Health Professionals' Perceptions of Dengue Fever, Malaria and Haemorrhagic Fever with Renal Syndrome in the Face of Climate Change in China

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Table of Contents

LIST OF TABLES

NOTE: This list does not contain the tables in Chapters 3, 4, 5, 6, 7 as these are published papers/submitted manuscript which have a different numbering sequence as in the list above.

LIST OF FIGURES

NOTE: This list does not contain the figures in Chapters 3, 4, 5, 6, 7 as these are published papers/submitted manuscripts which have a different numbering sequence as in the list above.

LIST OF ABBREVIATIONS

CDC	Center for Disease Control and Prevention
CHKD	China Hospital Knowledge Database
CI	Confidence Interval
DENV	Dengue Viruses
GDP	Gross Domestic Product
HIV	Human Immunodeficiency Virus
HFRS	Hemorrhagic Fever with Renal Syndrome
HTNV	Hantaan Virus
IRR	Incidence Rate Ratio
IPCC	Intergovernmental Panel on Climate Change
MEI	Multivariate El Nino southern oscillation Index
NDVI	Normalized Difference Vegetation Index
OR	Odds Ratio
STD	Sexually Transmitted Diseases
SARS	Severe Acute Respiratory Syndrome
SEOV	Seoul Virus
SOI	South Oscillation Index
US	The United States of America
WHO	World Health Organization

THESIS ABSTRACT

Background

Dengue fever, malaria and Hemorrhagic Fever with Renal Syndrome (HFRS) are common infectious diseases in China. The impact of climate change on infectious diseases has been studied extensively. An association between climatic factors and these emerging and re-emerging vector/rodent-borne diseases has been demonstrated in China. However, health professionals' perceptions of climate change and infectious diseases, and China's capacity to manage the challenge of these climate-sensitive diseases are still not clear. This study aimed to investigate health professionals' perceptions, and to explore the adaptive capacity of China's health system to deal with these diseases in the context of climate change.

Methods

With dengue, malaria and HFRS as case study diseases, questionnaire surveys were conducted to gauge health professionals' perceptions of climate change and infectious disease control and prevention, and to explore the current capacity of the health system to manage emerging and re-emerging infectious diseases in China, in the context of climate change. The study can be broadly divided into two parts. In the first part of the study, a questionnaire survey was conducted among public health professionals in the Chinese Centers for Disease Control and Prevention (CDC) at national, provincial, prefectural and county levels. The second part of the study was conducted among clinical health professionals in hospitals. Data analysis was undertaken using descriptive methods and logistic regression.

Results

Most health professionals were concerned about climate change, and agreed with the statement that the weather was becoming warmer. More than 80% of health professionals agreed that climate change would affect population health, and indicated that climate change would influence infectious disease transmission, especially vector-borne diseases such as dengue and malaria. Nearly all perceived that dengue had emerged or re-emerged, and indicated that there had been a geographic expansion of the disease. Roughly half indicated that malaria had re-emerged in some parts of China, especially in southwest China. More than half perceived that HFRS had re-emerged, especially in northeast China. Most health professionals indicated that the capacity of the health system to detect infectious disease outbreaks/epidemics was excellent, and was well prepared for the challenge that emerging infectious diseases may pose.

Conclusions

The findings showed that health professionals were concerned about climate change and believed that it would affect infectious disease transmission. This research has identified some of the significant factors contributing to the transmission of infectious diseases, such as climate variation, migrant population, increasing vector/rodent density, imported cases, lack of health awareness and poor environmental conditions. For dengue control, reducing and controlling the density of mosquito vectors would be most important. For malaria control, regional cooperation and information sharing were urgently needed to curb re-emergence. For HFRS control, rodent control measures and health awareness of HFRS risks should be strengthened. Most health professionals believed that the capacity of the health system to manage infectious diseases was excellent. However, to increase adaptive capacity, the results show there is a strong need to increase funding for disease surveillance and control, improve the capacity of lower-level CDCs and rural health care, and strengthen logistical support in hospitals.

DECLARATION

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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PRESENTATIONS ARISING FROM THE THESIS

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Tong, M. X. Perceptions of Malaria Control and Prevention in an Era of Climate Change: A Cross-sectional Survey among CDC staff in China: Oral presentation at the 2016 State Population Health Conference, Adelaide, Australia, 22 October 2016. doi: 10.1186/s12936-017-1790-3.

Tong, M. X. Health Professionals' Perceptions of Dengue Fever in the Face of Climate Change in China: Oral presentation at the 2016 National Climate Change Adaptation Conference Vulnerable Communities Network Masterclass, Adelaide, Australia, 8 July 2016. doi: 10.1016/j.envres.2016.03.043.

Tong, M. X. Perceptions of Capacity for Infectious Disease Control and Prevention to Meet the Challenges of Dengue Fever in the Face of Climate Change in Guangdong Province, China: Oral presentation at the 2016 National Climate Change Adaptation Conference, Adelaide, Australia, 4-7 July 2016. doi: 10.1016/j.envres.2016.03.043.

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OTHER PUBLICATIONS DURING CANDIDATURE

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DEDICATION

This project is dedicated to all health workers who are striving for a better public health, infectious disease control and prevention in the face of climate change worldwide, especially for the region of Asian-Pacific countries, and for the memory of our collaboration between University of Adelaide, University of South Australia, Monash University, Anhui Medical University, China CDC and other local CDCs in Anhui, Guangdong, Henan, Liaoning and Yunnan Provinces, under the supervision of Professor Peng Bi, Dr Alana Hansen, Dr Scott Hanson-Easey, and all other team members in Australia and China.

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CHAPTER 1 INTRODUCTION

1.1 Background

It is widely known that the global climate system has changed over the past century. The global average combined land and ocean surface temperature has increased by 0.85 ±0.2 ˚C due to rapid industrial development and human activities over the period 1880 to 2012 [1, 2]. In the most recent Intergovernmental Panel on Climate Change (IPCC) Report, it is predicted that the global average surface temperature will increase by 1.1-6.4 ˚C by 2100 compared to 1990, and other climatic variations, such as changes in precipitation, relative humidity, vapour pressure, sunshine duration and wind speed will also occur [2].

1.1.1 Climate change in China

China is one of the largest and topographically heterogeneous countries in the world with huge environmental, climatic and demographic differences [3]. China, located in East Asia, has a total area of 9.6 million square kilometres, and a population of 1.37 billion [4, 5]. The majority of the population lives in the eastern half of China [4]. The climate in China is different from region to region. Most areas are cold and dry in winter, and hot and rainy in summer. In northeast China, summers are hot and dry, and winters are extremely cold, with temperatures dropping to -20 ˚C [6]. In north and central China, there are frequent bouts of rain during summers with temperatures around 26 ˚C and cold winters with temperatures below 0 ˚C [6]. In the south of China, there are humid, semi-tropical summers with substantial precipitation, and temperatures can reach over 40 ˚C; and winters are cool with temperatures around 5-10 ˚C [6]. In addition, flooding can occur periodically in central, southern and western China near the Yangtze River, the Yellow River, the Huai River and the Pearl River, while drought can occur in north China [7].

China is currently experiencing climate change. During the past 100 years in China, annual average land surface air temperature has increased by 0.5-0.8 ˚C [8]. It is estimated that by 2050, the annual average land surface air temperature will increase by 2.3-3.3 ˚C as compared with that in 2000 [8]. The annual precipitation has decreased between 20-40 mm per decade over the last 100 years in most parts of north China, northeast China and east China, whilst precipitation significantly increased about 20-

60 mm per decade over the same period in south China and southwest China [8]. Precipitation in China is projected to increase nationwide by 5-7% by 2050, and southeast coastal regions may experience a further significant increase in rainfall [8]. Moreover, extreme climate events, such as extremes in temperature, flood and drought, may become more frequent and intensive throughout China [9]. In the north and northeastern areas of China, for example, drought will occur more frequently, while in the middle, eastern and southeastern parts of China floods will become more devastating, causing significant economic and agricultural losses. Furthermore, China has experienced rapid urbanisation in past three decades, which is associated with huge environmental and land use/cover changes, together with population relocations. The government has been well aware of the variations in climate and difficulties posed by climate change, and acknowledged China is one of the most vulnerable countries to the adverse impact of climate change [10], and has developed a White Paper on Climate Change in 2012, and released and updated 'China's Policies and Actions on Climate Change' in 2013, 2014 and 2015 [10-13].

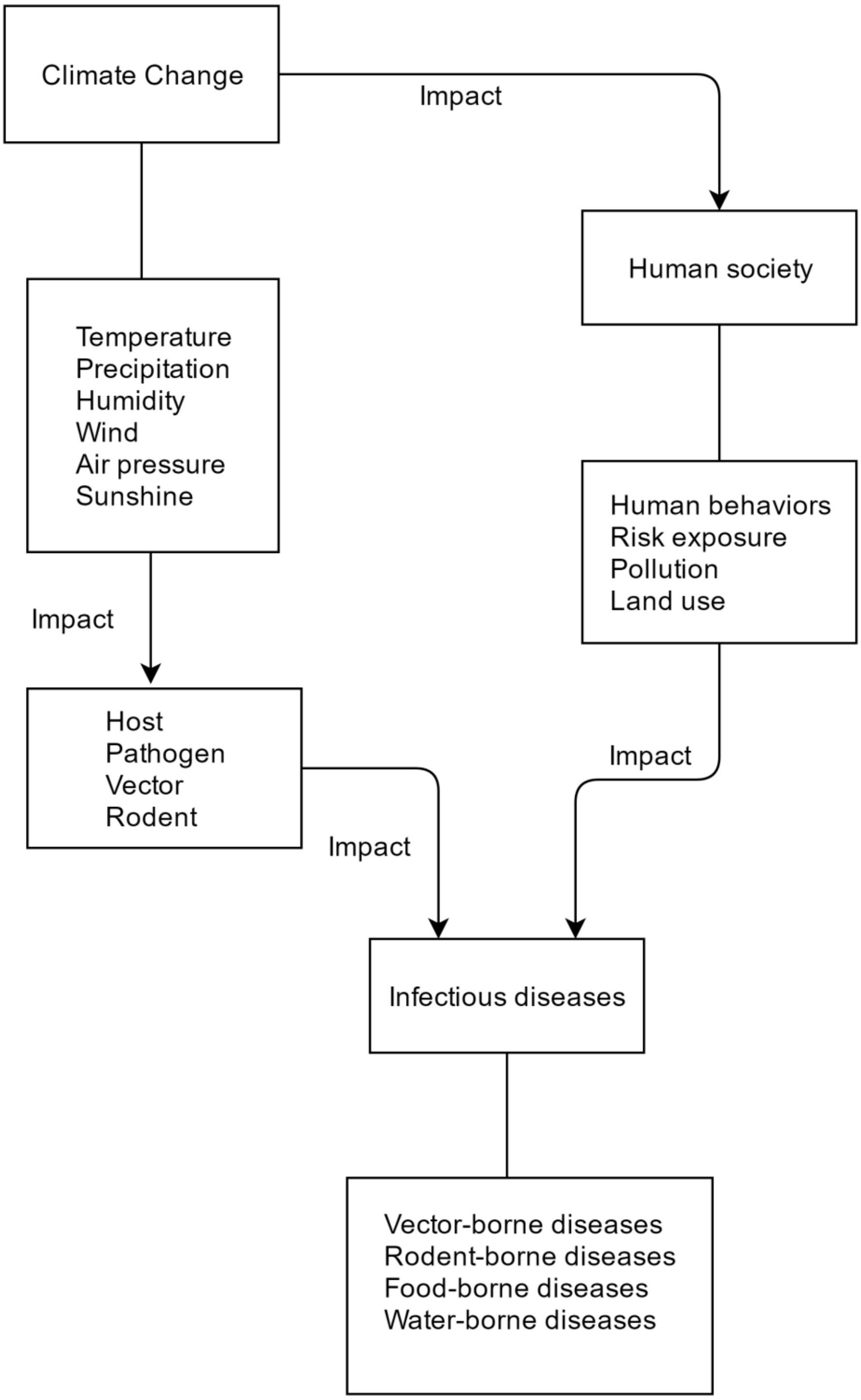
1.1.2 Infectious diseases in China

Infectious diseases are caused by pathogenic micro-organisms, such as bacteria, viruses, parasites or fungi. The diseases can be spread directly from one person to another or indirectly [14]. Vectors or rodents can act as an essential stage in the transmission of infection from one person to another or from animal hosts to humans in the case of zoonotic diseases [15]. China has a long history in the battle against infectious diseases. Before 1949, many infectious diseases occurred in China due to war, a poor health care system, and underdeveloped medical and public health facilities.

After the founding of the People's Republic of China, the new government faced tough infectious disease challenges, e.g., more than 3,400 human plague cases occurred with one-third of these resulting in death in 1950 [16]. Roughly 100,000 smallpox cases were reported in 1951; and in 1952 more than one million measles cases were reported with 41,000 deaths, and 2.93 million malaria cases with 39,000 deaths [16]. Furthermore, hundreds of thousands of Chinese died from diphtheria, pertussis, meningococcal meningitis and other diseases. The actual number of infectious disease cases and deaths was far in excess of the numbers reported, due to the lack of a disease reporting system at that time. In order to meet such challenges and improve population health, the Chinese government mobilised huge public health efforts to treat, control and prevent these infectious diseases. The government established nationwide anti-epidemic stations (now called Centers for Disease Control and Prevention), developed national health promotion campaigns, improved occupational health and food hygiene. Over the past three decades there has been a rapid socioeconomic development, better education and an improved public health system. Population health has been enhanced greatly and the incidence of infectious diseases has decreased dramatically from about 7,100 cases per 100,000 population in 1970 to around 270 cases per 100,000 population in 2007 [17]. Moreover, smallpox has been eradicated [18], and plague and cholera have been controlled in China [19]. However, due to various reasons, in 2016 the incidence of infectious diseases increased to 506 cases per 100,000 population in China [20]. The current estimates suggest there are about 7 million cases of infectious diseases in China's 1.3 billion population each year leading to approximately 17,000 deaths [21-23]. The latest health statistics report released in 2016 shows the most common of the 28 listed infectious diseases are viral hepatitis, pulmonary tuberculosis and syphilis, with dengue, malaria and HFRS ranked in Top 15 [23].

The complex relationship between climate change, infectious diseases and human society is illustrated in Figure 1.1. Climatic factors such as temperature, precipitation, humidity, wind, air pressure and sunshine have a direct influence on disease hosts, pathogens and the transmission of infectious diseases. Simultaneously, climate change has an indirect impact on infectious disease transmission via affecting human activities, e.g., changes in human behaviours, risk exposures, pollution and land use. Both the direct and indirect effects of climate change have an impact on infectious diseases, such as vector-borne diseases, rodent-borne diseases, food-borne diseases and water-borne diseases [24].

Figure 1.1 Climate change and infectious disease transmission



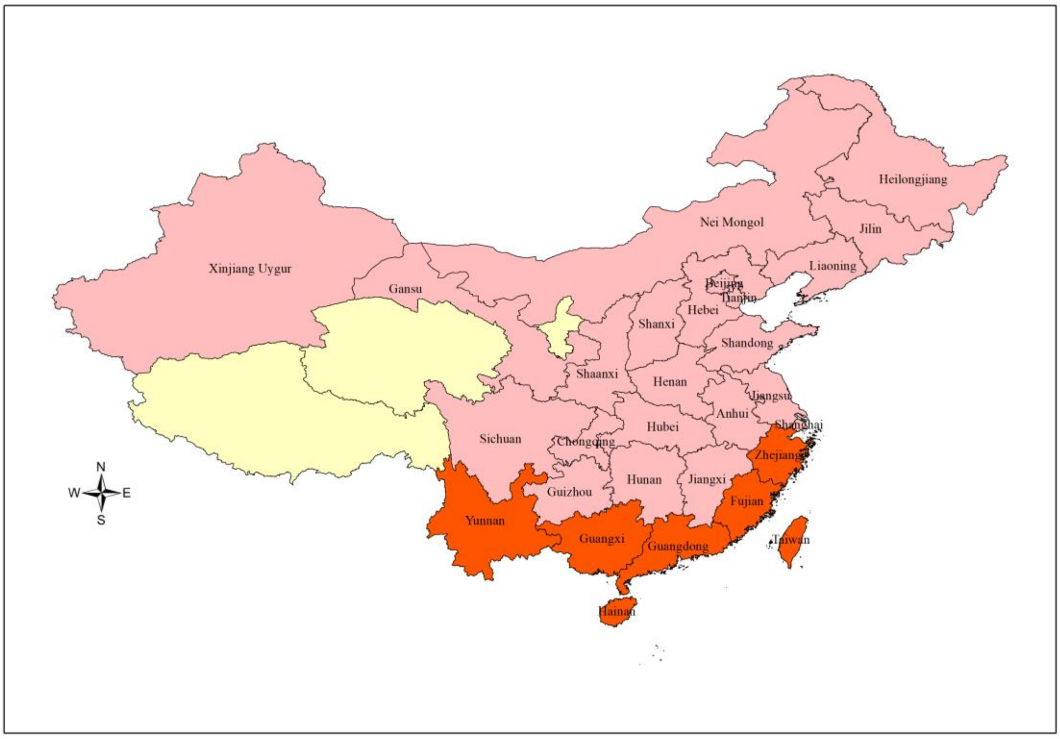
Climate change or climatic variation with unprecedented environmental and land use changes in China during the last few decades will favour the transmission of many climate-sensitive diseases, including vector-borne and rodent-borne diseases [25].

This thesis will focus on three major vector/rodent-borne infectious diseases in China: dengue fever, malaria and hemorrhagic fever with renal syndrome.

(1) Dengue fever (dengue) is an important climate-sensitive mosquito-borne viral disease that affects millions of people in the Pacific region and many other areas. The WHO estimates that 3.9 billion people in 128 countries are at risk of dengue infection; and 390 million dengue infections occur every year [26]. The disease is caused by any of four dengue viruses (DEN-1, DEN-2, DEN-3 and DEN-4) transmitted via *Aedes aegypti and Aedes albopictus* mosquitoes. Breeding sites include pools, streams, tree holes, discarded tyres, drains, tanks, flowers pots and other small holding containers [27]. In China, *Aedes albopicus* is the primary vector, and *Aedes aegypti* is less common. Most dengue cases are found in urban and semi-urban areas in tropical and sub-tropical climate regions. The disease can result in a severe febrile illness, high fever, headache, vomiting, muscle and joint pains, and sometimes leads to potentially lethal hemorrhagic complications [26]. There is no specific medication for dengue infection, and treatment mainly depends on the symptoms [26]. Although a dengue vaccine has recently been licensed, the main preventive measure is still vector/mosquito control [26].

    In China, no dengue fever cases were reported between 1949 and 1977 until an outbreak of DEN-4 dengue fever occurred in Foshan City of Guangdong Province in 1978 [28]. Since then there have been frequent outbreaks of dengue in Guangdong Province where 11,844 cases were reported during the period 1990 to 2005 [29], and an unprecedented outbreak occurred in 2014 in Guangdong Province leading to more than 44,000 cases [30-32]. Other parts of south China including Guangxi, Hainan, Taiwan and Fujian Provinces also frequently report dengue cases. Figure 1.2 shows the geographical distributions of dengue in China. The dengue outbreaks could be related to the increasing imported dengue cases from other countries, in addition to hot, humid and long lasting summers in south China initiating local dengue outbreaks [33]. Other risk factors, such as rapid urbanisation, environmental factors and climate change, may also play roles in dengue transmission and outbreaks.

Figure 1.2 Geographical distributions of dengue in China



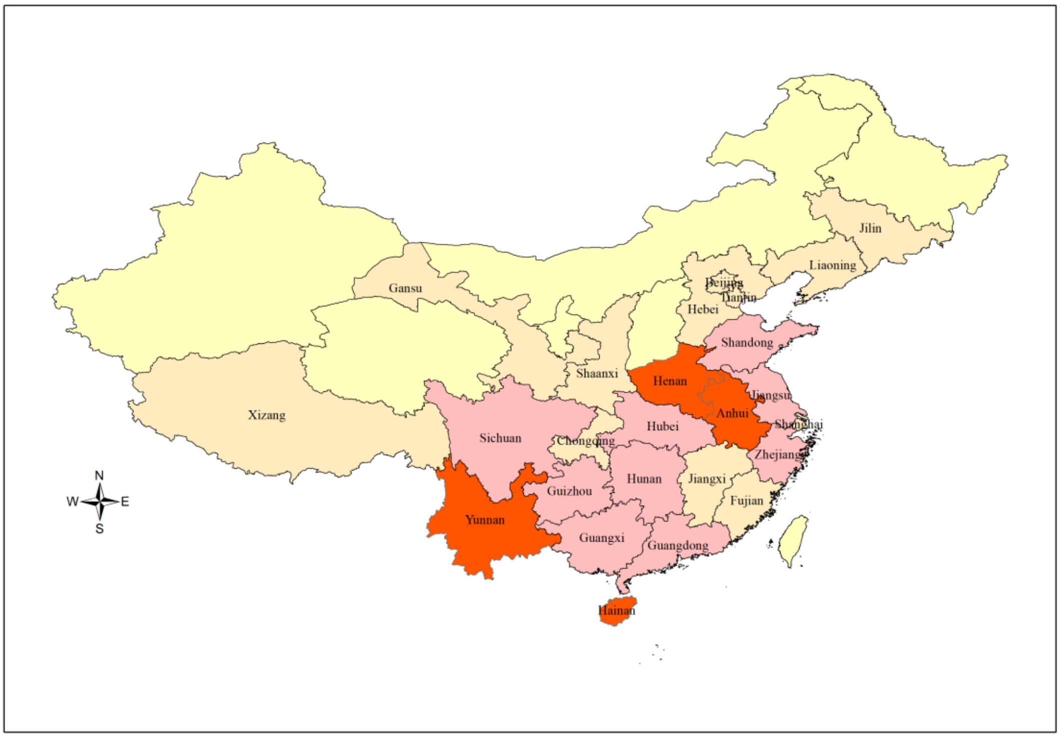
Areas of greatest dengue incidence 2005-2015 are shown in red (Guangdong, Guangxi, Yunnan, Fujian, Zhejiang, Hainan and Taiwan). Data source: China National CDC (http://www.chinacdc.cn).

(2) Malaria is a life-threatening parasitic disease caused by *Plasmodium*. WHO estimated that there were 212 million cases of malaria and 429,000 deaths in 2015 worldwide [34]. In 2015, 91 countries reported ongoing malaria transmission, and most cases concentrated in sub-Saharan Africa, Southeast Asia, Latin America and the Middle East. There are five *Plasmodium* species, which are able to infect humans, including *Plasmodium falciparum*, *Plasmodium vivax, Plasmodium ovale, Plasmodium malariae,* and *Plasmodium knowlesi*. The predominant species of malaria parasite in China are *Plasmodium vivax* and *Plasmodium falciparum* [35, 36]. *Plasmodium falciparum* is the deadliest of the five, while *Plasmodium vivax* is less virulent.

Commonly the disease is transmitted by the bite of the primary vector, female *Anopheles* mosquitoes, which breed in the streams, pools, paddy fields and other water bodies [37]. Symptoms include fever, fatigue, vomiting, headaches, yellow skin, seizures, coma, and in some cases death [38]. The disease can be treated with anti-malarial medications, but drug resistance is increasing and poses a challenge to malaria treatment in the 21st century. There is no vaccine for malaria, and the main preventive measures are mosquito control and prevention of bites.

In China malaria is a serious public health problem that the authorities aim to eradicate by 2020 [39, 40]. During the period 1950 to 1984, the incidence of malaria was more than 100 per 100,000 population [41]. The Chinese government has made considerable efforts to address this public health issue, such as active case detection, vector control, health education, free medications and rapid outbreak response. This has resulted in a significant decline in malaria occurrence during the 1980s and 1990s [42, 43]. As a result, the incidence has been lower than 10 per 100, 000 population since 1990 [41]. However, early this century there was a re-emergence of the disease over several years [42]. Malaria incidence rapidly increased after 2000 and reached its peak in 2006, during which there were 64,178 cases reported in China [44]. The majority of these cases occurred in southwest parts of China – Yunnan Province, bordered by Vietnam, Myanmar and Laos; and central and east regions of China – Anhui, Henan, Jiangsu and Zhejiang Provinces where China's large rivers, the Yangtze River, the Yellow River and the Huai River run through the regions (Figure 1.3) [44]. This could be due to climate change, increased mosquitoes, urbanisation, and more imported cases via travellers and returned workers from overseas.

Figure 1.3 Geographical distributions of malaria in China



Areas of greatest malaria incidence 2005-2015 are shown in red (Anhui, Henan, Yunnan and Hainan). Data source: China National CDC (http://www.chinacdc.cn).

