Climate Change and Vector-Borne Diseases in China

Subjects: Others
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Vector-borne diseases are among the most rapidly spreading infectious diseases and are widespread all around the world. In China, many types of vector-borne diseases have been prevalent in different regions, which is a serious public health problem with significant association with meteorological factors and weather events. Under the background of current severe climate change, the outbreaks and transmission of vector-borne diseases have been proven to be impacted greatly due to rapidly changing weather conditions.

Keywords: climate change ; meteorological factor ; vector-borne disease

1. Introduction

Except for COVID-19, climate change may be the most important global public health issue of our time [1] since it threatens all aspects of human health, including the risks of infectious diseases [2]. Vector-borne disease is one of the infectious diseases most sensitive to climate. It has put 80% of the population at infection risk [3] and causes more than 700,000 deaths every year all around the world [4]. Unfortunately, climatic conditions, especially rising temperature, have also been contributing to outbreaks of vector-borne diseases in recent years [5]. Previous studies have predicted that the spreading areas of vector-borne diseases will expand in many countries due to a rapidly changing climate [6][7]. Climate change has been proven to be one of the key drivers of changing the life activities, living environments, migration, and geographical distribution of vectors [8][9], which will ultimately increase the risk of vector-borne diseases [10].

China is one of the most vulnerable countries with respect to climate change [11]. Many studies have found the significant positive relationship between weather conditions and vector-borne diseases in China, including the effects of meteorological factors, such as temperature, precipitation, humidity, wind speed [12][13][14][15][16][17], and extreme weather events (e.g., extremely high temperatures, extremely high rainfall, and tropical cyclones) [18][19][20][21][22][23][24]. The 2020 China Report of the Lancet Countdown on Health and Climate Change showed that China's climate suitability for mosquito-borne dengue fever has increased by 37% in the past half century [25]. If nothing is done to address climate change, the malaria incidence in northern China will rise from 69% to 182% by 2050 [26].

2. Climate Change and Vector-Borne Diseases in China

2.1. The Relationship between Meteorological Factors and Vector-Borne Diseases

Most published studies used ecological design for risk assessment, in which the most frequently used mathematical models were the Ecological Niche Model (ENM), Distributed Lag Non-linear Model (DLNM), Generalized Estimated Equation (GEE), Generalized Linear Model (GAM), Logistic Regression and Autoregressive Integrated Moving Average Model (ARIMA), etc. The relationship between climate factors and vector-borne diseases was non-linear; a J-shape or reverse U-shape was always found between them, which means, respectively, that the risks increased continuously or increased and then decreased with the rise of certain meteorological factors. Temperature, precipitation, and humidity were the main parameters contributing to the transmission of vector-borne diseases [13][27][28][29]. Generally, temperature plays an important role in the number of reported insect-borne and rodent-borne diseases cases [30][31][32][33][34]. However, typhus group rickettsiosis was negatively related to average temperature, average ground temperature, and extreme minimum temperature [13]. The same negative correlation was also found between temperature and schistosomiasis [35]. Precipitation can promote the transmission of most insect-borne diseases [36][37] and interacts with temperature [16]. It is expectable that moderate precipitation (10–120 mm) and temperatures of 10–25 °C were the most favorable condition for HFRS incidence [38]. In addition, rising humidity is facilitates insect-borne disease transmission, such as dengue and plague [39][40]. Atmospheric pressure and wind speed were inversely related to vector-borne diseases but sunshine was positively related [29][41][42].

2.2. Potential Pathway of Meteorological Factors on Vector-Borne Diseases

Figure 1 shows the main effect path of the climate change on vector-borne diseases. Climate change can contribute to a lot of environmental problems, such as changing vegetation cover and land type, accelerating the melting of snow, and exacerbating the urban heat island effect, impacting urban water supply systems and population mobility. These changes can lead to the disruption of ecosystems' balance and loss of wildlife habitats, which may affect the reproduction, survival, spread, and distribution of pathogens, vectors, or intermediate hosts, ultimately increasing the risk of vector-borne diseases [43].

