space where discarded items could be easily filled with rain water which can create mosquito breeding sites (Thammapalo et al. 2005a).

International travel.

International trade and transports were suggested to have potential influence on the geographical distribution of vectors and pathogen (Gubler et al. 2001; Reiter 2001; Sutherst 2004). Commercial shipping might be linked to the spread of both A. aegypti and Aedes albopictus between regions (Romi et al. 1997). For example, after the introduction of used tires, an American species of A. albopictus has established in Italy (Romi et al. 1997). In addition, air-travel has greatly increased the dissemination of dengue viruses via rapid transit of viraemic individuals around the world (Kyle & Harris 2008). As a result, the worldwide movement of dengue virus has been greatly facilitated by air travel (Reiter 2001). Introduction of new dengue viruses by travellers was one of the important factors for causing hyper-endemicity in Puerto Rico and increased severity of the disease (Gubler & Trent 1993; Gubler et al. 2001).

Public health intervention.

The health risk arising from climate change may differ between countries depending on the quality of public health infrastructures (Githeko et al. 2000). In Canada and USA, good surveillance and vector control programmes limited the endemic transmission of DF, whereas in Mexico and other less developed countries the health infrastructures are still ineffective (Githeko et al. 2000). The majority of dengue endemic countries in Asia do not have laboratory based active surveillance system that can provide accurate early warning for epidemic DF (Gubler 2002b). In the pacific, only Australia, Tahiti and New Caledonia have good laboratory surveillance (Gubler 2002b). Recently, there have been considerable improvements in surveillance and vector control in Australia (Ritchie et al. 2002). Therefore, it seems unlikely that DF will become re-established as an endemic disease in Australia (McMichael 2003).

Conclusion

The review indicates that global climate change is likely to affect the seasonal and geographical distribution of DF in the Asia-Pacific region. The complex nature of the dengue transmission which involves vector ecology, viral factors, population immunity and socio-demographic changes makes it difficult to quantify how climate change affects dengue transmission. However, the impact of socio-environmental changes on dengue transmission is less well studied. Therefore, relative importance and interaction between socio-environmental and climatic factors remain to be elucidated and need further exploration. Biological judgement and caution are also necessary in interpreting a direct relationship between climatic factors or non-climatic factors and dengue transmission. We hope this review inspires further work to elucidate the relative importance
and interaction between climatic or non-climatic factors in the transmission of dengue.

There is the lack of data in many countries where dengue is endemic. To demonstrate the regional variation in the climate-dengue relationship, a multidisciplinary approach incorporating region-specific predicted climate changes and non-climatic factors could help to identify consistencies in interactions between dengue and certain climatic and non-climatic factors. Thus, a more sophisticated multivariable predictive model may be constructed for control and prevention of DF. Furthermore, multicentre or multicountry studies using both climatic and socio-environmental data could help to reveal the potential impact of climate change on dengue transmission in the Asia-Pacific region.

References


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