(3) Hemorrhagic fever with renal syndrome (HFRS) is a dangerous zoonotic rodent-borne disease with high fatality caused by hantaviruses. HFRS mostly occurs in Asia and Europe, with 70-90% of the world's cases being reported in China [45-48]. Humans can be infected by inhaling aerosols that are contaminated with the virus shed in excreta, saliva and urine of infected reservoir rodents or by contact with contaminated food and water [49, 50]. The symptoms of the disease include fever, hemorrhage, headache, back pain, hypotension and renal dysfunction [51, 52]. Most HFRS cases are caused by one of two major serotypes of hantavirus – Hantaan virus (HTNV) and Seoul virus (SEOV) in China [52]. The hosts for these viruses are *Apodemus agrarius* and *Rattus norvegicus*, respectively. *Apodemus agrarius* (striped field mouse) is prevalent in agricultural regions of China while *Rattus norvegicus* (brown rat) is prevalent in urban areas or around human environments, such as residences, restaurants, warehouses and stores [53]. Patients infected with

HTNV present with more severe clinical manifestations and suffer higher fatality rates compared with patients infected with SEOV [48]. Supportive therapy including management of patient’s fluid, electrolyte levels, oxygen, blood pressure and renal dialysis, are the main treatments for patients with hantavirus infections [54]. Hantavirus vaccine has been used to protect humans against the disease, but the primary prevention strategies are rodent control and avoiding contact with rodent’s urine, droppings and saliva, and infected food.

There were more than 1 million HFRS cases reported between 1931 and 1995 in China [49], and a majority of these were male farmers aged 30-50 years [47]. HTNV-associated HFRS cases usually peak during autumn and winter (between October and January) in agricultural areas, which could be associated with the harvest activities when farmers work in the fields without appropriate protection [49]. Comparatively, most SEOV-associated HFRS cases are frequently reported during spring and summer months in or around urban areas, which could be due to the reproduction of rodents during this period [55]. The number of HFRS cases peaked in 1986 (115,807 cases) and then declined considerably in the late 1990s (20,000-50,000 cases) due to numerous rodent control measures, such as deratization strategies, vaccination programs, better health care access and health education campaigns [56, 57]. However, the incidence of HFRS has once again rebounded in recent years, in particular the SEOV-associated HFRS infections continue to increase [57-60]. Currently, most HFRS cases in China are concentrated in north-eastern, central and eastern regions of China, e.g. Liaoning, Heilongjiang, Jilin, Shandong, Shaanxi and Anhui Provinces (Figure 1.4) [57]. The possible reasons could be related to climatic factors, rapid urbanisation and land use/cover change.

Figure 1.4 Geographical distributions of HFRS in China

Areas of greatest HFRS incidence 2005-2015 are shown in red (Anhui, Shandong, Shaanxi, Liaoning, Jilin and Heilongjiang). Data source: China National CDC (http://www.chinacdc.cn).

Climate change has and will continue to impact on the transmission of dengue, malaria and HFRS [25]. A considerable body of literature regarding the impact of climate change on infectious disease transmission has illustrated these relationships [39]. This full review of the literature is presented later in Chapter 2 of the thesis. Studies have found that climate change-induced higher temperature accelerates mosquito life cycles, increases mosquito reproduction [39, 61, 62]. Higher temperature also has an influence on the ecology of rodents, increasing the reproduction rate and rodent activities [60, 63]. In addition, human behaviour may change during hot days, with people more likely to sleep outdoors and wear fewer clothes, which increase the contact opportunities between vectors/rodents and humans [39, 49]. These factors help facilitate the transmission of dengue, malaria and HFRS. Thus, there is an imperative for authorities to pay attention to the health effects of climate change including infectious diseases transmission, and build the capacity of the health system to respond to such challenges.

1.1.3 The Chinese healthcare system

In the Chinese healthcare system, both preventive medicine (public health system) and clinical medicine (clinical health system) play important roles in the protection of population health.

In the Chinese public health system, the Centers for Disease Control and Prevention (CDC) work to protect and improve public health and safety by providing information to enhance health decisions, and promote health through partnerships with provincial health departments and other organisations [64]. The CDC system, formally established in 2002, was previously known as the Chinese Academy of Preventive Medicine at the national level, and Anti-Epidemic Stations at the Provincial and lower levels. The main duties of the CDC health professionals include disease prevention, control and surveillance. The administrative divisions of China's CDC system consist of four levels: national, provincial, prefectural and county CDC. There is a CDC in each county, prefecture, and province, in addition to the national CDC.

Currently, there are 39 notifiable infectious diseases classified as Categories A, B, C according to their epidemic levels and risk to the population in China [65, 66]. Diseases in Categories A and B pose a high risk to population health, and are likely to spread rapidly among the public and lead to disease epidemics or outbreaks [66]. Dengue, malaria and HFRS are classified in Category B [65]. The 39 notifiable infectious diseases are required to be notified to local CDCs by law.

In clinical the healthcare system, hospitals provide patient diagnosis, treatment and management with specialised medical care. Clinical health professionals in hospitals perform diagnosis, treatment and management of cases and have the responsibility to report cases of notifiable diseases to the relevant local CDC [67]. There are three tiers of hospitals: primary hospitals, secondary hospitals and tertiary hospitals. Primary hospitals are typically township hospitals providing minimal health care service to local communities. Secondary hospitals, normally affiliated with county-level cities, can provide comprehensive health care service for a large regional population. Tertiary hospitals are comprehensive hospitals at prefectural, provincial or national level cities, which can provide specialised health service, and play roles in medical training, education and scientific research for multiple regional populations.

1.1.4 Capacity to manage infectious diseases

Many studies have been undertaken to quantify the association between climate variability/climate change and dengue, malaria and HFRS [68-70]. However, studies concerning health professionals' perception of these infectious diseases and the current capacity of the health system to deal with these are rarely conducted [71, 72]. Only two relevant studies have been conducted in China, and these indicate that CDC staff had noticed the health risks and infectious diseases challenges posed by climate change [71, 72]. However, these studies were conducted among CDC staff in one province only, so the data might be insufficient to reflect the perception of a larger group of health professionals in different geographical areas of China. Health professionals' perceptions of diseases and the capacity in China to deal with these emerging and re-emerging diseases play a significant role in infectious disease control and prevention locally and nationally [73]. Furthermore, as an important part of the Chinese healthcare system, hospitals play significant roles in the protection of population health. So far there has been no study examining the perception of clinical professionals about climate change and infectious disease control and their capacity to deal with such challenges in Chinese hospitals. It is necessary to conduct this research to further investigate health professionals' perceptions of climate change and infectious diseases, and explore China's capacity to control emerging and re-emerging vector/rodent-borne diseases in order to identify challenges that may arise with climate change and reduce the adverse impact on population health.

1.2 Aims, research questions and objectives

1.2.1 Aims

This research project aims to make a contribution to better understanding health professionals' perceptions of climate change and infectious diseases, and the capacity of China's health system to deal with infectious diseases in the context of climate change. To achieve these aims, two studies were conducted among infectious disease control and prevention professionals, public health physicians, clinical staff, laboratory technicians and relevant health workers in CDCs and hospitals in China. The first study comprised investigations on the three case study diseases and mainly focused on the public health professionals in CDCs, while the second targeted clinical health professionals in hospitals. The research was conducted within the context of climate change and capacity of the health system in relation to infectious diseases.

1.2.2 Research questions

Based on the aims of this research project, the two main research questions were: 1) What are the health professionals' perceptions of climate change and its impact on emerging and re-emerging infectious diseases? 2) What is the perceived capacity of the health system to deal with these emerging and re-emerging infectious diseases in the face of climate change in China? The specific research questions were:

- What are public health professionals' perceptions of climate change and capacity of dengue control and prevention?
- What are public health professionals' perceptions of climate change and capacity of malaria control and prevention?
- What are public health professionals' perceptions of climate change and capacity of HFRS control and prevention?
- What are clinical health professionals' perceptions of the hospital healthcare system's capacity to meet the challenge of emerging and re-emerging infectious diseases in the face of climate change?

1.2.3 Research objectives

The objectives of this research project were: 1) To investigate the health professionals' perceptions of climate change and its impact on emerging and re-emerging infectious diseases, 2) To investigate the capacity of the health system to deal with emerging and re-emerging infectious diseases in the face of climate change.

The specific objectives of the project were to:

- Survey public health professionals to investigate their perceptions of emerging and re-emerging infectious diseases in the context of climate change.
- Survey clinical health professionals to investigate their perceptions of emerging and re-emerging infectious diseases in the face of climate change.

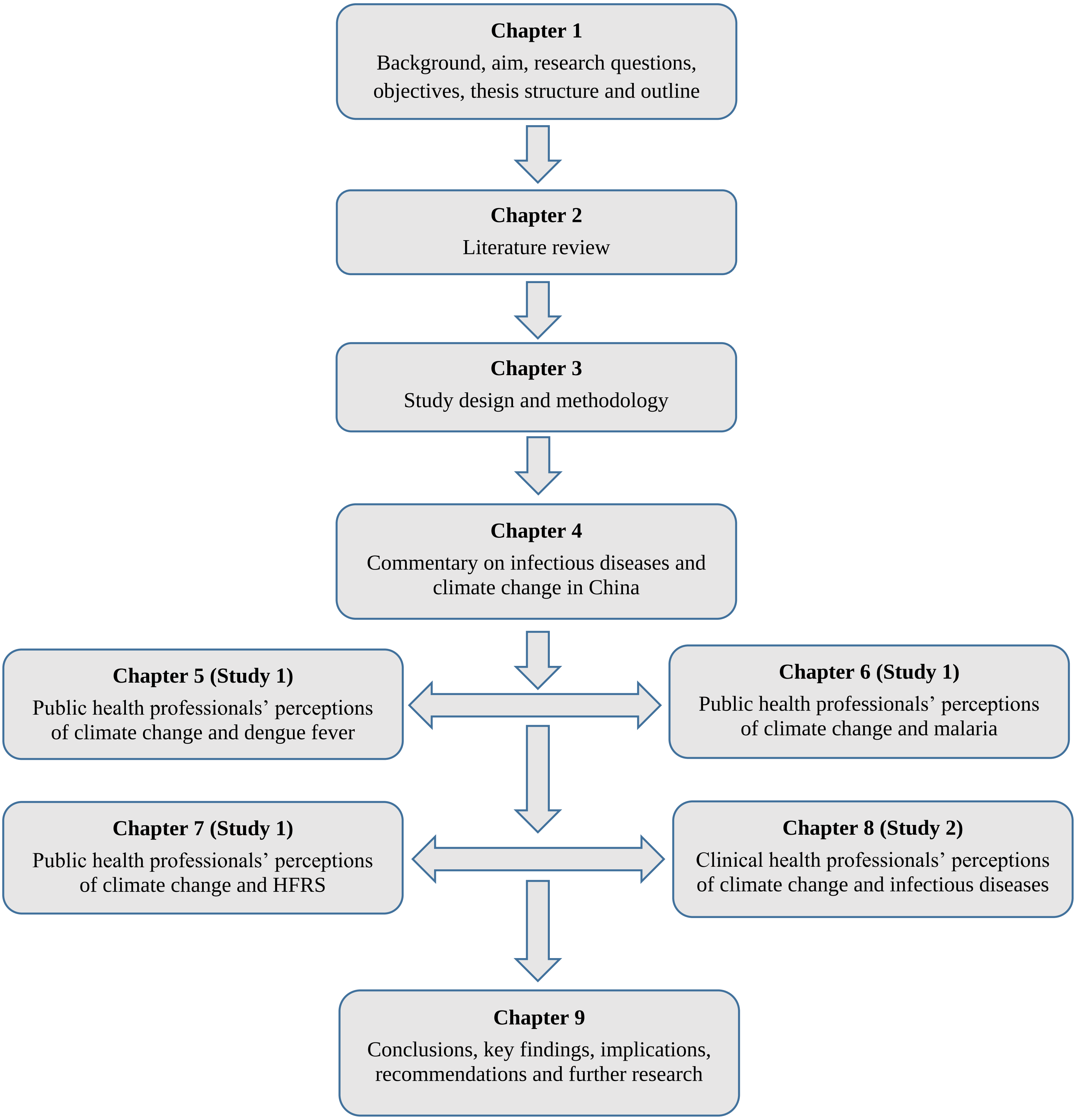
- Assess the efficacy of the health system to deal with infectious diseases in the context of climate change.

1.3 Thesis structure and outline

This thesis is structured in three parts. The first part includes the introduction, the literature review, study design and methodology (Chapters 1 to 3). The second part consists of five chapters (Chapter 4 to 8) organised in the form of published papers and/or manuscripts derived from studies conducted. Each article and/or manuscript addresses parts of the four research questions. The third part consists of the conclusions (Chapter 9), which highlight the key findings, implications, recommendations and further research directions. The schematic diagram of the thesis structure is shown in Figure 1.5.

The thesis is presented in the form of ***'Thesis by publication'***. Two studies were conducted for this research project; five published papers and/or manuscripts were derived from the studies. Of these, one publication was derived from the literature review, three published papers and/or manuscripts were derived from the first study, and one was derived from the second study. As the published papers and/or manuscripts were derived from the two studies, the materials and methods are similar, although the study settings differ. Details of the survey questionnaires for health professionals, and the setting and timing of data collection for each study can be found in Chapter 3.

Figure 1.5 Schematic diagram of thesis structure



NOTE: Published papers and/or manuscripts were drawn from Chapters 4-8.

Below is a brief description of the contents of each chapter:

Chapter 1 provides an introduction to the study and outlines an overview of the research project by describing the research background, research settings, case study diseases, research aims, questions and objectives. The schematic diagram of the thesis is then presented to show the thesis outline and the link to each chapter in framing the overall structure of the thesis.

Chapter 2 reviews the literature on emerging and re-emerging infectious diseases in the context of climate change in China. The aim of this chapter is to summarise the knowledge and understanding of meteorological factors and their associations with infectious disease transmission, using dengue, malaria and HFRS as examples of infectious diseases in China. The review examines the relationships between dengue, malaria, HFRS and metrological factors, capacity of the health system to deal with these diseases including health professionals' perceptions of climate change and its impact on emerging and re-emerging infectious diseases. It also emphasises the necessity and significance to better understand the capacity of the health system in China to meet such challenges and outlines further research directions.

Chapter 3 gives a general outline of the study design, questionnaire instrument, data collection, data management and data analytic approaches. It also provides an overall description of the geographical characteristics of the study region, and health professionals' demographic characteristics. More detailed methods will be addressed in Chapters 5 to 8.

Chapter 4 is an extension of Chapter 2 and is a published article discussing challenges from infectious diseases, urbanisation and climate change in China. It explores China's current capacity to manage infectious diseases, discusses the existing disease surveillance system, and underscores the critical importance of strengthening the system. It also explores how the growing migrant population, dramatic changes in the natural landscape following rapid urbanisation, and changing climatic conditions have contributed to the emergence and re-emergence of infectious diseases.

Chapter 5 is the first of the Study 1 articles. It presents a quantitative article using a cross-sectional study design that explores public health professionals' perceptions of climate change and its impact on emerging and re-emerging dengue fever in

Guangdong Province, China. It also appraises the capacity of infectious disease control and prevention in the context of climate change. Lastly, adaptation measures in the face of climate change and strategies in building capacity to deal with infectious diseases are explored. The chapter addresses the research question: *"What are the public health professionals' perceptions climate change and capacity of dengue control and prevention?"*.

Chapter 6 is the second of the Study 1 articles. It presents an article that investigates public health professionals' perceptions of malaria control and prevention in an era of climate change in China, which addresses the research question: *"What are the public health professionals' perceptions of climate change and capacity of malaria control and prevention?"*. The article describes public health professionals' understanding of the relationship between the emergence/re-emergence of malaria and climate change. It also indicates perceptions of the main reasons for such emergence/re-emergence of malaria. The study was quantitative and used a cross-sectional study design.

Chapter 7 is the third of the Study 1 articles. It comprises an article that gauged the perceptions of public health professionals concerning HFRS control and climate change, which addresses the research question: *"What are the public health professionals' perceptions of climate change and capacity of HFRS control and prevention?"*. The article describes public health professionals' views about current HFRS epidemic trends and their understanding of the association between HFRS and climate change. It also explores the main reasons for HFRS' emergence and re-emergence. As in the previous studies, a cross-sectional study design was used.

Chapter 8 is the Study 2 article. It presents a study that explores the capacity of the hospital healthcare system to deal with the challenge from emerging and re-emerging infectious diseases in terms of diagnosis, treatment and management, using the three case study diseases as examples. The chapter addresses the research question: *"What are the clinical health professionals' perceptions about the capacity of hospital healthcare system to meet the challenge of emerging and re-emerging infectious diseases in the face of climate change?"*.

Chapter 9 summarises the conclusions of the research project. It discusses the key findings of the research project, explores the potential implications and generates recommendations for capacity building to curb the health impact of the emerging and re-emerging infectious diseases due to climate change. It also describes the strengths and limitations of the research project. Lastly, areas for further research are suggested.

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CHAPTER 2 LITERATURE REVIEW

2.1 Introduction

This chapter provides a comprehensive literature review of studies relating to two main themes of the thesis – the link between climate change and infectious disease transmission in China, and the capacity of China's healthcare system to deal with the challenges from climate-sensitive diseases. The latter includes health professionals' perceptions of climate change and its impact on these diseases. To investigate the capacity of the healthcare system holistically, both public health and clinical health systems need to be considered together with disease surveillance, control, prevention, emergency response, diagnosis, treatment and management.

This chapter begins with a literature review of the quantitative association between meteorological factors and infectious diseases, using dengue, malaria and HFRS as examples, with a particular focus on climate variation and its impact on these disease transmissions in China. The direct health effects of climate variation on human health in general, such as exposure to high or low temperatures and their impact on chronic diseases, does not form part of the literature review. A review of the literature regarding China's capacity to manage infectious diseases follows. Finally, knowledge gaps are identified, suggesting there is much we are yet to understand about climate-sensitive diseases and, critically, that there is much work to be done to enhance China's capacity of the healthcare system to respond to emerging and re-emerging infectious diseases.

In terms of the scope of the literature review, it should be noted that the literature focuses on studies within China's mainland area, covering most of China. The meteorological factors considered include temperature, rainfall, humidity, air pressure, sunshine duration, wind velocity, fog, cloud and evaporation. Some studies also considered non-climatic factors, such as urbanisation, agriculture, housing, occupation and human activities [1-13].

Some studies used ecological proxy indicators, which are metrics serving as proxies for change in ecological systems. These include Normalised Difference Vegetation Index (NDVI), South Oscillation Index (SOI), and Multivariate El Niño Southern Oscillation

Index (MEI) which have been associated with climate-sensitive diseases [14-26], which are described thus:

1) NDVI is a graphical indicator that can be used to assess whether the target being observed contains live green vegetation or crops [27-30]. This can be considered as an integrated indicator reflecting climatic conditions such as temperature, humidity, and precipitation in local areas [15].

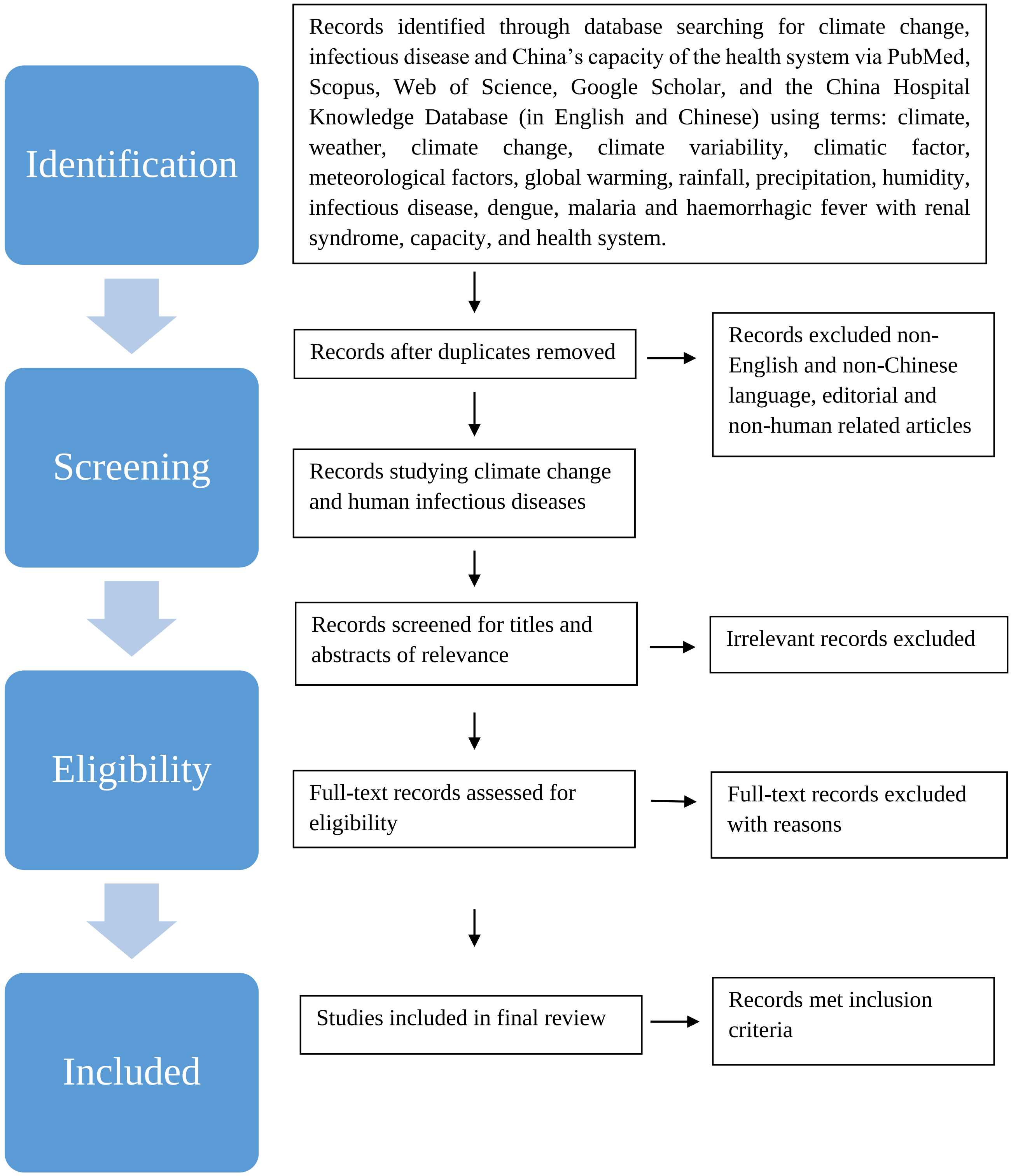
2) SOI is an index that is calculated based on the difference in air pressure between Darwin and Tahiti, and it provides an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean [31]. The sustained positive value of SOI is typical of La Niña conditions (wet and cool), and a negative value predicts an El Niño episode (dry and warm) [20, 21].

3) MEI, as an indicator of global climate pattern, is a method used to characterise the climatic conditions, e.g. sea-level pressure, sea surface temperature, surface air temperature and surface wind, contributing to the onset of the El Niño Southern Oscillation event, which is the most important oceanic-atmospheric phenomenon affecting climate variability, particularly in Pacific Ocean regions [32].

2.2 Method

A search of recently published research studies (between 2004 and 2016) was conducted to establish the impact of climate change on emerging and re-emerging infectious diseases in China. A review protocol to guide the review process was produced based on previously published methods [33]. A comprehensive search strategy was developed. The electronic databases PubMed, Scopus, Web of Science, Google Scholar and the China Hospital Knowledge Database were used to search for relevant literature. Figure 2.1 illustrates the search strategy, inclusion and exclusion process.

Figure 2.1 Flowchart of literature search strategy



2.2.1 Search strategy

The following electronic databases, published in English or Chinese, were used to search for climate change, infectious diseases and China's capacity of the health system with the abstract or full text.

- PubMed
- Scopus
- Web of Science
- Google Scholar
- China Hospital Knowledge Database (CHKD)

The 'Google' search engine was also conducted to source relevant 'grey literature', such as government reports.

A search strategy of random combinations of the following keywords [MeSH] terms and keywords [tiab] was used in this review. The field code 'tiab' is the abbreviation of 'title or abstract'.

- Climate
- Weather
- Climate change
- Climate variability
- Climatic variation
- Climatic factor
- Meteorological factor
- Global warming
- Temperature
- Rainfall
- Precipitation
- Humidity
- Infectious disease
- Communicable disease
- Dengue
- Malaria

- Hemorrhagic fever with renal syndrome
- Knowledge
- Attitude
- Perception
- Policy
- Regulations
- Guidelines
- Capacity
- Health system
- China

Titles and abstracts were first screened for relevance and full texts were then obtained to evaluate whether the article met the inclusion criteria below. Reference lists of each article were then checked for additional articles missed or unidentified in the initial electronic database search using citation snowballing of reference lists.