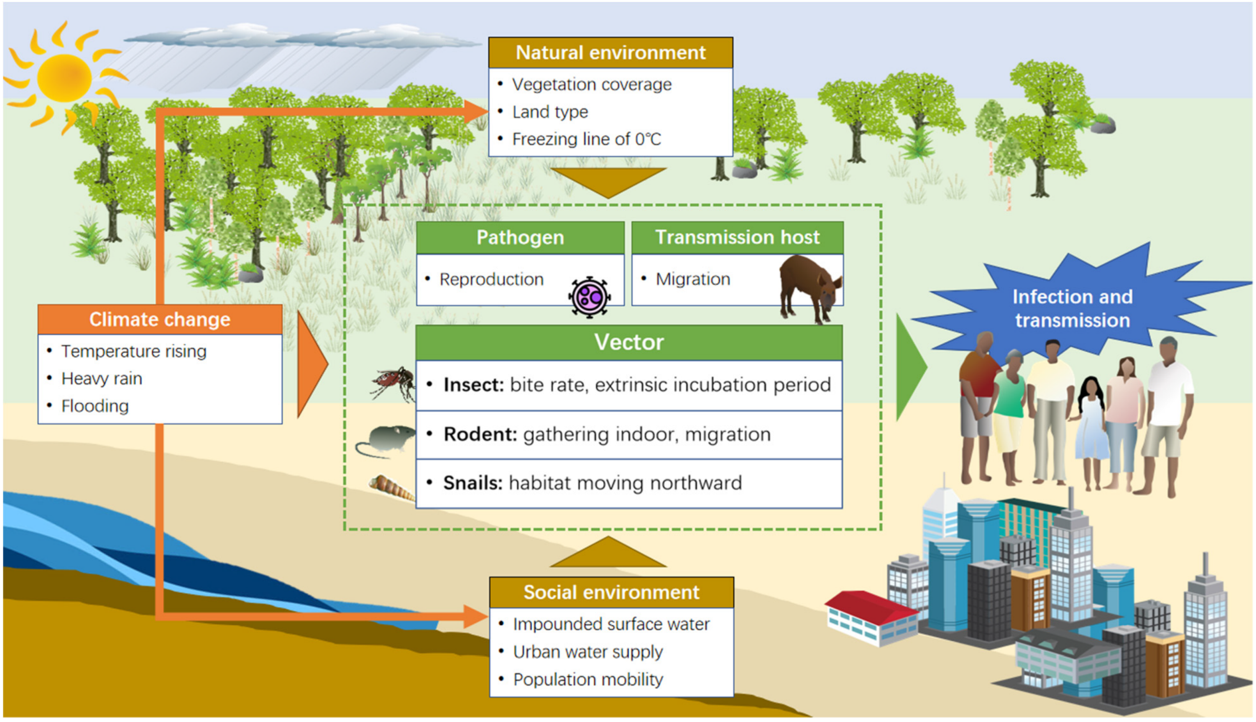

Figure 1. The main pathway of climate change impact on the risk of vector-borne diseases.

Rising temperatures can shorten the incubation and reproduction rates of dengue viruses and the life cycle of mosquitoes, which can contribute to the increase in the number and spread rate of vectors [44][45][46]. Moreover, high temperatures can increase vectors' survival rate [47], but when the temperature exceeds a certain threshold, it has an adverse effect on the reproduction and bite rates of insects [48]. When the temperature continues to be above 37 °C for several days, the mosquito breeding grounds are reduced by the evaporation of water, which in turn leads to a decrease in mosquito density and affects the prevalence of malaria [49]. Snails are the vectors of schistosomiasis and cannot survive in areas where temperatures are below 0 °C in January. Studies have proven that the habitat suitable for snails in Poyang Lake has moved northward due to rising temperatures [50][51][52]. In addition, rising soil surface temperatures can significantly affect the transmission of leishmaniasis by impacting the growth and development of its vector, sandflies, which carry out life activities in the first three life stages in soil close to the surface [53].

Precipitation can provide more habitats for mosquitoes, contributing to their survival and reproduction [54][55]. However, extreme precipitation can destroy vector habitats, disrupt the growth of insects, and wash eggs out of breeding grounds, further decreasing vector density and disease transmission [55][56][57]. Some scholars also believe that although heavy precipitation takes away vector organisms, the rest of the rain will become a potential breeding ground for adult mosquitoes [58]. In addition, heavy rainfall in eastern China also destroys rodent habitats, reducing rodent–rodent contact, human–rodent contact, and the spread of the virus [18]. However, in southern China, the migration of infected people and rodents may promote the spread of plague between regions, although flooding can kill the vectors [40].