2.2.2 Inclusion criteria

Studies published between 2004 and 2016 were included in this review, as the Chinese Center for Disease Control and Prevention (CDC) was formally established in 2002, although it was existing under the different name (Chinese Academy of Preventive Medicine) previously [34]. With the establishment of the China CDC significant changes and improvements occurred in China's public health infrastructures, disease surveillance, disease reporting and laboratory testing after the Severe Acute Respiratory Syndrome (SARS) outbreaks in 2003 [35]. Therefore, studies published after 2004 can more reliably and closely reflect the current capacity of the health system in China. The inclusion criteria included:

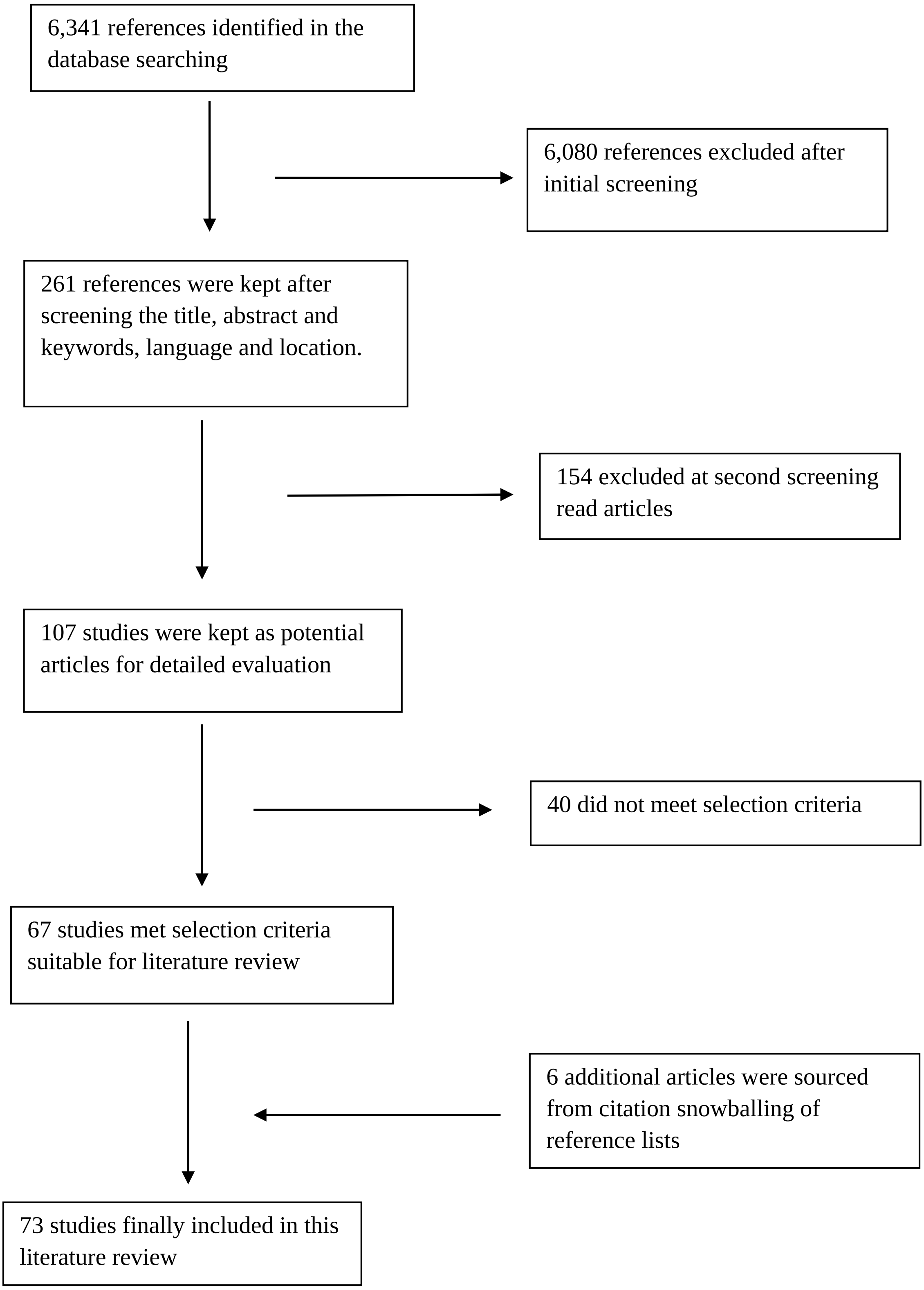
- Studies of effects of climatic factors or meteorological variables (e.g. temperature, rainfall and humidity, etc.) on the incidence and transmission of human infectious diseases (e.g. dengue, malaria and HFRS) or related to capacity of the health system, knowledge, attitude, perception, policy, regulation and guideline about climate change in relation to these diseases.
- Local and national studies in China
- Either English or Chinese language articles

2.2.3 Exclusion criteria

- Studies of the effects of climatic factors or meteorological variables on chronic diseases, migration, economics, agriculture, industry and general morbidity and mortality rather than selected infectious diseases
- Studies published in languages other than English or Chinese
- Publication date before 2004
- Review articles, editorials, letters, conference abstracts

The initial search generated 6,341 articles from PubMed, Scopus, Web of Science, Google Scholar and CHKD databases. Review of the titles, abstracts and location excluded 6,080 articles leaving 261 studies identified as potential review articles. Then, 107 full-text articles were identified based on the abstracts and evaluated for inclusion. Of these, 67 articles met the inclusion criteria and 6 additional articles were included from citation snowballing of reference lists. The process is shown in the data flow diagram (Figure 2.2). The details of final included articles are summarised in Table 2.1.

Figure 2.2 Flowchart outlining included and excluded articles



2.3 Results

The study sites of these reviewed articles covered most parts of China. Dengue fever transmission and its association with weather variables have been studied in Guangdong, Guangxi, Fujian and Zhejiang Provinces, which are located in the subtropical climate zone [36-38]. The relationship between climate variability and malaria has been studied in many regions of China, including Henan, Yunnan, Sichuan, Guizhou, Anhui, Jiangsu, Guangdong, Hubei, Jilin, Liaoning, Shandong, Hainan Provinces, Tibetan Autonomous Region and Chongqing Municipality [7, 8, 16, 18, 19, 39-46]. Studies examining HFRS and climatic variables have been undertaken in Anhui, Liaoning, Shandong, Shanxi, Jilin, Hunan, Heilongjiang, Hebei, Hubei, Jiangsu Provinces and Chongqing Municipality [5, 11, 18, 21, 47-54]. Figure 2.3 shows geographic locations of China.

Table 2.1 Summary of the studies reviewed

Study	Study area & period	Risk factors	Methods	Key findings
Dengue				
Xu et al. (2017) [55]	Guangzhou 2005-2015	Temperature, rainfall, mosquito density	-Time series analysis -Structural equation model (SEM) -Generalised additive model (GAM)	Climate has both direct positive effects on dengue incidence and indirect positive effects mediated by mosquito density. Temperature has a significant positive effect on both outbreak risk and intensity. Precipitation has a non-significant positive association with outbreak risk, and a significant positive association with outbreak intensity. There was a strong link between dengue incidence and density of mosquitoes.
Liu et al. (2017) [56]	Zhongshan 2001-2013	Temperature, rainfall, humidity, Breteau index (BI)	-Time-series regression tree analysis -Cross-correlation analysis	Dengue incidence rates were significantly positively associated with monthly maximum temperature and mean BI at 1-3 month lagged moving average, with monthly imported cases at a lag of 1 month. Minimum relative humidity was positively associated with the dengue incidence rates at a lag of 2 months.
Xiang et al. (2017) [57]	Guangzhou 2005-2014	Temperature, rainfall, humidity, sunshine duration, wind velocity	-Descriptive analysis -Spatial analysis -Distributed lag non-linear model (DLNM) -Generalised estimating equation models (GEE) with piecewise linear spline functions	Middle-aged and older people, people undertaking household duties, retirees, and those unemployed were at high risk of dengue. The optimal maximum temperature range for dengue transmission in Guangzhou was 21.6-32.9 ℃ and 11.2-23.7 ℃ for minimum temperature. A 1 ℃ increase of maximum temperature and minimum temperature within these ranges was associated with 11.9% and 9.9% increase in dengue at lag0. Average relative humidity was negatively associated with dengue when it exceeded 78.9%. Maximum wind velocity inhibited dengue transmission.

Zhang et al. (2016) [58]	Guangzhou, Zhongshan 2005-2014	Temperature, humidity, rainfall, dengue cases in Guangzhou	-Cross-correlation analysis -Generalised linear model (GLM)	Regular epidemics in Zhongshan generally occurred after a few weeks of Guangzhou outbreaks, except for 2013. Guangzhou dengue cases had a positive correlation with Zhongshan's weekly dengue cases (Relative Risk (RR) =2.016, 95% Confidence Interval (CI): 1.845-2.203). Minimum temperature (RR=1.335, 95% CI: 1.125-1.583), relative humidity (RR=1.207, 95% CI 1.151-1.265), and rainfall (RR=1.031, 95% CI: 1.026-1.037) had positive correlation with dengue case counts in Zhongshan.
Gu et al. (2016) [59]	Guangzhou 2005-2011	Temperature, humidity, air pressure, precipitation, wind speed, sunshine duration	-Boosted regression tree model (BRT)	Daily average temperature and humidity were positively associated with dengue infections. Daily precipitation could have a complex relationship with the risk of dengue. Daily sunshine was positively associated with dengue when durations were less than 9 hours. The risk increased with the increase in daily average wind speed from 0 m/s to 4 m/s. High temperature 20 to 30 ˚C and high humidity 90% to 100% with lag 62 days contributed to the dengue epidemic.
Jing et al. (2016) [60]	Guangzhou 2014	Temperature, Breteau index (BI), adult mosquito density	-Pearson correlation analysis -Cross-correlation analysis	Both BI and adult mosquito density are statistically significantly correlated with the daily newly reported cases. Temperature is closely correlated to the transmission of the dengue virus, which can be either a barrier or a facilitator of vector-borne diseases.
Zhu et al. (2016) [61]	Guangzhou 2014	Breteau index (BI), population density, transportation	-Spatio-temporal analysis -Markov china Monte Carlo (MCMC) method	The highest incidence rates were around the urban centre, which could be due to high concentrations of people, highly fluid population, abundant initial infections and high vector density. Population density and mobility play significant roles in dengue diffusion. The rapid decline of BI results in a rapid decline in the incidence rate.
Chuan et al. (2015) [62]	Guangzhou 2006-2014	Breteau index (BI), temperature, humidity, rainfall	-Time-series analysis	Mosquito density, monthly average temperature and minimum temperature play a critical role in dengue transmission in Guangzhou. An increase of 1 in the current month’s BI was

			-Negative binomial regression model -spearman correlation analysis	associated with 30.1-35.8% increase in dengue incidence. An increase of 1.0 ˚C in previous monthly minimum temperature and previous monthly average temperature were related to a 51.8% and 52.8% increase in dengue incidence, respectively. An increase of 1.0 ˚C in the current monthly minimum temperature was related to a 64.9% increase in dengue incidence when the current monthly minimum temperature was smaller than 18.3 ˚C.
Fan et al. (2014)[20]	Guangdong 2005-2011	Daily vapour pressure, humidity, atmospheric pressure, temperature, SOI	-Time-stratified case-crossover model	Atmospheric pressure (at lags of 0-3 days) and daily mean and minimum temperatures with 2- to 3-day lags were positively associated with dengue fever, while daily maximum temperature (at lags of 0-2 days) and SOI (at lags of 0-2 days) were negatively associated with dengue fever epidemics. No significant association was observed for humidity and rainfall.
Sang et al.(2014)[10]	Guangzhou 2006-2012	Mosquito density, imported cases, temperature, precipitation, vapour pressure, humidity, air pressure, wind velocity	-Autocorrelation and cross-correlation analysis -Principal component analysis (PCA) -Time-series Poisson regression analysis	Dengue fever cases were positively associated with mosquito density, imported cases, temperature, precipitation, vapour pressure and minimum relative humidity, and negatively associated with air pressure, with different time lags.
Wang et al.(2014)[63]	Guangzhou 2000-2012	Humidity, temperature, wind velocity, rainfall	-Cross-correlation analysis -Zero-inflated Poisson regression model	Dengue fever in Guangzhou showed a seasonal pattern. At the same temperature, egg hatchability of *A. albopictus* increases as the relative humidity rises. Extreme wind velocity tends to suppress mosquito flight. The number of dengue cases and minimum temperature at 1-month lag, along with average relative humidity at 0- to 1-month lag were all positively correlated with the prevalence of dengue fever, whereas wind velocity and temperature in the same

				month, along with rainfall at 2 months' lag, showed a negative association with dengue incidence.
Li et al.(2013)[36]	Guangzhou 2007-2012	Temperature, atmospheric pressure, wind velocity, humidity	-Negative binomial regression -Pearson's correlation	Each 1 ˚C rise of temperature corresponded to an increase of 10.23% (95%CI 7.68%-12.83%) in the monthly number of dengue fever cases, whereas 1hPa rise in atmospheric pressure corresponded to a decrease in the number of cases by 5.14% (95% CI 7.10%-3.14%). Each one meter per second rise in wind velocity led to an increase by 43.80% or 107.53%, and one percent rise of relative humidity led to an increase by 2.04% or 2.19%.
Lu et al.(2009)[1]	Guangzhou 2001-2006	Temperature, wind velocity, humidity, rainfall	-Time series Poisson regression analysis -Generalized Estimating Equation(GEE) approach -Quasi-likelihood based information criterion -Spearman rank correlation	Minimum temperature and wind velocity are significant predictors of dengue incidence. Further inclusion of minimum humidity in the model provided a better fit. Minimum temperature and minimum humidity, at a lag of one month, were positively associated with dengue incidence, while wind velocity was inversely associated with dengue incidence of the same month.
Yang et al.(2009)[37]	Cixi 2004	Occupation, temperature, humidity, precipitation, House Index and Container Index	-Descriptive analysis -Epidemiological investigation	Eighty-three cases, mainly young and middle-aged people between 20 and 50 (78.3%), were reported in the area of Cixi. There were no obvious occupational patterns. The majority of cases were female. The incidence of dengue fever had no relationship to temperature, humidity, or precipitation and the Breteau index of larvae showed a clear relationship only with the House Index and Container Index.
Lu et al.(2010)[38]	China 1970-2000	Temperature, humidity,	-Correlation analysis -GIS	Dengue fever outbreaks were significantly correlated with climatic variables with 8-10 weeks lags.

		rainfall, duration of sunshine		
Malaria				
Yang et al. (2017) [64]	Yunnan 2012	Temperature, rainfall, proportion of rural employees, rice yield	-Spatial-temporal cluster analysis -Geographically weighted regression	The incidence in the group aged 20-30 years was the highest. The majority (84.1%) of malaria cases occurred in farmers and migrant workers. Annual average temperature, annual cumulative rainfall, rice yield per square kilometre and proportion of rural employees were positively associated with the malaria incidence rate.
Guo et al. (2015) [65]	Guangdong 2005-2013	Temperature, duration of sunshine, precipitation, wind speed, atmospheric pressure, humidity	-Granger causality Wald test -Spearman correlation analysis -Distributed lag non-linear model (DLNM)	High temperature was associated with an increase in malaria incidence with the effect lasting for four weeks and a maximum relative risk of 1.57 by comparing 30 ˚C to the median temperature of 23.5 ˚C. An increase in sunshine hours was associated with a significant increase in malaria incidence when weekly sunshine duration was shorter than 40 hours/week. A J-shaped relationship was found between malaria incidence and precipitation with a threshold of 150 mm/week at the lag of 5 to 12 weeks.
Zhao et al. (2014)[66]	Southwest China 2004-2009	Temperature, rainfall, humidity	-Poisson regression, Distributed lag non-linear model (DLNM)	Large daily temperature fluctuations functioned to expedite malaria incidence in cooler environmental conditions. Under warmer conditions, high daily fluctuation led to slow down the mean temperature effect. The optimal mean temperatures were detected at 24-25 ˚C or 21-23 ˚C depending on the choice of lag ranges.
Zhao et al.(2014)[67]	Southwest China 2004-2009	Rainfall, temperature, humidity	-Multilevel Distributed Lag Non-linear Model (MDLNM)	Rainfall was associated with malaria cases in both hot and cold weather. Humidity was negatively associated with malaria during hot weather 4-5 weeks, while no significant during 13-15th weeks and cold weather.
Ding et al.(2014)[68]	Mengcheng 2007	Flooding and waterlogging,	-Stratified Cox model	Malaria was significantly associated with flooding and waterlogging after fitting meteorological factors. The strongest effect was shown

		humidity, rainfall, temperature, sunshine duration	-Stratified cox regression analysis -Years lived with disability(YLDs) -Multivariate analysis	with a 25-day lag for flooding and a 7-day lag for waterlogging. An increased risk of malaria was significantly associated with flooding and waterlogging.
Wardrop et al.(2013)[69]	Yunnan 1991-2006	Temperature, rainfall	-Distributed lag non-linear model -Generalised linear Poisson model -Linear regression	In all four counties in this study, peak malaria incidence was between July and September, corresponding with peak rainfall during the summer season. Additionally, smaller peaks in malaria were seen with higher monthly rainfalls during January and February. Increasing temperature resulted in increased malaria risk in all four areas and increasing rainfall resulted in increased malaria risk in one area and decreased malaria risk in one area.
Bi et al.(2013)[70]	Yunnan 2005-2010	Temperature, humidity, rainfall	-Spatial cluster analysis, distributed lag nonlinear model -Spearman's correlation -Poisson regression model	Two types of malaria were studies near the China-Myanmar border. Minimum temperature, relative humidity and rainfall were significantly associated with the transmission of *P. vivax and P. falciparum*, with the RRs of 1.19 (95% CI, 1.04-1.35) for temperature, 4.38 (95%CI, 1.86-10.30) for relative humidity and 1.18 (95%CI, 1.05-1.34) for rainfall overall.
Hsiang et al. (2013)[7]	Jiangsu 1973-1983 2000-2009	Mass drug administration (MDA), co-interventions, rainfall, GDP	-Population average negative binomial model -Poisson model, Generalised Estimating Equations with an autoregressive correlation	Total population MDA was negatively associated with malaria monthly incidence. However, co-interventions, rainfall and GDP were not associated with malaria incidence.

Li et al.(2013)[71]	Guangzhou 2006-2012	Temperature, humidity, atmospheric pressure, wind velocity, sunshine, rainfall	-Negative binomial regression -Preliminary analysis	Of the six meteorological variables studied, temperature, relative humidity and sunshine were statistically significant in the final model. Each 1 ˚C rise of temperature corresponded to an increase of 0.90% in the monthly number of malaria cases. One percent rise in relative humidity led to an increase of 3.99% and a one hour rise in sunshine led to an increase of 0.68% in the monthly number of cases.
Yang et al.(2012)[39]	China 1961-2000	Temperature, humidity	-Disease mapping using a biology-based model	Considering multiple environmental factors simultaneously, the environmental variables suitable for malaria transmission were found to have shifted northwards, which was especially pronounced in northern China. The unstable suitable regions showed increased transmission intensity due to prolonged suitable periods, especially in the central part of the country.
Luo et al.(2012)[46]	Guangdong 1980-2004	Temperature, humidity, rainfall	-Negative binomial distribution regression analysis -Time-series analysis method and by distributed lag non-linear model	Malaria incidence was highest when the temperature reached 32.3 ℃, the relative risk (RR) was 2.51 (95%CI: 1.99 - 3.16); when the relative humidity was 60.0%, RR as 1.19 (95%CI: 0.66 - 2.11); when the relative humidity was 86.6%, the risk of malaria was lowest at 0.51 (95%CI: 0.34 - 0.76); when the rainfall was 14.5mm, the risk of malaria was the highest at 1.29 (95%CI: 0.87 - 1.93).
Zhang et al.(2012)[40]	Yongcheng 2006-2010	Temperature, humidity, malaria incidence of the previous month, rainfall, wind velocity, duration of sunshine	-Geographical information system(GIS) -Time series analysis -Univariate analysis -Multivariate analysis	Monthly incidence at prefecture-level demonstrated a strong seasonal pattern with a peak from July to November. Yearly malaria incidence had a spatial association with yearly average temperature. The maximum temperature at one month lag, average humidity at one month lag, and malaria incidence of the previous month contributed to malaria incidence.

			-Generalised estimating equation (GEE) approach -Poisson and n-binomial regression	
Gao et al.(2012)[14]	Anhui 1990-2009	Temperature, rainfall, humidity, EI Nino/Southern Oscillation Index	-Spearman correlation analyses -Polynomial distributed lag (PDL) time-series regression -Spatial and temporal analysis	Monthly incidences of malaria were significantly associated with temperature, rainfall, relative humidity, and the multivariate EI Nino/Southern Oscillation index with lags of 0-2 months. Rainfall was found to have the highest correlation with the incidence of malaria, followed by RH, MEI and temperature.
Huang et al.(2011)[41]	Central China 1990-2009	Temperature, humidity, rainfall	-Spatial and spatiotemporal model -Bayesian hierarchical models -GIS	The way rainfall influenced malaria incidence was different from other factors, which could be interpreted as rainfall having a greater influence than other factors.
Huang et al.(2011)[42]	Motuo, Tibet 1986-2009	Temperature, humidity, rainfall	-Spearman correlation analysis -Cross-correlation analysis -Inter-annual analysis	Spearman correlation analysis demonstrated relative humidity was greatest relative to malaria incidence and the correlation coefficient was 0.543 (P<0.01). Strong positive correlations were found for malaria incidence lagging one to three months behind rainfall (r>0.4) and lagging zero to two months behind temperature and relative humidity (r>0.5) by cross-correlation. A strong negative correlation coefficient between differenced annual average maximum

			-Multiplicative seasonal autoregressive integrated moving average models(SARIMA),	temperature and differenced annual malaria incidence was significant.
Zhou et al.(2010)[8]	Huang-Huai River 1990-2006	Temperature, humidity, rainfall	-Spearman correlation, -Multiple regression analysis -Curve fitting and trend analysis -Entomological investigation	The annual average temperature and rainfall may have a close relationship with annual incidence. The average monthly temperature and rainfall were the key factors, with correlation coefficients of 0.501 and 0.304 (P<0.01). Humidity was not associated with malaria incidence.
Yang et al.(2010)[72]	China 1981-1995	Temperature, rainfall, humidity	-Integrated biology-driven and statistical model -Delphi approach -Multiple logistical regression -GIS	Temperature was found to be the most important environmental factor, followed by rainfall and relative humidity using the Delphi evaluation. However, relative humidity was found to be more important than rainfall and temperature in the ranking list according to the three single environmental factor regression models.
Zhang et al.(2010)[43]	Jinan 1959-1979	Temperature, rainfall, humidity, air pressure	-Time-series data analysis -Spearman correlation -Cross-correlation -Seasonal autoregressive integrated moving average(SARIMA) model	SARIMA models indicated that a 1 ˚C rise in maximum temperature may be related to a 7.7% to 12.7% increase and a 1 ˚C rise in minimum temperature may result in approximately 11.8% to 15.8% increase in number of malaria cases. An association between malaria incidence and rainfall and humidity was not detected in this study. Correlation analyses indicate air pressure was negatively correlated with monthly cases of malaria.

Xiao et al.(2010)[73]	Hainan 1995-2008	Temperature, rainfall, humidity	-Cross correlation and autocorrelation analyses, -Multivariate time series analysis -Spatial distribution analysis -Temporal distribution analysis -Poisson regression -GIS	The highest malaria incidences were mainly distributed in the central-south counties of the province. The peak incidence period was May to October when nearly 70% of annual malaria cases were reported. Humidity and rainfall were not relative to malaria incidence in Hainan.
Li et al.(2010)[9]	Three Gorges Reservoir Area 1997-2008	Mosquito density, temperature	-Pearson and Poisson models	The incidence rate of malaria was decreasing. Positive correlations were shown between indoor mosquito density and temperature (coefficient 0.281), between outdoor mosquito density and temperature (coefficient 0.355). Correlations of mosquito-borne diseases with indoor and outdoor mosquito density were positive, with correlation coefficient as 0.340 and 0.328 respectively.
Hui et al.(2009)[74]	Yunnan 1995-2005	Rainfall, temperature, humidity	-Temporal distribution analysis -Spatial autocorrelation analysis -Spatial cluster analysis -Spearman correlation analysis -GIS	The high-risk areas were mainly clustered in the bordering areas with Myanmar and Laos, and in the Yuanjiang River Basin. There was an association between malaria incidence and climatic factors with a clear 1-month lagged effect, especially in cluster areas. The relative humidity in the previous month had little or no effect on malaria incidence. The minimum temperature was correlated with malaria incidence.

Clements et al.(2009)[75]	Yunnan 1991-2006	Rainfall, temperature	-Bayesian Poisson regression models -Pairwise Pearson cross-correlations -GIS	Models revealed strong associations between malaria incidence and both rainfall and maximum temperature. There was a high incidence in some counties bordering Myanmar, Laos and Vietnam, and counties in the Red River valley. Clusters of counties in south-western and northern Yunnan were identified that had high incidence not explained by climate.
Wang et al.(2009)[15]	Anhui 2004-2006	Temperature, rainfall, Normalized Difference Vegetable Index(NDVI), elevation	-Principal component analysis -Logistic regression analysis -GIS	As the lowest minimum temperature increased by one unit, the probability of incidence of malaria decreased by 33%. As total annual rainfall, increased by one unit, the probability of incidence decreased by 27%. As elevation increased by 10 meters, the probability of incidence decreased by 2%. A one unit increase in NDVI was associated with a probability increase of 3.28 times.
Tian et al.(2008)[76]	Mengla 1971-1999	Temperature, rainfall, humidity, fog day of frequency	-Autoregressive integrated moving average (ARIMA) model -Ecological time-series analysis -Cross-correlation	The effect of minimum temperature on malaria incidence was greater in the cool months than in the hot months. The fog day frequency in October had a positive effect on malaria incidence in May of the following year. At the time scale of years, the annual fog day frequency was the only weather predictor of the annual incidence of malaria.
Wen et al.(2008)[77]	Hainan May-Oct 2000	Elevation, proportion of forest land area, grassland area, proportion of cultivated area, urban and rural residents, and industrial area,	-Spearman correlation analysis -Negative binomial regression analysis	The incidence of malaria showed: (1) positive correlations to elevation, proportion of forest land area and grassland area; (2) negative correlations to the proportion of cultivated area, urban and rural residents and to industrial enterprise area, land surface temperature; and (3) no correlations to meteorological factors, proportion of water area, and unused land area.

		meteorological factors		
Liu et al.(2006)[16]	Yunnan 1984-1993	Temperature, rainfall, sunshine duration, Normalised Differential Vegetation Index(NDVI)	-Principle component analysis -Grey correlation analysis -Factor analysis	Principal component factor analyses showed that remote sensing NDVI was the representative index of the first principal component and the first common factor of *Anopheles* density evaluation. Grey correlation analysis showed that in rainy season NDVI had a high grey correlation with *Anopheles* density and malaria incidence rate. The grey correlation analysis showed that in rainy season the grey degree of NDVI correlated with *Anopheles*.
Wen et al.(2005)[17]	Hainan 1995-1996	Normalised Difference Vegetation Index(NDVI)	-Spearman correlation analysis -GIS	The incidence of malaria showed positive correlations to mean and maximum values of NDVI.
Bi et al.(2005)[18]	Anhui 1966-1987	Southern Oscillation Index (SOI)	-Spearman correlation analyses	A positive correlation existed between the SOI and the incidence of malaria with no lag effect. The SOI could be used as an index in the study of the association of climate variability with the transmission of such diseases, particularly over larger areas, such as at a provincial or even state level, where averaging rainfall or temperature data across regions is inappropriate.
Liu et al.(2011)[78]	Pizhou 2001-2006	Temperature, rainfall, humidity, evaporation, cloud cover, sunlight time, low cloud	-Correlation analysis -Multiple regression	The incidence of malaria was positively correlated with temperature, rainfall, relative humidity, evaporation and total cloud cover, but no relation with low cloud and sunlight. The monthly minimum temperature and relative humidity were two major factors influencing malaria transmission.

Wu et al.(2011)[44]	Dianjiang 1957-2010	Temperature, rainfall, humidity, sunshine duration, air pressure, wind speed	-Principal component analysis -Multiple regression	Significant associations between malaria incidence and monthly mean temperature, rainfall and duration of sunshine were observed. Temperature was the greatest relative to malaria transmission.
Huang et al.(2009)[79]	Tongbai and Dabie Mountain areas 1990-2007	Temperature, rainfall	-Descriptive study	Temperature and rainfall were major determinants of malaria transmission and the yearly peak of cases occurred one month after the rainy season.
Su et al.(2006)[19]	Hainan 1995	Temperature, rainfall, humidity, NDVI	-Factor analysis -Principal component analysis -Multiple linear regression analysis	Rainfall and NDVI may relate to the malaria transmission and distribution.
Huang et al.(2004)[45]	Guizhou 1951-2000	Temperature, rainfall, humidity	-Correlation analysis -Path analysis	A significant relationship between malaria incidence and climatic factors was found, but the influences of climatic factors were not consistent among all study counties.
Hemorrhagic fever with renal syndrome				
Ge et al. (2016) [47]	Hubei 2005-2014	Temperature, humidity, rainfall, population density	-Spatial autocorrelation analysis -Spatio-temporal scan statistical analysis	Monthly average humidity was positively associated with HFRS cases. Human population density was positively associated with the outbreak of HFRS epidemic in Hubei. Other factors, such as temperature, and rainfall, did not display significant relations with the outbreak of HFRS.

			-Spearman's rank correlation analysis	
Bai et al. (2015) [48]	Chongqing 1997-2008	Temperature, rainfall, rodent density, GDP	-Spatio-temporal analysis -Poisson regression model -Zero-inflated negative binomial model	The monthly trend in HFRS incidence was positively associated with rodent density at lag0 and rainfall at a lag of 2 months, and negatively associated with temperature at a lag of 0 and 5 months. GDP was negatively associated with the incidence of HFRS.
Tian et al. (2015) [49]	Xi'an 2005-2012	Temperature, rainfall, rodent density	-Wavelet time series analysis -Cross-correlation analysis -Bayesian time-series Poisson adjusted model	Human HFRS cases correlated to rodent density, rainfall, and temperature with 2, 3, and 4-month lags. The best models indicated rodent density with 2 months previously and rainfall 2 to 3 months previously were positively correlated with HFRS cases.
Li et al. (2014) [80]	China 2005-2012	Temperature, precipitation, humidity, NDVI, elevation, land use, cultivated land area, grain yield	-Spatial auto-correlation analysis -Geographically weighted regression model	HFRS incidence was primarily affected by meteorological elements (such as temperature and precipitation), landscape factors (such as NDVI and land use), and geographical factors (such as elevation).
Lin et al. (2014)[50]	Jiaonan County 2006-2011	Temperature, humidity, rainfall	-Generalised additive model (GAM)	A positive association was found with HFRS occurrence for 1 ˚C increase on the current day being 2.56% when daily temperature was lower than 17 ˚C. An inverse association was found when daily temperature was higher than 17 ˚C. Inverse associations were also observed for humidity and rainfall.

Wu et al. (2014)[51]	Changchun 1998-2012	Temperature, precipitation, humidity	-Time series Poisson regression	Climate factors were associated with HFRS. As the average relative humidity increased by 1%, the HFRS incidences increased by 7.1% (P<0.001)
Xiao et al.(2014)[5]	Chenzhou 2006-2010	Rodent, NDVI, climatic factors, socioeconomic factors	-Principal component analysis -Cross-correlation analysis -Polynomial distributed lag(PDL) model	Urbanisation rate was significant negatively correlated with HFRS incidence(r=-0.903, P<0.001) and GDP (r=-0.627, P<0.05). HFRS incidence was positively correlated with rainfall and humidity in Chenzhou. Temperature and NDVI were positively associated with HFRS incidence. HFRS incidence was positively correlated with rodent density.
Li et al. (2014) [52]	Hebei 1999-2011	Rodent density, population density, NDVI, precipitation, temperature	-Correlation analysis -Multivariate linear analysis	The infection occurred mainly in males, aged 20-49 years, who were farmers. *Rattus norvegicus* was the main host animal. The incidence of HFRS was related to NDVI value, rat density and rats' virus carriage rate.
Li et al.(2013)[21]	Heilongjiang 2001-2009	Humidity, temperature, SOI	-Seasonal autoregressive integrated moving average model	Relative humidity with a one-month lag (β = -0.010, P = 0.003) and a three-month lag (β = 0.008, P = 0.003), maximum temperature with a two-month lag (β = 0.082, P = 0.028), and southern oscillation index with a two-month lag (β = -0.048, P = 0.019) were significantly associated with HFRS transmission.
Xiao et al.(2013)[11]	Changsha 2005-2010	Rodent density, El Nino Southern Oscillation index, rainfall, temperature, humidity, air pressure, Multivariate	-Time-series adjusted Poisson regression model -Cross-correlation analysis	A one unit increase in rodent density may be associated with a 33.3% increase in HFRS cases and one unit MEI increase may be associated with 66.4% increase in HFRS cases. Rodent density and MEI were the key determinants of HFRS transmission in Changsha with lags of 2-6 months. Mean temperature, rainfall, absolute humidity, MEI and NDVI were significantly correlated with the monthly notified number of HFRS cases with a lag of 1-6 months.

		ENSO Index (MEI)		
Xiao et al.(2013)[6]	Changsha 2005-2009	Land use, rodent density, normalised difference vegetation index (NDVI), temperature, precipitation, human activity	-Ecological niche model (ENM)	The number of HFRS cases was correlated with rodent density. The highest occurrence of HFRS was in districts with strong temperature seasonality, where elevation is below 200m, mean annual temperature is around 17.5 ˚C, and annual precipitation is below 1600mm.
Liu et al.(2013)[81]	Junan 1977-2001	Temperature, precipitation	-Case-crossover study -Conditional logistic regression	Temperature of 10-25 ˚C and moderate precipitation (10-120mm) in the current month was the most favourable condition for HFRS incidence. Any combination with mean temperature and monthly precipitation beyond its appropriate range in the preceding 2 months tended to be associated with a lower risk of HFRS.
Xiao et al.(2013)[22]	Changsha 1991-2010	Moisture, Multivariate EI Nino-Southern Oscillation Index(MEI), humidity, precipitation, air pressure, temperature	-Wavelet analyses -Generalised linear model with a Poisson distribution and a log link model -Cross-correlation analysis	There was a significant association of HFRS incidence with moisture conditions and MEI. Atmospheric moisture has a significant effect on the propagation of HFRS; annual incidence of HFRS was positively correlated with annual precipitation and annual mean absolute humidity.
Xiao et al.(2013)[23]	Changsha 2004-2011	Normalised difference vegetation index(NDVI),	-Cross-correlation analysis	Relative rodent density of HFRS host was significantly correlated with monthly mean temperatures, monthly accumulative precipitation, TVDI and NDVI with lags of 1-6 months. Antecedent

		temperature vegetation dryness index(TVDI), temperature, precipitation	-Autoregressive integrated moving average model with explanatory variables -Autocorrelation analysis -Time series analysis	patterns of food supply were the key determinants of the HFRS host population in Changsha.
Liu et al.(2011)[53]	Shenyang 2004-2009	Temperature, humidity, precipitation, air pressure, wind velocity	-Cross-correlation -Autocorrelation analyses -Principal component analysis -Multiple regression model -Principal components regression model (PCR)	The monthly trends of HFRS were significantly associated with local temperature, relative humidity, precipitation, air pressure, and wind velocity of the previous month.
Xiao et al.(2011)[24]	Changsha 2000-2009	Temperature, humidity, rainfall, multivariate EI Nino Southern Index (MEI)	-Time-series Poisson regression model -Cross correlation analysis	Monthly average temperature (18.00 ℃, $r = 0.26$, $P < 0.01$, 1-month lag period; IRR = 1.02, 95% CI: 1.00 - 1.03, $P < 0.01$), relative humidity (75.50%, $r = 0.62$, $P < 0.01$, 3-month lag period; IRR = 1.03, 95%CI: 1.02 - 1.04, $P < 0.01$), rainfall (112.40 mm, $r = 0.25$, $P < 0.01$, 6-month lag period; IRR = 1.01, 95% CI: 1.01 - 1.02, $P = 0.02$), and MEI ($r = 0.31$, $P < 0.01$, 3-month lag period; IRR = 0.77, 95% CI: 0.67 - 0.88, $P < 0.01$) were closely associated with monthly HFRS cases.
Fang et al.(2010)[82]	Shandong 1973-2005	Precipitation, humidity, temperature	-Spatiotemporal analysis -Panel data analysis, trend surface analysis	Three epidemic phases were identified over the 33-year period. Precipitation, humidity, and temperature are major environmental variables that were found to be associated with the seasonal variation of HFRS incidence in Shandong Province. Multivariate panel data

			-Least square regression using quadratic polynomials -Univariate analysis multivariate analysis -Panel Poisson model with fixed effects	analysis demonstrated that the three variables, monthly cumulative precipitation with 1-month lag, monthly average relative humidity with 1-month lag and monthly average temperature with 2-month lag, were significantly associated with HFRS incidence.
Zhang et al.(2010)[25]	Elunchun and Molidawahaner 1997-2007	Rainfall, land surface temperature, humidity, Multivariate El Nino Southern Oscillation(ENSO) Index (MEI)	-Cross-correlation analyses -Time-series Poisson regression models	Cross-correlation analyses showed that rainfall, temperature, humidity and MEI were significantly associated with monthly HFRS cases with lags of 3-5 months in both study areas. Poisson regression indicated that after controlling for autocorrelation, seasonality, and long-term trend, rainfall, temperature, humidity and MEI with lags of 3-5 months were associated with HFRS in both study areas.
Guan et al.(2009)[12]	Huludao 1990-2006	Virus-carrying index among rodents, temperature, precipitation, humidity, air pressure	-Structure Equation Model (SEM) -Correlation analysis -Pearson correlation	Temperature, precipitation, relative humidity and virus-carrying index among rodents showed positive correlations with the monthly incidence of HFRS with a lag of 3, 3, 3, and 1 month, respectively; while air pressure had a negative correlation with the incidence with a lag of 3 months. Climate affects HFRS incidence mainly through the effect on the reservoir in the study area.
Yan et al.(2007)[26]	China 1994-1998	Elevation, normalised difference vegetation index(NDVI), precipitation,	-Multivariate logistic regression analysis -Univariate analysis(X^2) -Univariate logistic analysis	HFRS incidence was remarkably associated with elevation, NDVI, precipitation, annual cumulative air temperature, semi hydromorphic soils, timber forests, and orchards. HFRS incidence significantly declined as elevation increased. Approximately 86.4% of HFRS cases occurred in areas with 0-500m elevation in the eastern part of China and the Sichuan Basin.

		annual cumulative air temperature, land surface temperature, soil type, land use	-Spearman correlation	
Lin et al.(2007)[83]	Liaoning 2000-2005	Humidity, forestation	-GIS-based spatial analysis -T-test -Spatial autocorrelation	Spatial cluster analysis suggested 16 and 41 counties were at increased risk for HFRS ($p < 0.01$) with the maximum spatial cluster sizes at ≤ 50% and ≤ 30% of the total population, respectively, and the analysis showed relative humidity and forestation in the cluster areas were significantly higher than in other areas.
Bi et al.(2005)[18]	Anhui 1971-1992	Southern Oscillation Index (SOI)	-Spearman correlation analyses	There was an inverse correlation between monthly average of the SOI and monthly incidence of HFRS with no lag effect in Anhui over the study period.
Luo et al.(2009)[13]	Heilongjiang 1984-2007	Temperature, humidity, rainfall, rat density	-Spearman rank correlation -Multiple stepwise regression	A significant correlation existed between mean temperature, relative humidity, rainfall in the past six months and HFRS incidence. Rat density was positively associated with HFRS incidence.
Liu et al.(2006)[84]	Shandong 1976-2002	Humidity, wind velocity, air pressure, temperature, rainfall, sunlight hours	-Case-crossover design -Conditional logistic regression	Meteorological factors such as mean temperature, precipitation, relative humidity, sunlight hours, mean air pressure and wind velocity were associated with HFRS incidence, but their effects were not equal in different seasons.
Wu et al.(2005)[54]	Jiangsu 1990-2002	Humidity, sunlight,	-Correlation analysis	Humidity, sunlight, precipitation, average temperature and lowest temperature were significantly associated with HFRS incidence.

		precipitation, temperature	-Multiple regression model	
Capacity Knowledge attitude perception policy				
Wei et al.(2014)[85]	Shanxi 2014	Perception, attitude	-Cross-sectional questionnaire survey -Descriptive analysis	A majority of the CDC staff were aware of the health risks from climate change, especially its impacts on infectious disease transmission in their jurisdictions, and believed climate change might bring about both temporal and spatial change in transmission patterns. It was thought that adaptation measures should be established.
Wei et al.(2014)[86]	Shanxi 2014	Perception, attitude, behaviour	-Cross-sectional questionnaire survey -Descriptive analysis	More than two-thirds of the respondents believed that climate change has happened at both global and local levels, and climate change would lead to adverse impacts to human beings. Most respondents (74.8%) indicated the emission of greenhouse gases was the cause of climate change, however, there was a lack of knowledge about greenhouse gases and their sources. In terms of mitigation and adaptation measures issued by the Chinese Government, respondents' perception showed inconsistency between strategies and relevant actions. Moreover, although the majority of respondents believed some strategies and measures were extremely important to address climate change, they were still concerned about economic development, energy security, and local environ- mental protection.
Feng et al. (2011) [87]	China 2011	China's capacity to detect emerging infectious diseases remains insufficiently. Pathogen-based surveillance remains underdeveloped – a reality that limits China's ability to rapidly detect emerging infections.		
Lu et al. (2008) [88]	China 2008	Twenty years of fiscal devolution and privatisation of the health care system have weakened China's preventive health infrastructure and rural health service access. Emergency preparedness for infectious disease threats is still hampered by bureaucratic rivalries, and poor sector and hierarchical coordination and reporting responsibilities. The infectious		

		disease situation among migrants should be paid attention. China faces a lack of resources, trained medical personnel, and a functioning health care system.
Wang et al. (2008) [89]	China 2008	Public health and hospital systems lack funding and qualified health workers, and this is especially serious in the poor parts of China. Migration promotes transmission of infectious diseases and creates major challenges for detection and control of epidemics of infectious diseases.

Figure 2.3 Map of China

The literature review revealed that several different study designs were employed to explore the relationship between meteorological factors and infectious diseases. These included spatial study designs, time-series and case-cross-over designs, spatial-temporal methods, descriptive study designs, and surveys [20, 64, 40, 79, 85]. A number of analytical approaches were used to assess the association between climatic factors and infectious diseases including Poisson regression models, pairwise Pearson and Spearman cross-correlation analysis, Principal Component Analysis, Generalised Estimating Equation approach, negative binomial regression analysis, multivariate time series analysis, and Seasonal Autoregressive Integrated Moving Average models [15, 65, 66, 69, 71, 40, 42, 73, 75]. Although each study design has its own advantages and limitations, the major findings from these studies showed three main meteorological factors – temperature, rainfall and humidity - might have an influence on the transmission of above infectious diseases to some extent.

2.3.1 Dengue and meteorological factors

Temperature, relative humidity and rainfall have been shown to be significantly associated with dengue transmission in most studies [1, 10, 20, 63, 36, 38]. Wind velocity, air pressure and SOI are other variables that have an influence on dengue transmission [1, 10, 20, 63, 36].

2.3.1.1 Temperature and dengue

In most of the studies, temperature was positively associated with dengue transmission. One study in Guangzhou indicated that each 1 ˚C rise of monthly mean temperature corresponded with an increase of 10.23% in the monthly number of dengue cases [36]. Moreover, Wang et al. and Lu et al. found monthly minimum temperature with a 1-month lag was positively correlated with dengue incidence [1, 63]. However, daily minimum temperature and daily maximum temperature sometimes showed an inconsistent relationship with the incidence of dengue. A study conducted in Guangzhou found both daily minimum temperature and maximum temperature at a lag of zero days was positively associated with dengue incidence [57]. Another study in Guangdong Province found daily mean and minimum temperatures with 2- to 3- day lags were positively associated with dengue, but daily maximum temperature at lags of 0-2 days was negatively associated with dengue [20].

Temperature has a complicated relationship with dengue incidence. Higher temperatures could increase the rate of larval and pupae development, reduce the time required for virus replication within the mosquitoes, increase the frequency of mosquito blood feeding, and hence increase the incidence of dengue [90-92]. In addition, high temperature may also change people's behaviour. However, extreme high temperatures may adversely affect breeding, kill eggs and pupae, and shorten the mosquito survival cycle, therefore reducing the transmission of dengue [90, 92].

2.3.1.2 Rainfall and dengue

Rainfall is another important climatic factor that influences the transmission of dengue as studies have indicated that rainfall is correlated with dengue [1, 10, 57, 38]. Lu et al and Sang et al also found dengue cases were positively associated with precipitation at lags of 3 to 4 months in Guangzhou, Guangdong Province [1, 10]. Whilst Xiang et al found the number of daily dengue cases was positively associated with the increase of 24-h rainfall amount below 11.9mm, the association reversed when 24-h rainfall exceeded 11.9mm [57].

Rainfall creates more breeding sites and increases the mosquito population. This increases the risk of dengue, especially in older urban areas with high-density populations and relatively poor drainage systems, as drains, tanks and small water containers are favoured breeding sites for the vector [93]. However, heavy rainfall may wash away these breeding sites and have a negative effect on dengue incidence [57]. Furthermore, it should be noted that rainfall might not be such an influencing factor for mosquito breeding sites in domestic garden settings where mosquito-breeding sites are often containers such as pot plants, which may contain water in the absence of rainfall [20].

2.3.1.3 Relative humidity and dengue

Relative humidity may be a risk factor for dengue transmission. A study in Guangzhou found relative humidity was positively associated with the dengue incidence of the same month; each 1% rise in relative humidity led to an increase of 2.04% to 2.19% in monthly reported dengue cases [36]. Other studies also found relative humidity to be positively correlated with dengue incidence [1, 10, 38]. However, relative humidity seems to be insignificantly, or even negatively associated, with dengue in some settings. One study found no significant association between dengue and humidity in Guangdong province [20], and another study in Guangzhou found average relative humidity was negatively associated with dengue incidence when it exceeded 78.9% [57].

Increased relative humidity can improve the hatchability of mosquitoes, enhance the mosquito survival rate, facilitate mosquito feedings, and thus increase the likelihood of dengue cases [63]. However, the positive association between relative humidity and dengue may be diminished or even reversed if the relative humidity is constantly high (approximately 69% to 83% annually) with little variation [20, 94], as can be the case in sub-tropical and tropical climates.

2.3.1.4 Other meteorological factors and dengue

Wind velocity, air pressure and SOI were found to be associated with the incidence of dengue with different time lags [1, 10, 20, 63, 36]. One study in Guangzhou found that each one meter per second rise in moderate wind velocity may lead to an increase of 43.8% or 107.5% in the monthly number of cases [36]. However, two other studies indicated that wind velocity was inversely associated with dengue incidence [1, 63]. This may be explained by the fact that strong winds suppress mosquito flight, reduce the biting rate and thus decrease dengue incidence, but moderate wind velocity could help spread the vector more widely and broaden the range of dengue incidence [63, 36].

Sang et al and Li et al found air pressure was negatively associated with dengue cases in Guangzhou [10, 36]. A 1hPa rise in air pressure was found to correspond to a 5.14% decrease in the number of dengue cases [36].

Studies have generally found there is a lag time of climatic factors on dengue transmission. This refers to the delayed effects between time of exposure and onset of disease; e.g. the delay between the date on which temperature, rainfall or humidity increases, and the time when the subsequent dengue cases occur [95]. The delayed effect of climatic factors on dengue incidence could be explained by climatic variables that indirectly influence the transmission of dengue, which is through the effect on the lifecycle dynamics of both dengue vectors (*Aedes aegypti and Aedes albopictus* mosquitoes) and dengue viruses [96].

2.3.2 Malaria and meteorological factors

Temperature, rainfall and humidity were three important variables related to the transmission of malaria [8, 97]. Other proxy indicators such as NDVI, SOI and MEI were also utilised to assess the association with malaria transmission [14, 15, 18].

2.3.2.1 Temperature and malaria

Almost all studies reviewed showed that temperature was positively associated with malaria incidence. One study in Jinan, Shandong Province, for instance, found that temperature was the most important climatic factor in determining the transmission of malaria, with a 1 ˚C increase in monthly mean maximum temperature associated with a 7.7% to 12.7% increase in the number of malaria cases, and a 1 ˚C increase in monthly mean minimum temperature leading to an increase in cases of 11.8% to 12.7% [43]. A similar effect of temperature on malaria transmission was also observed in Anhui, Henan, Hubei, Guangdong and Yunnan Provinces [8, 69-71, 46, 65, 64]. The optimal mean temperature for malaria transmission has been found to be between 21-25 ˚C [66]. Two studies, however, found that the lowest temperature in a year was either negatively associated or had no association with malaria incidence, which could be due to a short study period [15, 77]. For example, Wang et al. conducted a study in Anhui and found that if the lowest temperature in a year increased by one degree, the probability of malaria incidence would decrease by 33% [15]. However, they only analysed malaria incidence data over a two-year period. The other study conducted by Wen et al. (2008) in Hainan found no association between the incidence of malaria and meteorological factors with a study period only for six months [77].

Temperature may have an impact on the life cycles of mosquitoes and parasite replication [98]. Warmer temperatures can shorten the duration of parasite replication, and increase the reproduction rate of mosquitoes and also the contact rate with humans, hence increasing the disease incidence. Additionally, people in rural areas in China often sleep outdoors during hot nights, especially farmers who sleep near their crops at harvest season, and this can increase their risk of malaria that is transmitted by night-biting *Anopheles* mosquitoes [33]. However, extremely high temperatures may disrupt mosquito breeding, kill the eggs and larvae, and evaporate the water in breeding sites [99]. In contrast, extremely low temperatures may reduce the development rate of mosquitoes' life cycle and people are less likely to be outdoors in contact with mosquitoes in cold weather [99].

2.3.2.2 Rainfall and malaria

Rainfall was associated with malaria incidence in most studies reviewed, but the impact of rainfall on malaria transmission was not consistent. In most studies, rainfall was positively associated with malaria incidence [8, 14, 15, 17, 19, 65, 67, 70, 41, 42, 72-75, 78, 44, 79, 45]. However, a negative association or weak association between rainfall and malaria has also been reported in metropolitan areas of Jinan, Shandong Province, Mengla County of Yunnan Province and Hainan Province [43, 73, 76, 77].