2.3. The Regional Differentiation of the Relationship between Meteorological Factors and Vector-Borne Diseases

Both the relationship and the mechanism mentioned above have shown large regional differences. The correlation between the main meteorological factors (temperature, precipitation and humidity) and vector-borne diseases in different provincial/municipal/county administrative regions are shown in **Table 1**, in which "+" represents a positive correlation, "−" represents a negative correlation, "J" represents a J-shaped correlation, and "reverse U" represents a reverse U-shaped correlation. Generally, in southern China, temperature may contribute to the transmission of insect-borne diseases while adversely affecting it in the northern region. In contrast, the number of rodent-borne diseases cases may be decreased by temperature in southern China but be increased in the northern region. Meanwhile, a positive association between precipitation and insect-borne diseases can be found in the southern China, while the same relationship between precipitation and rodent-borne diseases is mainly distributed in the northern region.

The pathway of climate change impacting vector-borne diseases can also vary among regions. Small increases in temperature can greatly affect the spread of malaria in areas with lower average temperatures since the prevalence of malaria in hotter regions is much higher than in colder regions [59]. In addition, rainwater does not gather readily in the Yunnan–Guizhou Plateau because of the typical mountainous characteristics of it, and currents can destroy mosquito breeding habitats and reduce mosquito population density, which may not lead to the incidence of JE increasing with increases in rainfall in this area [60]. Heavy precipitation can also destroy rodents' habitats and reduce its populations. However, due to low winter temperatures in northern China, heavy precipitation may cause rodents to gather indoors, increasing the likelihood of human–rodent contact [16][61].

Table 1. The relationships between meteorological factors and vector-borne diseases according to the classification of different administrative regions in China.

Disease	Area	Time Period	Meteorological Factors		
			Temperature	Precipitation	Humidity
	Shandong				
	Jinan City	1959–1979	Max T (+) **	P (+)	H (+) *
			Min T (+) **		
	Henan				
	Yongcheng County	2006–2010	Monthly avg max T (+) ***	-	Monthly avg H (+) **
	Anhui	1990–2009	Monthly avg T(+) *	Monthly avg P (+) **	Monthly avg RH (+) *
	Shuchen County	1980–1991	Monthly avg max T (+) *** Monthly avg min T (+) ***	Monthly P (+) ***	Monthly avg RH (+) ***
Malaria	Hefei city	1999–2009	Monthly avg T (+) Monthly avg max T (+) *** Monthly avg min T (+) ***	P (+) *	H (+) ***
	Hefei City	1990–2011	Monthly min T (+) ***	P	RH (+) ***
	Yunnan				
	Mengla County	1971–1999	Monthly max T (+) * Monthly min T (+) *	Monthly P (−)	Monthly RH (−)
	125 counties	2012	Yearly avg T (+) **	Yearly P (+) **	
	Guangdong	2005–2013	High T (+)	P (J)	-
	Guangzhou city	2006–2012	Daily avg T (+) *	-	Daily RH (+) *
	Hainan	1995–2008	Monthly avg T (+) * Monthly avg max T (+) * Monthly min T (+) *	Monthly total P (+) *	-