A plausible explanation could be that rainfall creates a necessary microenvironment for mosquito life cycles, increases the mosquito population and the contact rate with human beings, thus increasing the incidence of malaria [33]. However, excessive rainfall or flooding may destroy and flush out the existing mosquito breeding sites and restrict the transmission of malaria [99]. Notably, in the long term high rainfall may create more breeding habitats for mosquitoes and increase malaria incidence [33, 74].

2.3.2.3 Relative humidity and malaria

Relative humidity has been proven to be an influencing factor in malaria transmission. A positive association between relative humidity and malaria incidence has been found in Anhui, Henan, Hubei, Jiangsu, Tibet and Yunnan Provinces [14, 70, 41, 42, 72, 78, 45]. However, several other studies in Hainan and Yunnan Provinces showed no association between relative humidity and malaria incidence [73, 74, 76].

High relative humidity may promote the transmission of malaria via prolonging the life of the mosquitoes [33], especially in Anhui, Henan, Hubei and Jiangsu Provinces where in these study sites there is a significant variation in relative humidity over a year from 10% to 90% [78, 100]. However, other study sites in Hainan and Yunnan have high, stable relative humidity of approximately 60% or above over the whole year, which is suitable for malaria transmission, but the sustained high humidity may fail to explain fluctuations in the humidity-malaria associations in these regions [72, 73, 76, 100].

2.3.2.4 Other meteorological factors and malaria

Other indicators, such as NDVI and SOI, were utilised in studies as ecological proxy indicators for the detection of the climate-malaria relationship [14-19].

NDVI has been proven to be correlated with the density of the malaria primary vector – *Anopheles* which serves as an index for predicting malaria outbreaks [16]. Studies in Anhui Province found NDVI was positively associated with the incidence of malaria [15]. With each 1 unit increase in NDVI, the probability of malaria occurrence was shown to increase 3.28 times [15]. Other studies in Hainan and Yunnan Provinces also found a positive relationship between NDVI and malaria incidence [16, 17, 19]. NDVI is associated with malaria mainly via affecting mosquito breeding [15, 17]. In China malaria mainly occurs in agricultural regions and rice growing areas where the NDVI is higher. Vegetation cover creates numerous microenvironmental breeding sites for mosquitoes. Simultaneously, high NDVI reflects indirectly that the local environmental conditions, such as appropriate temperature, humidity and precipitation, may suit vegetation growth and mosquito breeding and thereby contribute to malaria transmission [15].

SOI was found to be positively correlated with the incidence of malaria in Anhui Province [18]. One possible reason could be that SOI affects broader ecologic processes, and the positive SOI was associated with more rainfall and high temperature, which is associated with an increase in mosquito populations facilitating the transmission of malaria [18].

In addition, climatic factors have shown different time lag effects on malaria transmission. The lag effect of temperature, rainfall and relative humidity on malaria ranges from days to several months [14, 67, 42, 74]. This is likely related to the delayed influence of climatic factors on the life cycle of mosquitoes and the parasite, the development of the pathogen within the vector, and the incubation period of the parasite in humans [68, 42].

2.3.3 HFRS and meteorological factors

Temperature, rainfall and relative humidity have been shown to be associated with HFRS transmission [50, 51]. Wind velocity, air pressure, sunshine duration, and ecological proxy indicators including NDVI, SOI, and MEI may be associated with HFRS to some extent [5, 11]. In addition, non-climatic factors such as gross domestic product (GDP) and urbanisation are also believed to be associated with the incidence of HFRS [48].

2.3.3.1 Temperature and HFRS

Temperature showed both positive and negative relationships with HFRS incidence in the published literature. Most studies showed that temperature was positively associated with HFRS incidence with 1- to 6- month lag effect [5, 6, 11-13, 21, 23-25, 84, 54]. However, two studies conducted in Shenyang and Chongqing found the local temperature was negatively correlated with HFRS [48, 53]. Moreover, Lin et al found a changing correlation between HFRS and temperature [50]. A positive association was detected with HFRS occurrence when daily temperature was lower than 17 ˚C, while an inverse association was present when daily temperature was higher than 17 ˚C [50]. The temperature of 17 ˚C could be the most favourable condition for the rodents, thus facilitating transmission.

The changing association between temperature and HFRS may be due to differences in the environment, climate and rodents in different study regions [48]. Temperature has an influence on HFRS incidence via different approaches, such as its impact on the rodents' survival and reproduction, human behaviours and virus replication [5, 21, 48]. Mild temperatures from 10 to 25 ˚C could increase the activity of rodents and the rate of rodent reproduction, and thus lead to an increase in the incidence of HFRS [5, 21, 81]. Also, human behaviours may change when temperatures are high. For example, farmers may sleep outside during hot nights in summer and autumn during the harvest season, which provides more contact opportunities with rodents and increases the risk of HFRS [5]. However, a study in Jiaonan, Shandong Province, has shown that very high temperatures may increase the mortality of rodents, restrict the survival rate of viruses and reduce the transmission of HFRS [50].

2.3.3.2 Rainfall and HFRS

Rainfall was also shown to have an inconsistent association with the incidence of HFRS. Some studies have found a positive association between rainfall and HFRS cases [5, 12, 13, 22, 24, 25, 48, 49, 84]. Zhang et al found a 1 mm/day increase in monthly mean rainfall was associated with 1.1% (95% CI: 0.2-1.9%) increase in HFRS cases [25]. Xiao et al also predicted that a 1mm increase in monthly accumulated rainfall was associated with a 0.2% (95% CI: 0.1-0.3%) increase in HFRS cases [22]. Other studies, however, showed a negative association [50, 82], which may be due to different geographical locations. Meanwhile, a study in Heilongjiang Province found no relationship between rainfall and HFRS incidence [21].

Abundant rainfall could create a moist environment, which is an ideal condition for rodent breeding in agricultural areas. Moreover, rainfall could provide enhanced growth conditions for vegetation that directly or indirectly provides rodents with food, and subsequently increases the population size [5, 18, 26]. However, excessive rainfall and flooding in low-lying areas may destroy rodents' habitats, reduce food supply, and restrict human activities, therefore being negatively associated with HFRS incidence to some extent [53, 98]. Heavy rain may also force rodents to move to higher-lying regions or human living areas, which likely increases the contact rate with humans and increases the risk of HFRS transmission [53, 82, 98]. These combined influences may explain the complicated relationship between rainfall and HFRS incidence.

2.3.3.3 Relative humidity and HFRS

Relative humidity has been shown to have a mostly positive association with HFRS incidence, with studies showing a positive association between relative humidity and HFRS incidence with various lag periods between 1 and 3 months [5, 11-13, 21, 22, 24, 25, 47, 51, 83]. A study in Changsha found a 1% increase in monthly relative humidity was associated with a 2.8% (95% CI: 1.7-3.9%) increase in the incidence of HFRS at the lag of three months [24]. Another study conducted in Changchun, northeast China, found that a 1% increase in annual average relative humidity was associated with a 7.1% increase in HFRS incidence. However, this study used the annual average relative humidity rather than monthly, which may not reflect the real association [51]. Similar findings were reported in Hunan, Heilongjiang, Hubei, Jilin and Liaoning Provinces. However, three studies showed a negative relationship between humidity and HFRS incidence [50, 53, 82]. Two of those three studies were conducted in Shandong Province and one was conducted in Liaoning Province [50, 53, 82].

To some extent, relative humidity can reflect the extent of moist environment in rodents' habitats. High relative humidity provides a moist environment for the survival of rodents, increases the rodent population, and facilitates disease transmission [25]. However, very high relative humidity with heavy rainfall may change the positive association between relative humidity and HFRS incidence [50, 101]. A negative association between HFRS and humidity was found in most coastal regions with moist soil and suitable environmental conditions for rodents that can carry the disease. High relative humidity may accompany heavy rainfall which may destroy the suitable microenvironment, restrict human outdoor activities and reduce exposure risks to HFRS, thereby reducing the incidence of HFRS [50].

2.3.3.4 Other meteorological factors and HFRS

Wind velocity, air pressure and sunshine duration may be associated with HFRS incidence. A study in Shenyang showed air pressure and wind velocity were positively associated with HFRS cases [53], but another study conducted in Huludao, northeast China, found air pressure with a 3-month lag was negatively associated with the incidence of HFRS [12]. Liu et al. found sunshine duration and air pressure presented both positive and negative associations with the incidence of HFRS in different seasons [84].

Some studies showed that NDVI, MEI and SOI were associated with HFRS incidence. Of these, most studies showed the NDVI was positively associated with the incidence of HFRS in different parts of China [5, 6, 11, 23, 26]. Higher NDVI means more live green vegetation or crops, which can be food resources for rodents, associated with increases in rodent populations, especially the agricultural hantavirus host - *Apodemus agrarius*, and thus contributes to the transmission of HFRS in rural areas [5]. Although one study showed increased MEI might reduce the incidence of HFRS [24], three other studies found that MEI was positively associated with HFRS cases [11, 22, 25]. Studies in Changsha and Elunchun found a 1 unit increase in MEI leads to a 64.5% and 55.3% increase in HFRS cases with 6-month and 4-month lag, respectively [22, 25]. Furthermore, two studies in Heilongjiang and Anhui Provinces showed that SOI was negatively associated with the incidence of HFRS [18, 21].

In addition, urbanisation rate and GDP, a surrogate index of socioeconomic status, in China were found to have a significant negative association with HFRS incidence in Chongqing and Hunan Province [5, 48]. Studies have shown the majority of HTNV-associated HFRS occurs in agricultural areas accounting for up to 70% of HFRS cases, while most SEOV-associated HFRS cases are concentrated in urban areas [102]. This is due to the distribution of *Apodemus agrarius* and *Rattus norvegicus*, in agricultural and urban areas, respectively. Better living conditions in urban areas may indirectly restrict the contact of humans with SEOV-infected *Rattus norvegicus* [5]. However, in agricultural areas where the population is less likely to experience adequate living conditions, farmers are more likely to be exposed to HTNV-associated *Apodemus agrarius* in the fields during harvesting time [5, 48].

2.4 Summary of climate change and infectious diseases

Almost all studies found meteorological factors have an important impact on the transmission of dengue, malaria and HFRS to some extent. However, China is one of the largest and topographically heterogeneous countries with varying environmental and climatic characteristics and demographics.

Vector/rodent-borne diseases, such as dengue, malaria and HFRS, pose a significant threat to population health in China, and these infectious diseases have been shown to be influenced by certain meteorological factors such as temperature, rainfall and relative humidity. Meteorological factors affect the transmission of infectious diseases in a number of ways [103, 104]. First, meteorological factors influence the reproduction of the pathogens within the vector organism/rodent. Second, meteorological factors affect the distribution of vector/rodent species and population size. Third, meteorological factors affect human behaviours and activities, which could increase or decrease the contact rate with vectors or rodent hosts.

Although the Chinese government has made great efforts to improve infectious disease control and prevention, e.g. dengue national guidelines, malaria elimination programs, and HFRS prevention and control policies, these diseases are still emerging or re-emerging in China [88, 105, 106]. Along with climate change effects such as increasing temperature, more rainfall and more frequent extreme weather conditions, climate-sensitive diseases are expected to increase in this populous country [107]. Rising temperatures can extend epidemic seasons and enable vector survival in previously unaffected cooler regions of the country.

2.5 China's capacity of health system to deal with infectious diseases

China has been a fast developing country over the last three decades, and people are making great efforts to improve their quality of life by promoting economic growth and improving healthcare services. In this context and broad collectivist social culture, people, media and politicians are paying great attention to social stability and economic development, while the risks associated with development and issues such as climate change have been little discussed in the public domain so far [108, 109]. Studies concerning the capacity of the health system to deal with the emerging and re-emerging of infectious diseases, especially in the face of climate change, are very limited and scant.

Health professionals in Chinese public health system and clinical healthcare system play a significant role in infectious disease control, treatment and prevention. Their understandings of climate change and infectious diseases could appropriately reflect the China's capacity of health system to deal with emerging and re-emerging infectious diseases in the context of climate change.

Two studies have been conducted in Shanxi Province regarding the capacity of the CDC system to manage infectious disease in the face of climate via gauging perceptions of CDC health professionals [85, 86]. These found that surveyed CDC staff thought that climate change would have adverse impacts on human beings [86]. Most (77.7%) of the CDC staff believed that the potential emerging and re-emerging infectious diseases could be attributed to climate change [86]. The majority of the CDC staff (70.4%) were also aware of the health risks of infectious diseases from climate change, and more CDC staff believed that global warming would aggravate the burden of vector-borne diseases [85]. Nearly 80% of CDC staff believed the efficiency of the current infectious disease surveillance system was excellent [85]. Roughly, half of the surveyed CDC staff indicated that disease control and prevention system could rapidly detect epidemics of infectious diseases [85]. The majority considered adaptation measures, such as infectious disease surveillance systems, vector monitoring, in-house health professional training, related policies and guidelines development in infectious disease interventions, and collaborative research with other institutions, should be established and improved [85]. Moreover, these health professionals considered some strategies, such as reducing greenhouse gas emissions, optimising industrial structure and developing low-carbon energy, were extremely important to deal with climate change [86]. However, these studies were only conducted in one province with a relative small sample, and the results may not be representative of the views and opinions of all CDCs staff and other health professionals, including clinicians, on the issue of climate change and infectious diseases. In addition, specific diseases, such as dengue, malaria and HFRS were not explored in the context of climate change in their studies.

Other studies found China's capacity to manage infectious diseases and identify clusters of unusual syndromes or infections has been improved significantly in a post-SARS era [88, 89]. However, China's capacity to prepare for a rapid response to disease outbreak remains insufficient, and problems such as bureaucratic collaboration, hierarchical coordination, weak rural health system and poor public trust, still hamper further capacity improvement [88]. Furthermore, massive internal migrant populations may play a role in infectious disease transmission, challenging the control of epidemics of infectious diseases and overload the health care system [89]. The lack of funding and qualified healthcare workers, particularly in poor rural areas with a high burden of infectious diseases, and deficiency in pathogen-based surveillance, limits the capacity of the health system to provide infectious disease surveillance, control, prevention, diagnosis and treatment [87-89].

A recent publication in Europe, however, found most of the surveyed national infectious disease experts agreed that climate change would affect vector-borne, food-borne, water-borne, and rodent-borne diseases in Europe and institutional capacity is urgently needed to identify climate-sensitive infectious diseases and undertake adaptation assessments [110]. As China is one of the world's largest countries in terms of population and landmass, there is an imperative need to assess the capacity of the health system to respond to the challenges from emerging and re-emerging infectious diseases in the face of climate change. To understand the views of the health professionals such as CDC and hospital staff will be the first step to assess the capacity of the health system to deal with emerging and re-emerging infectious diseases in China.

2.6 Gaps in current knowledge

To the best of the author's knowledge, there is no comprehensive study focusing on the capacity of the health system to deal with diseases such as dengue, malaria and HFRS in the context of climate change in China. Nor are there any published investigations of health professionals' perceptions of the impact of climate change on infectious disease transmission.

As previously mentioned, there is a gap in knowledge regarding health professionals' understanding of the importance of the impact of climate change on the transmission of infectious diseases. This is vital for necessary guidelines to be developed to ensure the health system has the capacity to meet the demands of infectious disease outbreaks. Therefore, it is necessary to ascertain health professionals' perceptions of climate change and infectious diseases to gain an understanding of China's capacity to manage emerging and re-emerging infectious diseases outbreaks now and in the future. Additionally, more research needs to be conducted on risk factors, disease control and prevention methods (including vector control and vaccine production), and the effects of climate change on these diseases.

To fill these gaps, the following questions should be addressed in further research. First, what are health professionals' perceptions of infectious disease transmission and the capacity of the health system to manage these infectious diseases in the context of climate change? Second, how effective have infectious disease prevention and control programs been in China? Third, what are the main risk factors for emerging and re-emerging infectious diseases? Fourth, what significant aspects need to be improved for the capacity building in terms of China future infectious prevention and control programs?

The knowledge gaps identified in the literature review are fruitful areas for future climate change adaptation research. Addressing these gaps will provide a better understanding of the relationship between climate change and infectious diseases, and enable us to gauge the capacity of the health system in China to deal with emerging and re-emerging infectious diseases influenced by climate change. Finally, more knowledge in this area will assist policy makers and other stakeholders to formulate effective plans to reduce the adverse effect of climate change on infectious disease transmission. The research described in this thesis aims to address these research gaps.

2.7 References

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CHAPTER 3 STUDY DESIGN AND METHODOLOGY

3.1 Introduction

This chapter provides information about the research study design and methodology that could not be incorporated in the published chapters. This chapter describes the geographic and demographic characteristics of the study regions, and gives an overall outline of study design, the questionnaire, participant recruitment process, data collection, management and analysis. The methods relevant to each specific study are presented in Chapters 5 to 8.

As previously explained, public health professionals in China CDCs and clinical health professionals in hospitals play different roles, and may have different views on infectious disease control and prevention. Their views may also differ on the capacity of the public health system and clinical health system to deal with the challenges of emerging and re-emerging vector/rodent-borne diseases due to climate change. Two studies were undertaken to determine public health and clinical health professionals' perceptions of these issues.

Study 1 focuses on the perceptions of public health professionals in CDCs and the capacity of CDCs to deal with emerging and re-emerging infectious diseases due to climate change. Study 2 focuses on the perceptions of clinical health professionals in hospitals and the capacity of hospitals to deal with emerging and re-emerging infectious diseases due to climate change. This chapter is therefore organised into two sections.

The first section provides details of Study 1. A cross-sectional study design was utilised with a questionnaire survey among CDC public health professionals. The study was conducted with a single questionnaire for CDC staff and included components focusing on climate change, dengue, malaria and HFRS. Some questions in this questionnaire may not have been relevant in local regions if one or more of these diseases were not epidemic or did not occur in certain areas. Participants were able to skip questions not relevant to them or their area.

The second section provides details of Study 2. A questionnaire survey among clinical health professionals, using cross-sectional study design. The study was conducted with a questionnaire in three major hospitals in one province (Anhui). The questionnaire included questions on dengue, malaria and HFRS. While dengue is not common in Anhui Province, numerous imported cases from other provinces or overseas are reported. Malaria and HFRS are frequently reported in Anhui Province.

3.2 Study 1 - Questionnaire among public health professionals

3.2.1 Study site

Historically, before 1949, China had a high morbidity and mortality rate of infectious and preventable diseases [1]. Although tremendous efforts were made to control and reduce infectious diseases after 1949, some infectious diseases have rebounded and even increased since the 1980s [2]. For example, dengue has extended from southern China to neighbouring regions [3], malaria has re-emerged in central, east and southwest China [4], and HFRS has re-emerged in northeast China [5].

Covering an area of 9.6 million square kilometres, China has a population of 1.37 billion people with several climatic zones [6]. In this study, five provinces were selected where it was thought that participants could provide informed responses about their experience with dengue, malaria and HFRS. The provinces were Anhui Province (malaria and HFRS), Guangdong Province (dengue), Henan Province (malaria), Liaoning Province (HFRS) and Yunnan Province (malaria) (Figure 3.1). These study sites were selected with consideration of the incidence of the relevant diseases and advice from experts from China National CDC.

Anhui Province is located in east China, and has a total area of 139,600 square kilometres and a population of 60.8 million [7-9]. It has a warm-temperate, semi-humid monsoonal climate with an annual average temperature between 14 and 17 ˚C, and annual precipitation between 800 and 1,800 millimetres [7]. There are 5.71 million hectares of agricultural land and 4.18 million hectares of forestland areas, accounting for 40.9% and 29.9% of land size respectively in this province [10]. Anhui can be divided into three areas according to the terrain: the north plain, the north-central Huai plain, and the west and south mountains. China's largest river (the Yangtze), and the third-largest (the Huai River) run through the province [7]. Anhui has historically been a high-risk area for malaria and HFRS. The number of malaria cases in this region reached 1.12 million accounting for 33.9% of the whole nation in 1980 [11]. The authorities made a great effort to control malaria, and the incidence of malaria reduced to 1.3 cases per 100,000 population in 1999 from 52 cases per 100,000 population in 1990 [11]. However, the incidence in Anhui once again increased after 2000 with 34,984 cases reported in 2006 [12]. The incidence of HFRS in Anhui was more than 10 cases per 100,000 population during the 1980s and 1990s [13]. It was reduced to 0.17 per 100,000 population in 2008, and then increased to 0.32 per 100,000 population in 2013. Anhui Province is thus an ideal site to study malaria and HFRS.

Guangdong Province is located in south China, and has a total area of 179,800 square kilometres and a population of 106 million in 2013 [14, 15]. It is one of the most economically developed provinces in China [16]. The climate is humid subtropical and tropical monsoon climate characterised by high temperatures and plentiful rainfall. The annual average temperature is 21.8 ˚C, and annual average precipitation is 1,789.3 millimetres [17]. These climatic conditions in this region favour the transmission of dengue fever. After an outbreak of dengue fever occurred in Guangdong Province in 1978, there have been frequent outbreaks of the disease in this region. In 2014, there was an unprecedented outbreak leading to more than 44,000 cases [18]. Guangdong Province is therefore an ideal site to study dengue fever.

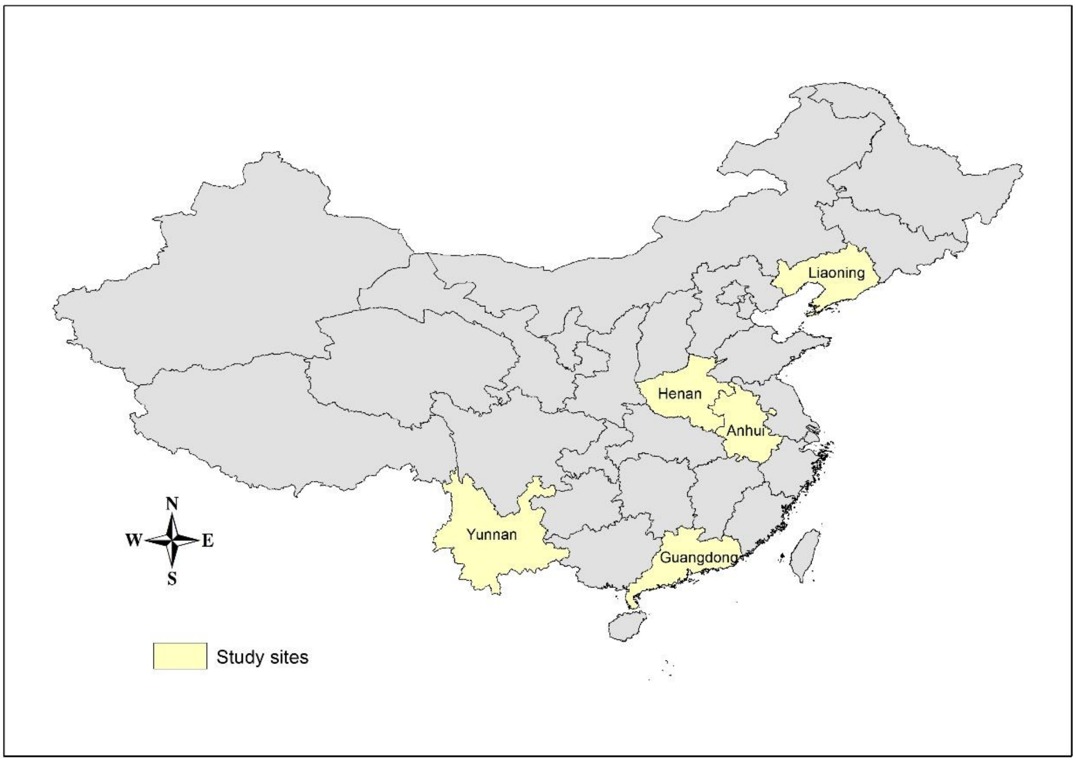
Henan Province is located in central China, and with a total area of 167,000 square kilometres and a population of 106.6 million [19]. It is the most populous province in China. Henan has a temperate climate with four distinct seasons. The average annual temperature is between 10.5 and 16.7 ˚C, and annual precipitation varies from 407.7 to 1,295.8 millimetres [19]. Henan historically has a high incidence of malaria. The number of malaria cases was highest in China during the 1970s, and the morbidity of the disease in this region was around 16.9% [20]. In 2006, Henan had the third highest number of malaria cases of all provinces in China [12], and therefore was chosen to study malaria.

Liaoning is located in northeast China, and has a total area of 145,800 square kilometres and a population of 42.7 million [21]. Liaoning has a temperate continental monsoon climate with four distinctive seasons [22]. The precipitation averages roughly 400 to 970 millimetres annually, and the annual average temperature is between 5.2 and 11.7

˚C [22]. Liaoning has been one of the highest risk areas for HFRS during the last decades with incidence up to 13.06 per 100,000 population in 2004 accounting for 21.69% of the cases in the country [23]. The incidence of HFRS in this region dropped to 1.71 per 100,000 population in 2008, and steadily increased to 2.96 per 100,000 population in 2013. Although the incidence has dropped dramatically in this region, Liaoning remains a high-risk area for HFRS in China.

Yunnan Province, located in the southwest of China and bordered by Vietnam, Myanmar, and Laos, has a total area of 394,000 square kilometres and a population of 46.8 million [24, 25]. It has a sub-tropical highland monsoonal climate. The hottest month is July (daily average temperature: 19 ˚C to 22 ˚C) and the coldest is January (daily average temperature: 6 ˚C and 8 ˚C) [26]. The annual precipitation is above 1,000 millimetres in most areas of Yunnan, and 85% of the precipitation falls between May and October [26]. Yunnan has a high incidence of malaria, especially *Plasmodium falciparum* malaria, and numerous imported malaria cases from countries of South-eastern Asia [12, 27]. Yunnan had China’s highest number of reported malaria cases over the period from 1999 to 2004 [28]. Yunnan is one of the high-risk areas for malaria in China.

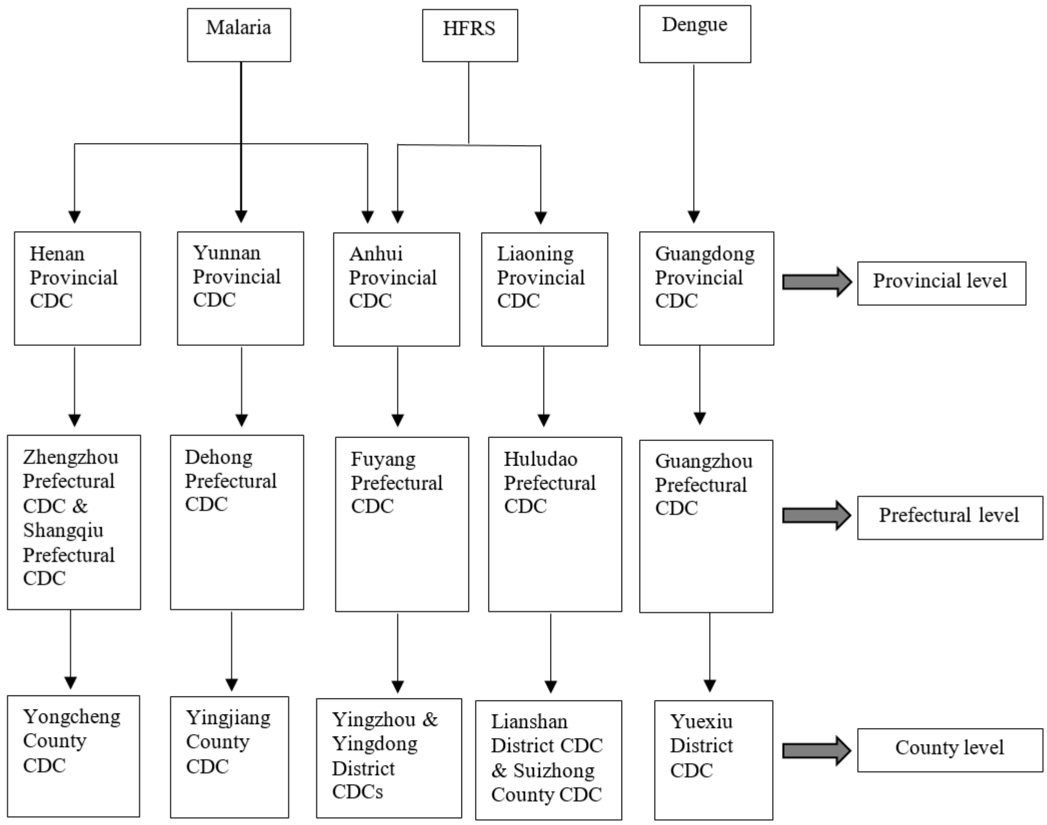
Figure 3.1 Location of study sites in China (Study 1)



3.2.2 Study participants

The study participants were public health professionals in China CDCs, whose roles included infectious disease control and prevention, public health, medical laboratory examination and emergency response. As previously mentioned in Chapter 1, there are four levels of CDC in China: National-level CDC, Provincial-level CDC, Prefectural-level CDC and County/District-level CDC [29]. There is a CDC in each province, prefecture, and county/district. Eighteen CDCs in five provinces were involved in this study; five provincial-level CDCs, six prefectural-level CDCs, and seven county/district-level CDCs. The targeted CDCs in each province were selected through discussion with key informants in the China National CDC with consideration of disease incidence. Figure 3.2 shows the participants and CDCs were selected for the dengue, malaria and HFRS studies. Specifically, participants were recruited from the following departments at all levels of CDCs including Communicable Disease Control and Prevention, Disinfection and Vector Control, Medical Laboratories and Emergency Response and Preparedness.

Figure 3.2 Participants were selected from these CDCs for study 1



3.2.3 Sampling size

The sampling unit was considered as a single public health professional within the CDC system of China. The sampling size was defined as the minimum number of professionals (sampling units) required. A number of factors were taken into consideration for determining the sample size of the study, including cross-sectional design, feasibility of the fieldwork, cost, time, and available resources. The minimum sample size to draw statistical inferences from the study population was calculated from the following formula [30]:

$$imss = \frac{Z^2 * P * (1 - P)}{C^2}$$

Where imss = initial minimum sample size,

Z = Z statistic for confidence interval,

P = Estimated proportion of study population having a good understanding of climate change and infectious disease transmission.
C = Precision/margin of error that was tolerated.

This survey takes the confidence interval of 95% to achieve the accuracy, and the corresponding Z value is 1.96; P takes the value of 0.5, which means 50% of individuals in the study population would have a good understanding of climate change and infectious disease transmission. The reason is that the standard error is largest when P = 0.5, so this is a conservative assumption that allows for P being unknown a priori [31]. The level of precision was set at 5%, i.e. a significance level of 0.05. The initial minimum sample size was derived from the following calculations:

$$imss = \frac{1.96^2 * 0.5 * (1 - 0.5)}{0.05^2} = 384$$

However, the minimum sample size needs to be corrected for a finite number of public health professionals in national, regional or local CDCs from the following formula:

$$fmss = \frac{imss}{1 + \frac{imss - 1}{pop}}$$

Where fmss = final minimum sample size,
imss = initial minimum sample size,
pop = finite population.

Based on information from national, regional and local CDCs in 2015 [32-41], the number of staff undertaking work in the field of infectious disease control and prevention, public health, medical laboratory and emergency response in each CDC is listed below in Table 3.1. The final minimum sample size for each CDC was calculated accordingly.

Table 3.1 The number of staff and minimum sample size of CDCs

Province	CDC	Number of staff	Minimum sample size
Anhui	Anhui Provincial CDC	138	102
	Fuyang Prefectural CDC	38	35
	Yingzhou District CDC	20	19
	Yingdong District CDC	20	19
Guangdong	Guangdong Provincial CDC	150	108
	Guangzhou Prefectural CDC	151	109
	Yuexiu District CDC	50	44
Henan	Henan Provincial CDC	100	79
	Zhengzhou Prefectural CDC	50	44
	Shangqiu Prefectural CDC	50	44
	Yongcheng County CDC	50	44
Liaoning	Liaoning Provincial CDC	137	101
	Huludao Prefectural CDC	50	44
	Lianshan District CDC	25	24
	Suizhong County CDC	25	24
Yunnan	Yunnan Provincial CDC	237	147
	Dehong Prefectural CDC	25	24
	Yingjiang County CDC	15	14
Total			1025

3.2.4 Questionnaire

The questionnaire was developed following prior discussions with academics in China and after a review of relevant literature that had previously examined health professionals' perceptions and capacity of the health system in the context of climate change [1, 42-46]. The full questionnaire aimed to explore the following five parameters: (1) participants' understanding of climate change, (2) which infectious disease or groups of infectious diseases would most likely be affected by climate change, (3) perceptions of existing infectious disease control and prevention systems, (4) suggested adaptation measures in the face of climate change, and (5) strategies to strengthen the current capacity to deal with emerging and re-emerging infectious diseases to meet climate change challenges. The questionnaire is included in Appendix A.

3.2.4.1 Structure and content of the questionnaire

The structure and content of the questionnaire were informed by the objectives of this study. Based on the objectives, the questionnaire was drafted to consist of four main parts, i.e. Climate Change, Future Infectious Disease Risks in a Changing Climate, Capacity Building to Deal with Disease Risks, and Demographics.

Part A Climate Change: This part consisted of seven questions. The first two questions asked participants to indicate how concerned they were about climate change and their perceptions of local climate change. The response choices for the concern of climate change were "Very concerned", "Concerned", "Concerned slightly" or "Not concerned". The response options were "Yes" – becoming warmer, "No" or "Unsure". The next three questions asked participants' perceptions of climate change and its impact on population health and infectious disease transmission. The final two questions in this part were about participants' understanding of climate change. A five-point Likert scale was employed to measure respondents' perceptions and understanding of climate change. The response options were "Agree strongly", "Agree somewhat", "Neither agree nor disagree", "Disagree somewhat" or "Disagree strongly".

Part B Future Infectious Disease Risks in a Changing Climate: This part consisted of five questions. The first question asked participants to indicate which infectious diseases they thought climate change will affect most in their area. Four categories of diseases were presented: food-borne diseases, water-borne diseases, vector-borne diseases and rodent-borne diseases. Specific diseases in each category were also presented. The response choices were “Agree strongly”, “Agree somewhat”, “Neither agree nor disagree”, “Disagree somewhat” or “Disagree strongly”. The second question comprised ten statements to ask participants about the transmission and epidemics of mosquito-borne and rodent-borne diseases. The response choices were “Yes”, “No” or “Unsure”. The third and fourth questions comprised 12 statements specifically about dengue and malaria control and prevention. The response choices were “Agree strongly”, “Agree somewhat”, “Neither agree nor disagree”, “Disagree somewhat” or “Disagree strongly”, plus an open-ended question to explore the main risk factors for dengue and malaria. The fifth question comprised ten statements to gauge participants’ views specifically on HFRS control and prevention. The response choices were “Agree strongly”, “Agree somewhat”, “Neither agree nor disagree”, “Disagree somewhat” or “Disagree strongly”, plus an open-ended question to explore the main risk factors for HFRS.

Part C Capacity Building to Deal with Disease Risks: This part consisted of five questions. The first comprised 12 statements to appraise participants’ views on the capacity of infectious disease control and prevention in China. The response choices were “Agree strongly”, “Agree somewhat”, “Neither agree nor disagree”, “Disagree somewhat” or “Disagree strongly”. The second question addressed climate change adaptation, planning, communication and coordination. This question included eight statements to which the response choices were “Agree strongly”, “Agree somewhat”, “Neither agree nor disagree”, “Disagree somewhat” or “Disagree strongly”. The third question asked participants to indicate the importance of strategies in building capacity to curb the population health impact of emerging and re-emerging infectious diseases due to climate change in China. This question comprised 16 statements which were gauged by participants as “Very important”, “Important”, “Unsure”, “Not important” or “Useless”. The last two questions in this part were open-ended questions that aimed to explore the major barriers to effective disease control and any other important issues regarding China’s capacity to deal with emerging and re-emerging vector/rodent-borne diseases.

Part D *Demographics:* This section collected information about participants' socio-demographic information related to age, gender, affiliation, professional classification, professional field, the length of employment and level of education. No identifying information about the participants was collected.

3.2.4.2 Content validity of the questionnaire and translation

The draft questionnaire was fully assessed for content validity, appropriateness and comprehensibility through a review by the supervision panel (n=3), research team members (n=12) and a research steering committee comprising experts in Australia and China (n=8). Relevant revisions were made in accordance with their recommendations. The questionnaire was then translated into Chinese with appropriate Chinese proofreading.

3.2.4.3 Pilot testing

The questionnaire was piloted among 18 staff in the China National CDC in Beijing, who were considered to share similar characteristics with the intended study participants. The pilot testing was conducted to ensure the questionnaire was clear and understandable. The result of the pilot testing indicated that the questionnaire was generally clear and understandable, and the maximum duration to complete the questionnaire was less than 30 minutes. Minor modifications were made as a result of the pilot testing.

3.2.5 Data collection and management

The approach by which participants were recruited, the study setting and timing of data collection has been described in the published papers. This section describes detailed recruitment process and outlines how data were collected and managed.

In May 2015, two Chinese-born researchers (including the author) travelled from Australia to China to meet the China CDC delegates in Beijing. The China CDC appointed one researcher to assist with questionnaire distribution and collection. To facilitate the distribution of questionnaires and maximise response rates, investigators made initial contact by telephone with key informants selected from the sampled CDCs. These key informants were informed of the survey's aim and main content, and invited their colleagues to participate in the survey. Paper-based questionnaires (Appendix A) together with study information sheets (Appendix B) were distributed to selected CDCs by mail. Participation in the research was voluntary, and no incentives were offered to participants. Several days later the researchers travelled to Anhui, Henan, Liaoning, Guangdong and Yunnan provinces to personally collect the completed questionnaires.

In total, 1,134 questionnaires were distributed and all were returned. However, due to missing data, 90 of these questionnaires were eliminated leaving 1044 valid questionnaires. Therefore, the overall response rate for this study was 92%. The number of distributed questionnaires and returned valid questionnaires are illustrated in Table 3.2. The demographic characteristics of the participants (public health professionals) are described in Table 3.3. A database was developed using EpiData 3.1 software (EpiData Association, Odense M, Denmark) and the data from the questionnaires were entered into this database. The data were then saved in a password protected computer. All returned questionnaires were securely locked in a filing cabinet to protect confidentiality.

Table 3.2 The number of questionnaire distribution and collection in CDCs

Province	CDC	Number of distributed questionnaires	Number of valid questionnaires
Anhui	Anhui Provincial CDC	110	87
	Fuyang Prefectural CDC	35	31
	Yingzhou District CDC	20	18
	Yingdong District CDC	20	16
	CDC not indicated	-	2
Guangdong	Guangdong Provincial CDC	109	96
	Guangzhou Prefectural CDC	121	111
	Yuexiu District CDC	50	43
	CDC not indicated	-	10
Henan	Henan Provincial CDC	88	82
	Zhengzhou Prefectural CDC	56	43
	Shangqiu Prefectural CDC	51	49
	Yongcheng County CDC	54	52
	CDC not indicated	-	5
Liaoning	Liaoning Provincial CDC	120	117
	Huludao Prefectural CDC	50	48
	Lianshan District CDC	30	29
	Suizhong County CDC	30	30
	CDC not indicated	-	3
Yunnan	Yunnan Provincial CDC	150	136
	Dehong Prefectural CDC	25	24
	Yingjiang County CDC	15	12
Total		1134	1044

Table 3.3 Demographic characteristics of public health professionals

Characteristics	Number	Percent (%)
CDC		
Anhui	154	14.8
Guangdong	260	24.9
Henan	231	22.1
Liaoning	227	21.7
Yunnan	172	16.5
Levels of CDC		
Provincial	518	50.6
Prefectural	306	29.9
County	200	19.5
Age group (years)		
20-39	585	59.0
≥40	407	41.0
Gender		
Male	492	47.8
Female	538	52.2
Educational level		
Below undergraduate	241	23.8
Undergraduate degree	495	49.0
Postgraduate degree	275	27.2
Length of employment at CDC (years)		
≤9	402	43.8
10-19	274	29.8
≥20	242	26.4
Professional level		
Junior	309	29.6
Intermediate	410	39.3
Senior	232	22.2
Other	93	8.9

3.2.5 Data analysis

Data analysis was undertaken to focus separately on the three diseases, yielding three separate studies (see Chapters 5, 6, 7). Data relating to dengue were sourced from the questionnaires distributed in the dengue-prone area of Guangdong. For the malaria study, questionnaires used were from the malaria-prone areas of Anhui, Henan and

Yunnan. For the HFRS study, questionnaires from the HFRS-prone areas of Anhui and Liaoning were used.

The data were transferred to Stata 13 (Stata Corporation, College Station, Texas, USA) for analysis. Descriptive analysis was conducted using simple frequency calculations to describe the demographic characteristics of the public health professionals and categorical variables. The association between demographic variables and perception variables was assessed using Chi-square test or Fisher's exact tests if expected cell frequencies were less than or equal to five [43]. Ordinal logistic regression was used to determine the association between ordinal responses and demographic variables. The odds ratio (OR) with 95% confidence intervals (CI) and p-value from regression models were calculated. All statistics were analysed with a two-sided test and p-values less than 0.05 were considered statistically significant.

3.3 Study 2 - Questionnaire among clinical health professionals

3.3.1 Study site

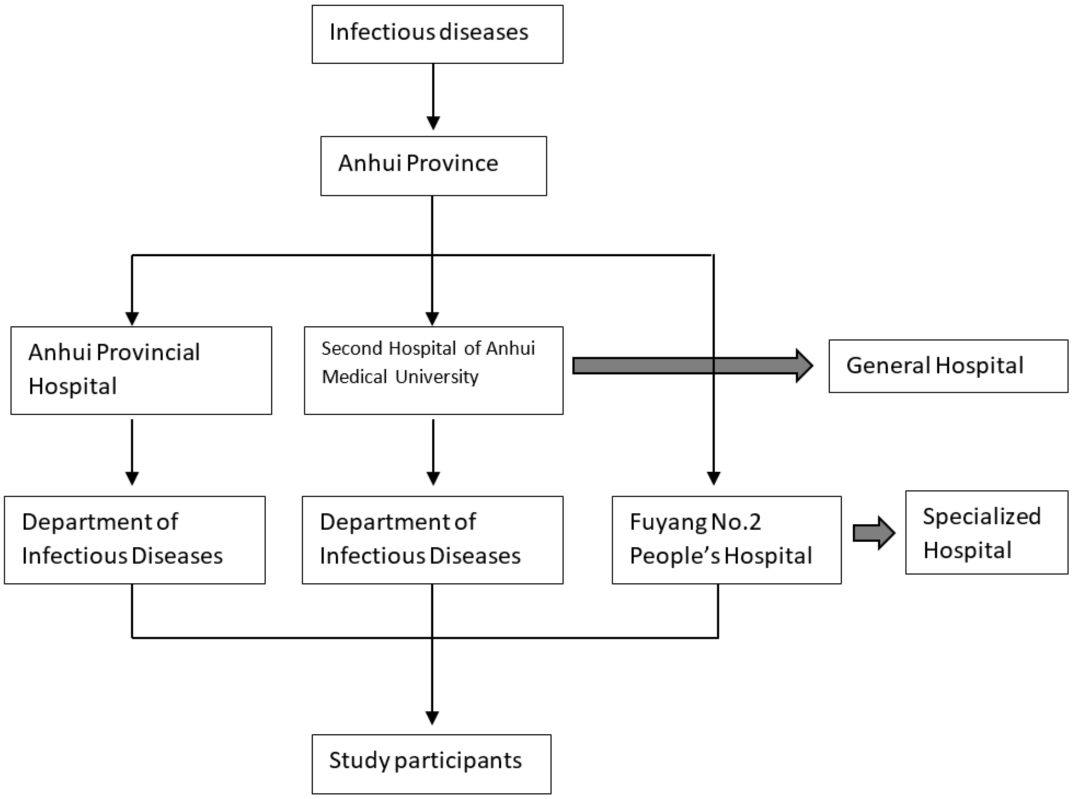
The study site of Anhui Province was selected to focus on clinical health professionals in hospitals. This was due to the research team's collaboration with colleagues in Anhui Medical University and the high incidence of malaria and HFRS in Anhui's large population [7, 47-49]. The geographic, demographic and climatic conditions of Anhui Province are described in Section 3.2.1.

Figure 3.3 Location of study site in China (Study 2)

3.3.2 Study participants

Participants were clinical health professionals from three major hospitals in Anhui Province. Figure 3.4 illustrates the selected hospitals from which study participants were recruited. Two hospitals were located in the capital city (Hefei) and one was located in the prefectural level city (Fuyang). Two hospitals in Hefei - Anhui Provincial Hospital and The Second Hospital of Anhui Medical University are general hospitals and participants were clinical health professionals whose roles pertained to infectious disease diagnosis, treatment and management. Fuyang No.2 People's Hospital was a hospital where the work of most clinical health professionals is related to infectious diseases treatment and control. Targeted hospitals were selected through discussion with key informants and a research team member in the Anhui Medical University.

Figure 3.4 Participants were selected from these hospitals for study 2



3.3.3 Sampling method

The sampling method was similar to that used in Study 1 (Section 3.2). The sampling unit was defined as a single clinical health professional in hospitals of Anhui, China. Health professionals from three hospitals in the province were involved in this study 2.

3.3.4 Questionnaire

The questionnaire was designed based on previous studies and relevant literature on climate-sensitive diseases in China [1, 42-46, 50, 51]. The questionnaire asked participants to indicate their thoughts on climate change, to what extent there is an association between climate change and the case study diseases, perceptions of disease occurrence, the capacity of hospitals to deal with infectious diseases, and strategies to build the capacity of the hospital sector to curb the health impact of climate change on infectious diseases. An open-ended question was included to elicit qualitative data on vector/rodent-borne disease control, diagnosis, treatment and management in the context of climate change. The questionnaire is included in Appendix C.

3.3.4.1 Structure and content of the questionnaire

The structure and content of the questionnaire were informed by the objectives of this study. Based on the objectives, the questionnaire was drafted to consist of four main parts: Demographics, Climate Change, Future Infectious Disease Risks in a Changing Climate, and Capacity Building to Deal with Disease Risks.

Part A *Demographics:* Participants' demographic information, such as age, gender, department, occupation, professional classification, the length of employment and level of education was collected in this part of the questionnaire. No identifying information was collected.

Part B *Climate Change:* This part consisted of three questions. The first question in this part asked participants to indicate how concerned they were about climate change. The response choices for the concern of climate change were "Very concerned", "Concerned", "Concerned slightly" or "Not concerned". The second question asked "Do you think your area is becoming warmer?". The response choices were "Yes" – becoming warmer, "No" or "Unsure". The third question had five statements about climate change and health. A five-point Likert scale was used with the response choices being "Agree strongly", "Agree somewhat", "Disagree somewhat", "Disagree strongly" or "Unsure".

Part C *Future Infectious Disease Risks in a Changing Climate:* This part consisted of 13 questions. The first question "To what extent do you think there is an association between climate change and these infectious diseases?" asked participants to indicate their thoughts on the likelihood of an association between climate change and infectious diseases including dengue, malaria and HFRS. The response choices were "Extremely likely", "Very likely", "Somewhat likely", "Not likely" or "Unsure". The next five questions were about infectious disease trends, risk factors, and epidemiological characteristics. The following questions were about infectious disease diagnosis, treatment and management.

Part D *Capacity Building to Deal with Disease Risks:* This part comprised three questions. The first question had 13 statements about capacity of the participants' hospitals to deal with infectious diseases to which participants could "Agree strongly", "Agree somewhat", "Disagree somewhat", "Disagree strongly" or "Unsure". The second question was about the importance of a range of strategies in building capacity to curb the population health impact of emerging and re-emerging infectious diseases due to climate change in China. This question included 14 statements to which the responses were "Extremely important", "Very important", "Important", "Less important" or "Not important". The last question was an open-ended question that asked participants to comment more openly on vector/rodent-borne disease control, diagnosis, treatment and management in the context of climate change.

3.3.4.2 Content validity of the questionnaire and translation

The draft questionnaire was fully assessed for content appropriateness and comprehensibility through a review by supervision panel (n=3), research team members (n=12) and a research steering committee comprising experts in Australia and China (n=3). The final version of the questionnaire was obtained after several rounds of modifications and discussions with experts. The questionnaire was then translated into Chinese with appropriate Chinese proofreading.

3.3.4.3 Pilot testing

Pilot testing was conducted in a clinical department of a university amongst 10 volunteers who were considered to share similar characteristics with the intended study participants. Volunteers were informed of the intent of the pilot testing and assured confidentiality. The result of the pilot testing indicated that the questionnaire was clear and understandable, and the maximum duration to complete the questionnaire was less than 30 minutes. Minor modifications were made as a result of the pilot testing.

3.3.5 Data collection and management

The approach by which participants were recruited, the study setting and timing of data collection has been described in the manuscript (Chapter 8). This section describes detailed recruitment process and outlines how data were collected and managed.

In November 2015, a group of investigators and researchers conducted the questionnaire survey in Anhui. To maximise the response rate, the principal researchers selected and informed six key senior contacts from the three hospitals for assistance with the dissemination of information about the study including the survey aims, objectives and main content by telephone. Thereafter, the principal researchers distributed questionnaires (Appendix C) together with study information sheets (Appendix D) to the three hospitals by mail. The six key senior contacts in the three hospitals distributed questionnaires to potential participants. The process of participation was voluntary, and no incentives were offered. As responses were anonymous, participants were given clear instructions not to include any identifying information on the questionnaire. After the completion of the survey in each hospital, the completed questionnaires were initially mailed back to Anhui Medical University for data collection, and then packaged and mailed to researchers at the University of Adelaide.

In total, 650 questionnaires were distributed and returned. However, due to missing data, 39 of these questionnaires were eliminated leaving 611 valid questionnaires. The response rate for this study was 94%. The number of distributed questionnaires and returned valid questionnaires are shown in Table 3.4. The demographic characteristics of participating clinical health professionals are described in Chapter 8. The database was developed using EpiData 3.1 software (EpiData Association, Odense M, Denmark) and the data from the questionnaires were entered into this database. These data were then saved in a password protected computer. All the questionnaires were stored in a locked filing cabinet to protect confidentiality.