Disease	Area	Time Period	Meteorological Factors		
			Temperature	Precipitation	Humidity
Dengue	Guangdong				
	Guangzhou City	2006–2015	Extremely high T (+) *	Extremely high P (+) *	Extremely high H (+) *
	Guangzhou City	2005–2015	Monthly avg max T (+) **	Monthly total P (+) **	-
	Guangzhou City	2007–2012	Monthly avg T (+) **	-	Monthly avg RH (+) **
	Guangzhou City	2001–2006	Min T (+) ***	Monthly total P (+)	Min H (+)
	Guangzhou City	2000–2012	Monthly avg min T (+) *	Monthly total P (+) *	Monthly avg RH (+) *
	Guangzhou City	2005–2011	Daily avg T (+) * Daily min T (+) * Daily max T (−) *	Daily P (+)	Daily H (+)
	Zhongshan City	2001–2013	Monthly max T (+) * Monthly max DTR (+) *	-	Monthly avg RH (+) * Monthly max RH (+) *
	Fujian	1978–2017	Monthly avg T (+) *	Monthly total P (+) *	-
	Guangxi	1978–2017	Monthly avg T (+) *	Monthly total P (+) *	-
	Yuanan	1978–2017	Monthly avg T (+) *	Monthly total P (+) *	-
Japanese encephalitis	Shandong				
	Jinan City	1959–1979	Monthly avg max T (+) *** Monthly avg min T (+) ***	Monthly total P (+) *	Monthly avg RH (+) ***
	Linyi City	1956–2004	Monthly min T (+) **	-	Monthly avg RH (+) *
	Shannxi	2006–2014	Monthly min T (−)	Monthly P (+)	-
	Anhui				
	Jieshou County	1980–1996	Monthly avg max T (+) * Monthly avg min T (+) *	Monthly total P (+) **	-
	Hunan				
	Changsha city	2004–2009	Monthly avg max T (+) * Monthly avg min T (+) *	Monthly total P (+) *	Monthly avg AH (+) *
	Sichuan				
	Nanchong City	2007–2012	Daily avg T (+) *	-	Daily avg RH (+) *
	Chongqin				
	12 counties along the Yangtze River	1997–2008	Monthly avg T (+) ***	Monthly total P (−) ***	-

Disease	Area	Time Period	Meteorological Factors		
			Temperature	Precipitation	Humidity
Scrub typhus	Shandong	2006–2013	Monthly avg T (reversed U) ***	Monthly total P (−) ***	Monthly avg RH (−) ***
	Laiwu City	2006–2012	Monthly avg T (+) **	Monthly avg P (+) **	Monthly avg RH (+) **
	Anhui	2006–2013	Monthly avg T (reversed U) ***	Monthly total P (−) ***	Monthly avg RH (+) ***
	Jiangsu	2006–2013	Monthly avg T (reversed U) ***	Monthly total P (−) ***	Monthly avg RH (+) ***
	Yancheng City	2005–2014	Monthly avg min T (+) ***	Monthly total P (+) ***	Monthly avg RH (−) ***
	Guangdong				
	Guangzhou City	2006–2012	Daily avg T (+) **	Daily P (+) **	Daily avg RH (−) *
Typhus group rickettsiosis	Yunan				
	Xishuangbanna	2005–2017	Weekly avg T (J) *	Weekly avg P (reversed U) *	-
SFTS	Jiangsu	2010–2016	Max T in warmest month (+) *	P in warmest month (+) *	-
Leishmaniasis	Xinjiang				
	Jiashi County	2005–2015	Monthly avg T (+) **	Monthly total P	Monthly avg RH (−) **
Plague	Gansu				
	Sunan County, Subei County	1973–2016	Monthly avg T (+) *	Monthly avg P (+) *	Monthly avg RH (−) *
HFRS	Yunnan	1982–2013	Extreme max T (−) **	-	Avg RH (+) **
	Guizhou	1982–2013	Extreme max T (−) **	-	Avg RH (+) **
	Guangxi	1982–2013	Extreme max T (−) **	-	Avg RH (+) **
	Liaoning	2005–2014	Weekly max T (+) *	Weekly P (+) *	Weekly avg RH (+) *
	Shenyang City	2004–2009	Monthly avg T (−) * Monthly avg max T (−) * Monthly avg min T (−) *	Monthly total P (−) *	Monthly avg RH (−) *
	Heilongjiang	2005–2014	Weekly max T (+) *	Weekly P (+) *	Weekly avg RH (+) *
	Anhui	2005–2014	Weekly max T (+) *	Weekly P (+) *	Weekly avg RH (+) *
Schistosomiasis	Hubei	1976–1989	Avg T in July (−) *	Avg P in July (−) *	-
	Anhui	1997–2010	Monthly avg T (−) *	Monthly total P (−) *	
	Jiangxi	2008	-	Monthly min P (−) ** Monthly max P (−) **	

The bold fonts in the region column are provinces in China. Max (maximum), Min (minimum), Avg (average), T (temperature), DTR (the difference between the maximum and the minimum daily temperature), P (precipitation), H (humidity), RH (relative humidity), AH (absolute humidity). “*” (The result is significant at level of α = 0.05), “**” (The result is significant at level of α = 0.01), “***” (The result is significant at level of α = 0.001).

3. Summary

The most significant health threat faced from climate-related vector-borne diseases in China is mosquito-borne diseases, while the concern and health threat from rodent-borne diseases is decreasing. Aedes aegypti and Aedes albopictus are the main mosquito vectors transmitting viruses. Globally, Aedes aegypti, mainly distributed in South America, play an active role in increasing Zika transmission risks. Aedes albopictus, on the other hand, is mainly distributed in the southeastern United States, southern China, and the northern summer season in southern Europe; it is the main vector of mosquito-borne diseases in China [62]. In the last few decades, the mosquito-borne disease malaria once posed a high infection risk in China. However, on June 3th 2021, China was declared malaria-free by the World Health Organization, although today 40% of the world’s population still lives in malaria-endemic regions, with Africa being the most severe malaria-endemic region. Within the past few years, dengue fever has become the most important mosquito-borne disease health threat facing China, especially in Guangdong Province. The transmission risk of dengue is significantly increasing since it has been spreading from the coastal areas of southern China to northern areas in recent years [63].

Temperature, precipitation, and humidity were the main climate factors contributing to the transmission of vector-borne diseases [64][65][66].

The correlations between climate and vector-borne diseases were also hugely different among regions throughout Chinese mainland. One reason was the influence of regional factors, ecological regional factors and social regional factors included. Climatic differences between regions can be a critical contributor. For instance, it is more suitable for insects in the south of China, where it is warmer and wetter, compared with the north, so insect-borne disease more likely to occur in southern cities, such as Guangdong, Fujian, and Yunnan. In addition, the relationship between temperature and rodent-borne diseases showed different types of association, in that it was linear in the temperate zone and non-linear in the warm temperature zone [16]. Additionally, land type can impact vector habitats; for example, the typical mountainous characteristics of the Yunnan–Guizhou Plateau make rainwater unable to gather there, reducing the breeding area and reproduction of mosquitoes [60]. Areas with high vegetation coverage are more conducive to mosquito breeding, and areas rich in water are more suitable for the reproduction of snails, thus promoting the spread of relevant vector-borne diseases.

Social regional factors, such as urbanization, have been identified as an important factor affecting vector-borne disease transmission. On the one hand, urbanization can destroy suitable environments for mosquito breeding, thus impacting the spread of relevant mosquito-borne diseases [54]. One the other hand, the level of urban facilities varies among urban, suburban, and rural. A study conducted in Brazil indicated that the risk of dengue was higher in more rural areas than in highly urbanized areas during extremely wet conditions, and the dengue risk following extreme drought was higher in areas that had a higher frequency of water supply shortages [67]. In addition, population structure also plays an important role since vector-borne diseases are more likely to spread in high-density population areas [68] and in different susceptible populations. For example, the high-risk group for malaria in Guangzhou is males aged 20–44 [69]; the unemployed and retired here were more likely to be infected with dengue [68]. Women, the elderly, and farmers in Shandong, Jiangsu, and Anhui are more susceptible to scrub typhus [27]; middle-aged and elderly farmers are high-risk populations for severe fever with thrombocytopenia syndrome [70], while the leishmaniasis tends to be transmitted in people under 20 years old in Xinjiang [53]. Additionally, agricultural ecosystems and artificial ecological engineering change the climate of local areas, leading to small-scale outbreaks of vector-borne diseases [52][71]. Socio-economic levels, public education levels, immunization rates, and people’s awareness of health can also play an important role in the transmission of vector-borne diseases [47][72][73].

However, these ecological and social regional factors are changing greatly. Climate change has a profound impact on the structure and function of natural ecosystems in China, such as severe land loss, change in vegetation cover, reduction in river runoff, and forest destruction, which interfere with vector habitats and alter the spread dynamics of pathogens across species. Moreover, China is in the rapid advance period of industrialization, urbanization, and modernization with a slowing total population growth, an aging population, and an adjusted fertility policy. The risk of vector-borne diseases will increase continuously in China in the future. However, at present, studies mostly focus on the effect of single meteorological factors on vector-borne diseases, although the outbreak of vector-borne diseases was proven to be determined by a combination of different meteorological factors. Only the studies on hemorrhagic fever with renal syndrome indicated the interaction and marginal effects among temperature, precipitation, humidity, and the effect of temperature and its interactions with relative humidity and rainfall on malaria [74].

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