Table 3.4 The number of questionnaire distribution and collection in hospitals

Hospital	Number of distributed questionnaires	Number of valid questionnaires
Anhui Provincial Hospital	45	38
The Second Hospital of Anhui Medical University	35	30
Fuyang No.2 People’s Hospital	570	543
Total	650	611

3.3.6 Data analysis

These data were transferred to Stata 13 (Stata Corporation, College Station, Texas, USA) for data analysis. Participants’ demographic characteristics were descriptively analysed. Ordinal logistic regression was used to explore the association between ordinal responses and demographic variables. The predictor variables were age, gender, professional level, length of employment, education, and occupation. The odds ratio (OR) with 95% confidence intervals (CI) and p-value from regression models were calculated. All statistics were analysed with a two-sided test and p-values less than 0.05 were considered statistically significant.

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CHAPTER 4 COMMENTARY ON INFECTIOUS DISEASES, URBANIZATION AND CLIMATE CHANGE IN CHINA

Statement of Authorship

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Name of Principal Author (Candidate)	Michael Xiaoliang Tong		
Contribution to the Paper	Conceptualise the manuscript structure, wrote manuscript. Revised the manuscripts based on reviewers' comments and suggestions. Re-submitted for publication.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Commentary

Infectious Diseases, Urbanization and Climate Change: Challenges in Future China

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Abstract: China is one of the largest countries in the world with nearly 20% of the world's population. There have been significant improvements in economy, education and technology over the last three decades. Due to substantial investments from all levels of government, the public health system in China has been improved since the 2003 severe acute respiratory syndrome (SARS) outbreak. However, infectious diseases still remain a major population health issue and this may be exacerbated by rapid urbanization and unprecedented impacts of climate change. This commentary aims to explore China's current capacity to manage infectious diseases which impair population health. It discusses the existing disease surveillance system and underscores the critical importance of strengthening the system. It also explores how the growing migrant population, dramatic changes in the natural landscape following rapid urbanization, and changing climatic conditions can contribute to the emergence and re-emergence of infectious disease. Continuing research on infectious diseases, urbanization and climate change may inform the country's capacity to deal with emerging and re-emerging infectious diseases in the future.

Keywords: climate change; urbanization; infectious disease; disease surveillance; challenges; disease control and prevention

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1. Introduction

China is one of the largest and most populous countries in the world with nearly 20% of the world's population [1]. Over the last few decades, China has witnessed an unprecedented economic boom with its Gross Domestic Product (GDP) per capita growing from $193 in 1980 to $6092 in 2012 [2]. However, such great economic growth may have been achieved at the cost of the environment and public health programs as compared to other aspects of development including economy, education and technology. One issue is infectious diseases, which continue to impair population health in this populous country [3]. Although infectious diseases only accounted for about 0.89%–1.06% of all deaths in China in 2011 [4], estimates suggest that there are about 7 million cases of notified infectious diseases, such as viral hepatitis, pulmonary tuberculosis, dengue and malaria, occurring amongst the 1.3 billion population, leading to approximately 17,000 deaths each year [4,5]. Tremendous efforts were made to reduce infectious diseases after 1949 [6], but some infectious diseases have rebounded and even increased in some areas since the 1980s [7–10]. Malaria, for example, has been a serious public health problem in China for many years and great efforts have been made to address the problem. Despite a remarkable decline in its incidence from about 2800 per 100,000 in 1970 to 10 per 100,000 in 1990, malaria has re-emerged in some areas since 2001, e.g., Henan, Hubei and Anhui provinces [11].

Prior to the outbreak of severe acute respiratory syndrome (SARS) in 2003, infectious diseases control and prevention had not been given enough attention [7]. The SARS outbreak started in Guangdong Province in November 2012 and challenged the then Chinese infectious disease control and prevention system. After the SARS outbreak, the Chinese government invested heavily in disease control and prevention [12]. As a result, there have been great improvements in public health infrastructure and public health workforce with new laboratories built, a surveillance system upgrade and increases in numbers of public health professionals [12,13].

The recent outbreak of Ebola virus disease in West Africa in 2014 has drawn worldwide attention [14], and accordingly, public health professionals in China have estimated the risk of imported cases and proposed pro-active disease control and prevention actions to minimize the risk of the transmission of the disease to China [15]. This is partly because China has a close trade relationship with Africa involving a frequent flow of travelers [16–18]. Public health authorities have been made aware of the need to continuously strengthen capacity to manage current infectious disease control systems to cope with possible emerging and re-emerging infectious diseases challenges.

China is an economically, geographically and climatologically diverse country with a huge population which may be the epicenter of new diseases and strains [19]. However, it remains uncertain how well current disease prevention and management system can sufficiently respond to future challenges of emerging and re-emerging infectious diseases, which may be exacerbated by the rapid process of urbanization, high numbers of migrant workers, and the impacts from a changing climate. In this light, this paper aims to examine China's capacity to manage infectious diseases in the future, especially in terms of disease surveillance and the likely impacts of two important issues affecting infectious disease trends—increasing urbanization and climate change.

2. Disease Surveillance

A timely disease surveillance system is essential for detecting, reporting and monitoring cases and outbreaks of infectious diseases. The existing public health system in China has been equipped with a comprehensive web-based real-time disease surveillance system built into a network of Centers for Disease Control and Prevention (CDC) at the national level, provincial level, prefectural level and county level. China's disease surveillance system enables 98% of counties and higher-level hospitals and 88% of township hospitals to have direct connection to the CDC disease reporting system [20,21]. If a notifiable infectious disease case is diagnosed and laboratory confirmed, the case will be reported to the web-based real-time surveillance system, the public health officer, the CDC and the health department, who will take responsibility to investigate the case when necessary [22]. Laboratory diagnostic capacity has also been strengthened in recent years [7]. However, the capacity of this system to detect and verify emerging/re-emerging infectious diseases and rapidly respond to future disease outbreaks still has room for improvement [16,23,24]. The status of the overall infectious disease surveillance infrastructure, health workforce and the underreporting of infectious diseases in some areas of China are of concern.

Firstly, previous research has demonstrated that the overall infectious disease surveillance infrastructure was underfunded in China, especially in poor and rural areas [7,22,23]. Although China has risen to become one of the largest economic powers in the world over recent decades, its health care investment is out of pace with its rapid economic growth [25]. Compared with other countries in the world, China ranks among the poorest in terms of public financing for health care [25]. Consequently, the lack of funding in public health has resulted in limitations in technical capacity and insufficient human resources in disease control and prevention to meet the challenge of potential emerging and re-emerging infectious diseases outbreaks [23]. Whilst China's comprehensive county-to-national level network CDC surveillance and reporting system has been reported as being one of the best in the world [7], greater effort is required to improve the infectious disease surveillance infrastructure. In urban areas infectious disease surveillance infrastructure has received, and continues to receive, financial support from local governments. However, maintenance and update of disease surveillance in county-level rural areas has relatively been neglected, leading to a regional imbalance between urban and rural areas [7]. Furthermore, despite the relative supremacy of urban disease surveillance infrastructure over its rural counterpart, it still has some limitations. In urban areas, for instance, most public health resources are concentrated in tertiary hospitals and central public health departments, while disease surveillance infrastructure in community-level health service centers needs to be strengthened. Better pathogen-based surveillance infrastructure for disease detection in urban areas and a more rapid response to infectious disease outbreaks is needed to ensure the risks of transmission are minimized in areas of high population density [16]. It is imperative, therefore, that initiatives and actions to maintain and update rural disease surveillance infrastructure be taken, whilst concomitantly reinforcing and optimizing urban disease surveillance infrastructure.

Secondly, the health workforce in some rural areas remains poorly trained and unmotivated [7]. In rural and poor areas there are relatively few health workers who have been professionally trained to effectively deal with infectious disease outbreaks. Likewise, few health professionals at provincial or lower levels CDCs have received formal epidemiological training and communication with international counterparts would be limited [7]. The 'Chinese Field Epidemiology Training Program' was established in 2001 with the support of the World Health Organization (WHO) and the US Centers for Disease Control (USCDC) with a view to developing and strengthening China's disease surveillance, field epidemiology, and response capacity. As of 2014, only 194 public health professionals had graduated from the program [26]. However, it still cannot meet the increasing needs for an adequate number of competent and motivated epidemiologists. In addition, for clinical doctors in hospitals, patients are their priority, not public health, which may have an influence on disease surveillance and reporting. One possible reason is that Chinese medical values, cultural norms and heavy workload have shaped clinical doctors who mainly focus on disease treatment rather than prevention [27]. However, in the modern health care system doctors play an important role in infectious disease detection, diagnosis, reporting, treatment and cooperation with local CDC staff. This concern is especially applicable in China, where it is estimated that more than 70% of the health care visits occur at village-level rural clinics. However, local health workers may lack relevant skills in awareness, diagnosis and treatment of rare diseases and emerging infectious diseases [7]. In this light, it is of critical importance to provide systematic and regular training for the health care workforce in CDCs, hospitals and relevant health departments, especially in rural and remote areas of inland provinces.

Thirdly, underreporting of infectious diseases is not uncommon in some areas of China, although in recent years the situation has improved as regulations are now in place. Disease reporting has been listed as an important indicator for evaluating local government's performance and hospitals are now randomly inspected to monitor the accuracy and quality of infectious diseases reporting. Underreporting may still occur due to various reasons [28]. Moreover, hospital doctors may not always report diseases as required [29]. Effective communication and information sharing between local hospitals and CDCs are critical for addressing the threats to disease control and prevention, yet doctors do not gain any direct and tangible benefits from the provision of disease surveillance information [24]. This communication and information sharing may benefit from effective incentive mechanisms to ensure accurate disease reporting procedures.

In summary, strengthened disease surveillance infrastructure, better trained health workers and further consideration of underreporting are needed to improve the infectious disease surveillance system. The importance of improving the system is further accentuated by the likely impacts on infectious disease transmission of two important issues facing this nation: urbanization and climate change.

3. Urbanization

The process of urbanization is of particular concern in modern China. China's accelerated development during the last few decades has resulted in rapid urbanization with unprecedented large-scale population movement within the country. Reports have indicated 54.7% of the total population lived in urban areas by the end of 2014, while the rate was only 26% in 1990 [30,31]. Rapid urbanization has brought numerous benefits to the country and substantially improved Chinese people's standard of living on the whole; public health, however, has not progressed to the same extent. This is especially the case for the migrant population, who have made considerable contributions to the country's economic development and urbanization, but often have less benefits in terms of income, job security, training, education, and health care [32–34].

At present, China is estimated to have a migrant population exceeding 221 million [35]. The migrant population, often described as the "floating population", largely consists of people originating from rural areas to urban areas in search of better economic and social opportunities. The "floating population" constitute a salient and disadvantaged group in China accounting for more than 10% of China's total population [24]. The migrants are often poor and less educated than the general population in urban areas. They typically live in low quality housing with inadequate sanitation, and have limited access to local health services. The needs of the migrant population have not been taken into full consideration in health care policy-makers' formulation of relevant policies and regulations, such as health insurance, occupational injury and infectious disease prevention strategies including immunization. Meanwhile, the "floating population" itself is reluctant to spend its already limited discretionary resources on health care. It comes as no surprise that the overall health status of rural-urban migrants is generally lower than that of local urban residents [33]. In particular, migrants can be more susceptible to infectious diseases, such as tuberculosis, human immunodeficiency virus (HIV) and sexually transmitted diseases (STD), as well as vector/food-borne diseases, and are less likely to receive proper treatment or be cured of infectious diseases than local permanent residents [7,34]. Further, children of migrant parents are also shown to have poorer health, lower nutrient intakes and constrained access to education compared to children of local or permanent residents [36]. Additionally, vaccination coverage among migrant children is lower than the rates for children of local or permanent residents [36]. These factors, in addition to the large size, high mobility and poorer health of the migrant population, have the potential to contribute to the spread of infectious diseases, adversely impacting on national health. Access to health care, insurance coverage, education and community support needs to be extended to the migrant population irrespective of residence and employment status.

The rapid process of urbanization has also caused dramatic changes in natural landscapes in China. New buildings, houses, roads, changed river flows and reduced vegetation impact on local ecological systems [37], and consequently influence the transmission of infectious diseases [37,38]. Studies have found that urbanization can impact on vector/rodent-borne infections, as many highly adaptable species in urban areas are important reservoir hosts for vector-borne and rodent-borne pathogens [39,40]. Moreover, accumulated garbage and discarded materials in cities provide food and habitats for rodents and vectors. Where water supplies are inadequate it can be necessary to store water in containers which can become an ideal habitat for mosquito larvae. By contrast, during the rainy season poor drainage systems can also create breeding sites [40,41]. These factors contribute to the emergence and re-emergence of vector/rodent-borne diseases, such as Japanese encephalitis, dengue fever and hemorrhagic fever with renal syndrome (HFRS) [40].

As the process of urbanization continues to accelerate and cities expand in size, there can be negative impacts on public health. High-density living is associated with close contact between humans and increased risks of disease transmission. Additionally, there are higher risks of human-pathogen and human-vector interaction in crowded areas where environmental health and sanitation conditions are poor. The large numbers of migrant workers in the cities constitute a high-risk group who can be more susceptible to local disease agents yet lack health insurance and may delay seeking treatment, thereby increasing the risk of disease transmission to others. These issues see the health care needs in high-density urban areas exceeding current resources. Forward planning needs to consider the implication of urbanization on disease prevention and control in China's rapidly growing mega-cities.

4. Climate Change

Like rapid urbanization, increasing climate change is of great concern to the Chinese government and people [42,43]. Many infectious disease agents such as viruses and bacteria, and vectors such as mosquitoes are influenced by seasonality and changes in temperature, rainfall and humidity [44]. It is widely understood that the process of rapid development and excessive human activities have caused an increase of 0.85 ± 0.2 °C in global mean temperature during the period from 1880 to 2012 [45]. The most recent Intergovernmental Panel on Climate Change report (IPCC Fifth Assessment Report) has predicted an increase of 1.1–6.4 °C in the average global land and ocean surface temperature from 1990 to 2100 and highlighted the significant impact of the rising temperature on infectious disease transmission and human health [45]. In China the rapid economic development during the last few decades has been accompanied by unprecedented environmental changes with a warming climate and more frequent weather-related natural disasters [46]. Studies have found that the average surface temperature in China has risen by 1.3 °C over the past 58 years (1951–2008) [47]. Precipitation from 1900 to 2005 has declined in southern parts of China, but increased by 22%–33% in northwest China [45]. There have also been increased frequency and intensity of extreme weather events such as droughts, landslides, mudslides, and regional and mountain floods [42]. These changes in climate will likely favor the transmission of many climate-sensitive diseases, such as mosquito-borne and rodent-borne diseases by affecting the ecology of the diseases, impacting upon their distribution and the number of disease cases.

Studies in China have indicated an association between climatic factors and the incidence of vector-borne diseases such as malaria and dengue fever, and diseases with rodent reservoirs such as HFRS [48–50]. Malaria and dengue are mosquito-borne infectious diseases caused by parasites of the genus *Plasmodium* and dengue viruses, respectively [51,52]. Climatic factors such as temperature and rainfall have been shown to be associated with the incidence of malaria and dengue via a changing impact on the lifecycles of mosquitoes and parasites, and virus replication [53]. Higher temperature can shorten the duration of parasite and virus replication, enhance the reproduction rate of mosquitoes, and increase the frequency of blood feeding and contacts with humans, causing higher incidence of malaria and dengue. However, extremely high temperature may also disrupt mosquito breeding, kill the eggs and larvae, evaporate water in breeding sites and shorten the mosquito survival cycle, leading to a decline in disease incidence [44]. Likewise, rainfall influences the incidence of malaria and dengue.

Increased rainfall favors mosquito development by providing aquatic breeding sites, subsequently increasing mosquito populations and the potential incidence of malaria and dengue [44]. Although excessive rainfall and flooding may destroy the existing mosquito breeding sites and restrict disease transmission in the short term, it is likely to create more breeding habitats for mosquitoes and increase disease incidence over time [44].

The incidence of HFRS has also been associated with climatic factors such as temperature, rainfall and relative humidity. Warmer conditions can increase activities of rodents and the rate of rodent reproduction, thus leading to an increase in the incidence of HFRS [54–56]. However, hot and dry conditions and lower relative humidity may increase the mortality of rodents, reduce the survival rate of hantaviruses in the reservoir, and thus curb the transmission of HFRS [57,58]. Plentiful rainfall can create an ideally moist environment for rodents and better growth conditions for vegetation that provide a food source, thus leading to an increase in the population size of rodents and contributing to HFRS transmission [55,59,60]. Similarly, increased relative humidity can promote rodent reproduction, infectivity and stability of the virus, and thus increase the incidence of HFRS [50].

The capacity of China's current infectious disease control and prevention system to address the daunting challenges of emerging and re-emerging climate-related infectious diseases due to climate change is still under researched and investigated. Research conducted among CDC staff in a Provincial CDC about their perceptions of, and attitudes towards, climate change and infectious diseases, found that CDC health professionals had noticed a climate change-related temporal and spatial change in the transmission patterns of certain infectious diseases such as vector-borne diseases, air-borne diseases and water-borne diseases [61,62]. Adaptation measures and actions were also proposed, such as strengthening existing disease surveillance systems and vector monitoring; building CDC capacity in terms of infrastructure and in-house health professional training; developing and improving relevant legislation, policies and guidelines; improving coordination among various government departments; engaging the community in infectious disease research and intervention, and conducting collaborative research in infectious diseases with other institutions [61,62]. However, the two studies were conducted in one province only and similar studies need to be conducted to enhance understanding of the associations between climatic variables and infectious diseases, and to develop appropriate climate change adaptation measures.

5. Conclusions

Since the outbreak of SARS in 2003 the public health system in China has improved due to all levels of governments' increased investment in disease control and prevention. The health status of the Chinese people has also improved [63]. However, infectious diseases still remain a major cause of morbidity and mortality, and this may be exacerbated by rapid urbanization and unprecedented impacts from climate change. Although infectious diseases in China have been significantly reduced over recent decades, China's current capacity to manage emerging and re-emerging infectious disease outbreaks is facing formidable challenges. A timely, streamlined, well-funded and efficient disease reporting and surveillance system is essential to monitor the threat of potential epidemics, which may not only affect population health in China but may also have wider implications for global health. In order to deal with future infectious disease threats effectively and promptly, comprehensive prevention and response strategies, which integrate a variety of complementary actions and measures, are needed. More research about infectious diseases, urbanization, climate change, and changing demographics needs to be conducted to support efforts to build China's capacity to control and prevent the spread of emerging and re-emerging infectious diseases in the future.

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Author Contributions

Michael Xiaoliang Tong wrote the original text. Alana Hansen, Scott Hanson-Easey and Peng Bi revised and edited the manuscript. Scott Cameron, Jianjun Xiang, Qiyong Liu, Yehuan Sun, Philip Weinstein, Gil-Soo Han and Craig Williams reviewed the document. All authors read and approved the final manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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CHAPTER 5 PUBLIC HEALTH PROFESSIONALS' PERCEPTIONS OF CLIMATE CHANGE AND DENGUE FEVER

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Contribution to the Paper	Collected data, performed data analysis, interpreted data, conceptualised the manuscript structure, wrote manuscript. Revised the manuscripts based on reviewers' comments and suggestions. Re-submitted for publication.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		ite	19 Mar 2017

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Perceptions of capacity for infectious disease control and prevention to meet the challenges of dengue fever in the face of climate change: A survey among CDC staff in Guangdong Province, China

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ABSTRACT

Background: Dengue fever is an important climate-sensitive mosquito-borne viral disease that poses a risk to half the world's population. The disease is a major public health issue in China where in 2014 a major outbreak occurred in Guangdong Province. This study aims to gauge health professionals' perceptions about the capacity of infectious disease control and prevention to meet the challenge of dengue fever in the face of climate change in Guangdong Province, China.
Methods: A cross-sectional questionnaire survey was administered among staff in the Centers for Disease Control and Prevention (CDCs) in Guangdong Province. Data analysis was undertaken using descriptive methods and logistic regression.
Results: In total, 260 questionnaires were completed. Most participants (80.7%) thought climate change would have a negative effect on population health, and 98.4% of participants reported dengue fever had emerged or re-emerged in China in recent years. Additionally, 74.9% of them indicated that the capability of the CDCs to detect infectious disease outbreak/epidemic at an early stage was excellent; 86.3% indicated laboratories could provide diagnostic support rapidly; and 83.1% believed levels of current staff would be adequate in the event of a major outbreak. Logistic regression analysis showed higher levels of CDCs were perceived to have better capacity for infectious disease control and prevention. Only 26.8% of participants thought they had a good understanding of climate change, and most (85.4%) thought they needed more information about the health impacts of climate change. Most surveyed staff suggested the following strategies to curb the public health impact of infectious diseases in relation to climate change: primary prevention measures, strengthening the monitoring of infectious diseases, the ability to actively forecast disease outbreaks by early warning systems, and more funding for public health education programs.
Conclusion: Vigilant disease and vector surveillance, preventive practice and health promotion programs will likely be significant in addressing the threat of dengue fever in the future. Further efforts are needed to strengthen the awareness of climate change among health professionals, and to promote relevant actions to minimize the health burden of infectious diseases in a changing climate. Results will be critical for policy makers facing the current and future challenges associated with infectious disease prevention and control in China.

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1. Introduction

Dengue fever is an important climate-sensitive mosquito-borne viral disease that poses a risk to half the world's population. The disease, which is caused by any of four dengue viruses (DENV) transmitted via *Aedes aegypti and Aedes albopictus* mosquitoes, can result in a severe febrile illness, and sometimes leads to potentially lethal haemorrhagic complications (World Health Organization, 2015). The World Health Organization (WHO) estimates that currently approximately 3.9 billion people are at risk of dengue fever; 390 million dengue infections occur annually worldwide; and of an estimated 500,000 people with severe dengue fever that require hospitalization each year, about 2.5% die due to complications (Bhatt et al., 2013; Brady et al., 2012; World Health Organization, 2015). There was no dengue fever case reported between 1949 and 1977 in China until an outbreak occurred in Guangdong Province in 1978 (Wu et al., 2010). Over the last three decades, dengue fever incidence has tended to be highest among the populations in South China, especially in Guangdong Province where *A. albopictus* mosquitoes are the primary vectors and DENV-1 is the predominant serotype circulating in this region (Huang et al., 2016; Lai et al., 2015). Since the 1990s there have been frequent outbreaks of dengue fever in Guangdong Province with 1658 cases being reported between 2005 and 2010, and 94.3% of these cases were local infections (Li et al., 2012). In 2014 an unprecedented outbreak led to more than 44,000 cases, of which most were locally infected cases (which may be due to the transmission from the imported cases from Southeast Asia) and primarily concentrated in older urban areas with relative poor drainage systems and numerous sites with stagnant water (Lai et al., 2015; Zhao et al., 2014).

Many infectious disease agents such as viruses and bacteria, and vectors such as mosquitoes are influenced by variations in temperature, rainfall and humidity (Bai et al., 2013). It is widely understood that there has been an increase of 0.85 ± 0.2 °C in global mean temperature during the period from 1880 to 2012 (Intergovernmental Panel on Climate Change, 2013). The most recent 2014 Intergovernmental Panel on Climate Change report (IPCC Fifth Assessment Report) has predicted an increase of 1.1–6.4 °C in the average global land and ocean surface temperature from 1990 to 2100 and highlighted the negative impact of the rising temperature on infectious disease transmission and human health (Intergovernmental Panel on Climate Change, 2013). Guangdong Province has been one of the fastest growing economic development areas in China during the last few decades and has been subject to unprecedented environmental changes with its warming climate and frequent weather-related natural disasters (Liu, 2009; The National Development and Reform Commission, 2013; Zhang et al., 2013). These changes in climate are likely to have a significant influence on the transmission of climate-sensitive diseases, especially vector-borne diseases such as dengue fever, by affecting the ecology of the diseases, impacting upon their distribution and the number of disease cases (Bai et al., 2013; Naish et al., 2014). Specifically, higher temperatures can shorten the duration of virus replication, and increase mosquito reproduction and contacts with humans. Changes in rainfall and relative humidity can also affect microenvironments for mosquito breeding (Bai et al., 2013; Naish et al., 2014). Thus, climate variations contribute directly or indirectly to the incidence and distribution of dengue fever. One study in Guangdong found each 1 °C rise of monthly mean temperature corresponded to an increase of 10.23% in the monthly number of dengue cases and each 1% rise of relative humidity led to an increase by 2.04–2.19% in monthly reported dengue cases (Li et al., 2013). Other studies also found climatic factors, such as temperature, relative humidity and rainfall, were positively associated with dengue transmission in Guangdong (Fan et al., 2014; Li et al., 2013; Lu et al., 2009; Sang et al., 2014; Wang et al., 2014). Currently, there are very limited climate change adaptation strategies/measures relevant to emerging and re-emerging infectious diseases, especially in developing countries including China (Meng et al., 2015). Hence, the capacity to control and prevent dengue fever is of a significant concern to public health authorities. Although Guangdong Province is one of the most developed areas in China, it remains uncertain to what extent current disease control and prevention measures can effectively respond to future challenges of dengue fever in the face of climate change.

Disease surveillance and communicable disease control and prevention are important duties for the Centers for Disease Control and Prevention (CDC) in China to protect the health of local populations (Chinese Center for Disease Control and Prevention, 2015). There are three levels of CDCs in each Province: a provincial-level CDC whose main duties include disease control and prevention across the Province, and the provision of professional management, technical support and organizational coordination to the CDCs in lower levels; prefectural-level CDCs and county/district-level CDCs which are responsible for infectious disease detection, response, control and elimination, and outbreak investigation in local areas. In light of this, CDC staff should be acutely aware of emerging health threats and be able to shed light on the current capacity of infectious disease control and prevention. The knowledge and experience of CDC staff may be able to help policy makers prioritize areas for action and make informed decisions (Weir et al., 2010). This is especially important because China's capacity for infectious disease control and prevention in the face of climate change may present numerous methodological challenges and knowledge gaps remain (Xun et al., 2010). Therefore, we investigated the CDC staff's perceptions of the current capacity and future strategies to meet the challenge of climate-sensitive diseases including dengue fever.

The purpose of this study was to gauge perceptions about the capacity of infectious disease control and prevention to meet the challenge of dengue fever, in the face of climate change. This study will contribute to an understanding of CDC staff's perception of infectious disease control and prevention in a changing climate.

2. Methods

2.1. Study site

Located in South China, Guangdong Province has a total area of 179,800 square km and a population of 106 million in 2013 (Guangdong Government, 2015b, 2015c) (Fig. 1). It is one of the most economically developed Provinces in China (National Bureau of Statistics of China, 2014), where it has a humid subtropical and tropical monsoon climate characterized by high temperatures and plentiful rainfall. The annual average temperature is 21.8 °C, and annual average precipitation is 1789.3 mm (Guangdong Government, 2015a). The mosquito populations are positively associated with temperature, precipitation and relative humidity in this area, and annually start to increase in February, peak around September and then decrease afterward (Yi et al., 2003; Yu et al., 2010). Breeding sites include pools, streams, tree holes, discarded tires, drains, tanks, flowers pots and other water containers (Yi et al., 2003). Guangdong has 21 prefecture-level divisions, comprising 58 districts, 23 county-level cities, and 40 counties. There is a CDC in each county/district and prefecture, in addition to the Guangdong Provincial CDC.

Fig. 1. Location of study site in China.

2.2. Study participants

A cross-sectional questionnaire survey was conducted among CDC staff in Guangdong Province in May 2015. The participating CDCs were the provincial CDC, a prefectural CDC and a county CDC. The inclusion criteria were those undertaking work in the field of infectious disease control and prevention, public health, medical laboratory and emergency response. Specifically, they were recruited from the following departments in all levels of CDCs including Communicable Disease Control and Prevention, Disinfection and Vector Control, Medical Laboratories and Emergency Response and Preparedness. To facilitate the distribution of questionnaires and maximise response rates, investigators made initial contacts with key informants selected from the sampled CDCs and briefly introduced the survey's aim and main content, then invited them and their colleagues to participate in the survey. After informed consent was obtained from individuals, 280 questionnaires together with information sheets were distributed to selected CDCs. Completed questionnaires were later collected under the support of key informants. The participation was voluntary and no incentives were offered to participants.

2.3. Questionnaire

The questionnaire was developed after a review of relevant literature (Center for Strategic & International Studies, 2008; Semenza et al., 2012; The National Development and Reform Commission, 2013, 2014; Wei et al., 2014a, 2014b). The full questionnaire aimed to explore the following five parameters: (1) participants' understanding of climate change, (2) which infectious diseases or groups of infectious diseases would most likely be affected by climate change, (3) perceptions of existing infectious disease control and prevention systems, (4) suggested adaptation measures in the face of climate change, and (5) strategies to strengthen the current capacity to deal with emerging and re-emerging infectious diseases to meet climate change challenges. Some questions had open-ended responses. Experts in China National CDC validated the draft questionnaire and relevant revisions were made in accordance with recommendations of experts. The questionnaire was then piloted among 18 staff in the China National CDC to ensure it was clear and understandable. Three well-trained researchers conducted the questionnaire survey. To ensure confidentiality and to reduce potential bias, the survey did not include any identifying information about the participants. All questionnaires were completed independently and later collected from a central point in each CDC. This study reports on a subset of questions relating to dengue fever, climate change and organizational capacity of disease control. The relevant section of the questionnaire is included in the Appendix. All distributed questionnaires were returned – 260 were complete and 20 questionnaires were incomplete. Therefore, the actual response rate for this study was 92.8%.

2.4. Statistical analysis

All questionnaires were entered into a database using EpiData 3.1 (EpiData Association, Odense M, Denmark) and all analyses were performed using Stata 13 (Stata Corporation, College Station, Texas, USA). Descriptive analysis was used to summarize participants' demographic characteristics. Chi square or Fisher's exact tests was used to test the relationships between demographic variables and perception variables (Wei et al., 2014a). Ordinal logistic regression was used to determine the association between different levels of CDC and the capacity for infection control and prevention. Gender, age, education, length of employment, professional level and specialty were adjusted in the full model. The odd ratios (OR) with 95% confidence intervals (CI) were calculated and a p value less than 0.05 was considered to be statistically significant.

2.5. Ethics approval

This study obtained ethics approval from the Human Research Ethics Committee of the University of Adelaide (Approval No. HS-2013-052), the University of South Australia (Approval No. 32268), Monash University (Approval No. CF13/3263-2013001642), Anhui Medical University (Approval No. 2013007) and the Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002). Informed consent was obtained from individuals. This consent procedure was approved by the Chinese Center for Disease Control and Prevention, and conducted in accordance with its guidelines.

3. Results

3.1. Study participants' demographic characteristics

Table 1 presents the demographic characteristics of 260 participants aged from 22 to 58 years who completed the questionnaire survey. Participants from the provincial-level, prefectural-level and county-level CDCs accounted for 36.9%, 46.5% and 16.5%, respectively. More than half of the participants (56.8%) held a Bachelor degree, and 36.4% held a Master's degree or above. Nearly half of participants (46.5%) had been employed at the CDC for less than 10 years, 31.1% had been employed 10–19 years and 22.4% for 20 or more years. There were 28.9% employed at junior level, 31.9% at intermediate level, and 33.5% at senior level. The professional specialties of participants were: infectious disease control and prevention (including communicable disease control and prevention, disinfection and vector control, and immunization) (38.1%), public health (including environmental, occupational, food and school hygiene) (23.8%), medical laboratory (27.1%), and emergency response (11%).

3.2. Study participants' perception of climate change

Participants were asked about their perceptions of climate change. The majority of participants (74.9%) were either concerned or very concerned about climate change, 23.6% were slightly concerned and 1.5% were unconcerned. In all, 203 participants (78.4%) agreed with the statement that the weather was becoming warmer, 48 participants (18.5%) were unsure, and 8 participants (3.1%) did not feel the weather was becoming warmer (data not shown). Table 2 presents the responses of the participants regarding climate change. Almost half (49.8%) strongly agreed that climate change would have a negative effect on population health, 30.9% agreed somewhat; and 93.8% and 93.1% either agreed strongly or somewhat that predicted increasing temperatures and precipitation would influence the transmission of infectious diseases. Nearly all (94.8%) indicated that they believed climate change would have an impact on vector-borne diseases, and a higher proportion of participants (96.1%) indicated climate change would influence dengue fever. However, only 26.8% of participants reported having a good understanding of climate change, and most (85.4%) indicated they needed more information about the health impacts of climate change.

There was a significant association between education and believing predicted increasing precipitation would influence the transmission of infectious diseases ($p=0.002$), and that 'climate change would affect vector-borne diseases' ($p=0.023$) and 'dengue fever' ($p=0.003$). Believing that 'climate change would affect vector-borne diseases' ($p=0.026$) and 'dengue fever' ($p=0.016$) was also significantly associated with the length of employment at the CDC. Specifically, participants with less than 20 years of employment at CDCs were more likely to have these beliefs than groups employed for other lengths of time. There was no other significant association detected between these perceptions of climate change and demographic factors such as age, gender, organizational levels of CDC, professional level and speciality.

3.3. Study participants' perceptions of dengue fever control and prevention

Most participants (86.3%) thought the density of mosquitoes had increased over the past 10 years, although 84.6% claimed there were some vector control programs in place. Among them, 91.4% indicated mosquito-borne diseases had increased over the period in their jurisdiction, and 66.2% attributed the increase to climate change. Nearly all participants (98.4%) reported that dengue fever had emerged or re-emerged in Guangdong in recent years and 71.7% of participants believed that there had been a geographic expansion of the disease in Guangdong. Furthermore, 81.4% of participants perceived some dengue fever outbreaks were occurring at different times of the year to normal. In terms of community awareness, 24.8% of participants strongly agreed that the local residents were well informed about how to reduce the risk of dengue fever around their home, and 44.9% agreed somewhat. Twenty one percent of participants strongly agreed with the statement that current prevention methods and control programs had been effective in reducing the incidence of dengue fever, and 37.0% agreed somewhat (data not shown).

In addition, an open-ended question, 'what do you think are the main risk factors for dengue in your region?' was used to explore main risk factors for dengue in Guangdong. Several main risk factors for dengue fever outbreaks were frequently reported including imported dengue cases, increasing mosquito density, hot weather, plentiful rainfall, numerous sites with stagnant water, high-density population, increasing population mobility, poor sanitation living areas and lack of health awareness in the local community.

3.4. Study participants' appraisal of infectious diseases prevention and control

In terms of the efficacy of current infectious disease control and prevention in China, 74.9% of participants believed that the ability of the CDC to detect infectious disease outbreak/epidemic early was excellent, and 86.3% indicated laboratories could rapidly provide diagnostic support. Regarding human resources, 83.1% believed current staff would be adequate in the event of a major outbreak, and 77.7% indicated current staff were adequately experienced in handing complex investigations, and 75.2% thought the staff were kept up to date and well informed about current infectious disease trends. Less than two-thirds of participants (64%) indicated their CDC had conducted research on climate-sensitive diseases. However, 85.1% of participants indicated current infectious disease surveillance platforms and network-based reporting systems needed to be strengthened, 89.8% believed their CDC should strengthen vector surveillance systems and 93.7% indicated more funding was needed to achieve this goal (data not shown).

There was a statistically significant association between the perceived capacity of the CDC and the different levels of CDCs. Ordinal logistic regression analysis was used to examine the associations between demographic characteristics (independent variables) and perceived CDC capacity (dependent variables). Results showed that provincial and prefectural CDC participants were more confident about the ability of CDCs to detect a disease outbreak than the county level (reference level) of CDC participants. In the ordinal logistic regression model without adjustment for covariates such as gender, age, education, length of employment, professional level and specialty (model 1), the odds ratios and 95% confidence intervals for the ability of CDCs to detect a disease outbreak were 1.0, 4.78 (95% CI 2.37–9.65) and 5.65 (95% CI 2.73–11.70) (p for trend < 0.01) for the county CDC; prefectural CDC; and provincial CDC respectively. Table 3 presents the ordinal logistic regression after fully adjusting the possible impact of gender, age, education, length of employment, professional level, and specialty (model 2), the odds ratios and 95% confidence intervals for the ability of CDCs to detect infectious disease outbreak were 1.0, 4.08 (95% CI 1.62–10.25) and 4.82 (95% CI 1.80–12.89) (p for trend < 0.01) for the county CDC; prefectural CDC; and provincial CDC respectively. Moreover, staff from prefectural and provincial CDCs were more likely to believe that they were adequately capable in the event of a major outbreak, they were adequately experienced in handling complex investigations, and laboratories could rapidly provide diagnostic support in the case of an epidemic. Additionally

Table 1
Demographic characteristics of the participants (N=260).

Characteristics	Number[a] (n)	Percent (%)
Age group (years)		
22–39	163	66.3
≥40	83	33.7
Gender		
Male	128	49.2
Female	132	50.8
Levels of CDC		
Provincial	96	36.9
Prefectural	121	46.5
County	43	16.5
Educational level		
Below undergraduate	17	6.8
Bachelor degree	142	56.8
Master degree or above	91	36.4
Length of employment at CDC (years)		
≤9	106	46.5
10–19	71	31.1
≥20	51	22.4
Professional level		
Junior	75	28.9
Intermediate	83	31.9
Senior	87	33.5
Other	15	5.8
Specialty		
Infectious disease control and prevention	80	38.1
Public health	50	23.8
Medical laboratory	57	27.1
Emergency response	23	11.0

[a] The number of participants may not add up to 260 as some questions were not answered.

Table 2
CDC staff's perception of the likely impact of climate change.

Climate change	Agree strongly	Agree somewhat	Neither agree or disagree	Disagree somewhat	Disagree strongly
	N (%)	N (%)	N (%)	N (%)	N (%)
Will have a negative effect on population health	129 (49.8)	80 (30.9)	43 (16.6)	5 (1.9)	2 (0.8)
Increasing temperatures will influence infectious diseases	152 (58.7)	91 (35.1)	13 (5.0)	2 (0.8)	1 (0.4)
Increasing precipitation will influence infectious diseases	145 (56.0)	96 (37.1)	15 (5.8)	1 (0.4)	2 (0.8)
Will have an influence on vector-borne diseases	109 (56.8)	73 (38.0)	10 (5.2)	0	0
Will have an influence on dengue fever	167 (65.0)	80 (31.1)	9 (3.5)	1 (0.4)	0
I have a good understanding of climate change	10 (3.9)	59 (22.9)	127 (49.2)	45 (17.4)	17 (6.6)
I need more information about climate change health impacts	102 (39.4)	119 (46.0)	34 (13.1)	4 (1.5)	0

compared with county CDCs, provincial and prefectural CDCs conducted more research on climate-sensitive diseases.

3.5. Perceptions of adaptation measures in the face of climate change and strategies in building capacity to deal with infectious diseases including dengue fever

Participants' perceptions of response measures of climate change adaptation are embodied in Table 4. More than 90% of participants thought that more research needed to be done to identify high-risk areas due to climate change, and on early warning systems for disease outbreaks. Furthermore, 88.2% believed there needed to be more staff training for them to better understand the impacts of climate change, and 86.9% indicated that there needed to be more funding for climate change research. Most participants (80.4%) thought that policymakers could adjust the current strategies for disease control and prevention in the face of climate change. In particular, 96.9% of participants indicated that more efficacious communication was needed among different sectors to deal with disease outbreaks. In terms of health promotion, 97.7% of participants agreed that there needed to be more health promotion programs in communities to educate the public about measures to minimize disease risks.

Table 5 shows participants' perceptions towards strategies in building capacity to curb the population health impact of emerging and re-emerging infectious diseases in the face of climate change in Guangdong. Over 60% of participants believed that: primary prevention measures; better response mechanisms; improved monitoring of infectious diseases; effectively predicting possible disease outbreaks; collaboration with other sectors; more funding for public health education programs, and better training of doctors in rural areas were very important strategies. More than half suggested that: establishing worldwide infectious diseases surveillance and emergency systems; formulating standard reporting procedures for the health sector and CDCs; improving field data collection and reporting; more affordable access to health care to aid in disease diagnosis; reducing underreporting of cases particularly in rural areas, and better education standards among public health and health care workers were very important.

4. Discussion

Given the potential health impacts due to climate change, it is important to ascertain China's capacity for infectious disease control and prevention, and the capacity of the healthcare system to prepare for the challenge of emerging and re-emerging infectious diseases. To our knowledge, this is the first study to investigate the views of CDC health professionals in Guangdong Province concerning dengue fever transmission due to climate change. Results can provide vital evidence for policy-makers, service providers and other stakeholders in the developing climate change policies, especially regarding dengue fever control and prevention.

Our study demonstrated that the majority of participants (74.9%) were concerned about climate change and 78.4% felt the weather was becoming warmer. This rate was higher than results in another study of CDC staff and perceptions of climate change conducted in Shanxi Province in Northern China (Wei et al., 2014a). This is perhaps because Guangdong province is hotter and more humid than Northern China (Guangdong Government, 2015a; Shanxi Government, 2015). Nearly half the participants (49.8%) strongly agreed climate change would have a negative effect on population health, and 30.9% agreed to some extent. This implies almost 20% of CDC staff do not believe there will be a negative health impact due to climate change, contrary to published studies that have found a likely association between climate variability and human health (Mathee et al., 2010; McMichael et al., 2006; Xu et al., 2012). Furthermore, most participants indicated that increasing temperatures and precipitation would have an influence on infectious disease transmission.

The vast majority of participants thought that climate change would lead to a higher incidence of vector-borne diseases, and specifically, nearly all thought climate change would lead to an increase in dengue fever. This indicates that more investment and resources should be allocated to vector-borne disease control, especially on dengue fever control and prevention in the future in the context of climate change. However, less than one third of health professionals had a good understanding of climate change and most participants indicated they need more information about the health impacts of climate change. This result is consistent with the findings of Wei et al. (2014b) in Shanxi Province, which suggested there was an urgent need to conduct more in-house training among health professionals in CDCs about climate change and health impact. In addition, our study found participants employed for less than 20 years in the CDCs and had higher educational levels were more likely to believe climate change would affect the incidence of vector-borne diseases and dengue fever

Table 3
Ordinal logistic regression (model 2) OR (95% confidence interval) for CDC capacity of infectious disease control and prevention in prefectural level CDC and provincial level CDC compared to the county level CDC.

	Prefectural CDC OR (95% CI)	Provincial CDC OR (95% CI)	p for trend
The ability of the local CDC to detect a disease outbreak	4.08 (1.62–10.25)	4.82 (1.80–12.89)	< 0.01
The laboratory can rapidly provide diagnostic support in the case of an outbreak	16.11 (5.53–46.93)	26.58 (8.49–83.22)	< 0.01
Staff are adequate in the event of a major outbreak	3.94 (1.59–9.78)	6.66 (2.51–17.71)	< 0.01
Staff are adequately experienced in handling complex investigations	5.90 (2.24–15.51)	10.65 (3.74– 30.34)	< 0.01
CDC conducts research on climate-sensitive diseases	7.84 (2.38–25.89)	27.62 (7.72–98.88)	< 0.01

Values are odds ratios (OR), 95% confidence interval (CI) from ordinal logistic regression model. Model 2 adjusted for gender, age, education, length of employment, professional level and specialty.

Table 4
CDC staff's perceptions of infectious disease control and prevention towards climate change adaptation.

Response measures to climate change	Agree strongly	Agree somewhat	Neither agree or disagree	Disagree somewhat	Disagree strongly
	N (%)	N (%)	N (%)	N (%)	N (%)
More research needs to be done to identify high risk areas due to climate change	118 (46.3)	115 (45.1)	21 (8.2)	0	1 (0.4)
More work needs to be done on early warning systems for disease outbreaks	142 (54.8)	104 (40.2)	11 (4.3)	1 (0.4)	1 (0.4)
There needs to be more staff training on the impacts of climate change	104 (40.8)	121 (47.5)	27 (10.6)	2 (0.8)	1 (0.4)
The budget for climate change research needs to be increased	121 (46.7)	104 (40.2)	33 (12.7)	1 (0.4)	0
Policymakers need to revise current strategies in the face of climate change	98 (37.7)	111 (42.7)	50 (19.2)	0	1 (0.4)
Better communication is needed between sectors to effectively deal with disease outbreaks	169 (65.0)	83 (31.9)	8 (3.1)	0	0
There needs to be more health promotion programs to educate the public about measures to minimize disease risks	162 (62.3)	92 (35.4)	6 (2.3)	0	0

than staff employed for more than 20 years. This could be because they are more likely to have university education and junior staff may be more likely to attend training programs.

Although 84.6% of participants claimed there were some vector control programs in their jurisdictions, less than 60% of participants indicated that those programs had been effective in reducing the incidence of dengue fever. Moreover, the majority thought mosquito numbers had increased and more than 90% indicated mosquito-borne diseases had increased in the past years. Perceptions may have been influenced by the unprecedented outbreak of dengue fever in Guangdong in the previous year (Zhao et al., 2014), or indicate there may be some deficiency in the vector control programs and more effort needs to be put into mosquito surveillance and control for dengue fever (Lai et al., 2015). Furthermore, increased numbers of mosquitoes have also been identified in other countries. For example, studies in Nepal found the mosquito population has increased and dengue vectors – *A. aegypti* and *A. albopictus* mosquito populations have expanded to higher altitudinal areas based on an entomological survey and key informant interviews (Dhimal et al., 2014a, 2015, 2014b). This may be attributed to climate change. However, in our survey less than two-thirds of CDC staff considered the increase of mosquito-borne diseases associated with climate change.

Almost all participants noted that dengue fever had emerged or re-emerged in recent years and the majority indicated there was a trend to expansion of the geographic distribution of the disease. The appraisal is consistent with findings from the peer-reviewed literature which shows dengue fever has been reported over recent decades from Guangdong Province, other southern China areas including Hainan, Guangxi and Fujian provinces, to the western region (Yunnan Province), and even in central China (Henan Province) (Lai et al., 2015; Wu et al., 2010). Other countries such as Nepal, Vietnam and Mexico have also reported dengue fever emergence/re-emergence and geographic expansion (Brunkard et al., 2008; Dhimal et al., 2014b; Do et al., 2014). Several reports have suggested this may be associated with climatic variations, such as changes in temperature, precipitation and relative humidity (Brunkard et al., 2008; Das et al., 2014; Do et al., 2014; Fan et al., 2014; Khormi and Kumar, 2014; Li et al., 2013; Sang et al., 2014; Wang et al., 2014). Moreover, most participants indicated some dengue fever outbreaks were occurring at different times of the year than normal. The plausible explanation is that the increasing numbers of imported dengue cases combined with higher temperatures over last few years in Guangdong may initiate local dengue fever outbreaks and extending the peak season (Chen, 2011). This indicates that climate change could pose an increasing challenge of dengue fever control and prevention in China. In addition, about one third of participants thought local residents were not well informed about how to reduce the risk of dengue fever around their home. Health education programs in local communities should therefore be strengthened.

Open-ended questions provided the opportunity for CDC staff to provide more opinions (i.e., not limited to the questions within the questionnaire) about the risk factors for dengue fever in

Table 5
CDC staff's perceptions towards strategies in building capacity to curb the population health impact of emerging and re-emerging infectious diseases in the face of climate change in Guangdong, China.

How important are these response strategies to climate change	Very important	Important	Unsure	Not important	Useless
	N (%)	N (%)	N (%)	N (%)	N (%)
Primary prevention measures	165 (64.0)	74 (28.7)	17 (6.6)	2 (0.8)	0
Better response mechanisms when outbreaks occur	160 (61.5)	90 (34.6)	10 (3.9)	0	0
Having more staff available to undertake epidemiological investigations of disease outbreaks	117 (45.0)	114 (43.9)	23 (8.9)	4 (1.5)	2 (0.8)
Strengthening international cooperation to address climate change challenges	129 (49.6)	114 (43.9)	17 (6.5)	0	0
Strengthening the monitoring of infectious diseases	166 (63.9)	86 (33.1)	8 (3.1)	0	0
Establishing worldwide infectious diseases surveillance and emergency systems	146 (56.4)	99 (38.2)	13 (5.0)	0	1 (0.4)
Formulating standard reporting procedures for the health sector and CDCs	143 (55.0)	101 (38.9)	16 (6.2)	0	0
Improving field data collection and reporting	152 (58.5)	92 (35.4)	16 (6.2)	0	0
The ability to actively forecast disease outbreaks by early warning systems	166 (64.1)	79 (30.5)	14 (5.4)	0	0
Collaboration with veterinary sector with regard to both surveillance and responses to an outbreak	157 (60.4)	94 (36.2)	9 (3.5)	0	0
Collaboration with hospital with regard to both lab detection and response to an outbreak	165 (63.7)	87 (33.6)	6 (2.3)	0	1 (0.4)
More affordable access to health care to aid in disease diagnosis	146 (56.2)	106 (40.8)	8 (3.1)	0	0
More funding for public health education programs	169 (65.0)	86 (33.1)	5 (1.9)	0	0
Underreporting of cases is an important issue particularly in rural areas	149 (57.3)	88 (33.9)	18 (6.9)	4 (1.5)	1 (0.4)
Better training of doctors in rural areas to provide greater capacity to identify and treat diseases	164 (63.1)	90 (34.6)	6 (2.3)	0	0
Better education standards among public health and health care workers	137 (52.9)	109 (42.1)	11 (4.3)	2 (0.8)	0

Guangdong. CDC staff reported risk factors such as imported dengue cases, increasing temperature, plentiful rainfall, high-density population and increasing population mobility contributed to the dengue transmission in Guangdong. These are generally consistent with other studies (Meng et al., 2015; Sang et al., 2014; Tong et al., 2015). In Guangdong Province, warmer and wetter weather with higher rainfall throughout the year contribute to ideal environmental conditions for the dengue vectors. The presence of stagnant water in domestic surroundings and construction sites provides numerous breeding sites for mosquitoes (Alirol et al., 2011; Liu et al., 2014). Moreover, fast development and urbanization have resulted in increasing internal migration and high-density living in urban areas. Globalization and a close trade relationship with Southeast Asian and African countries, especially those countries with dengue epidemics all year round, have resulted in many imported dengue cases to Guangdong Province which play a significant role in initiating local dengue outbreaks (Bodomo, 2010; Chen, 2011; He et al., 2007). Comprehensive prevention strategies with effective control measures involving improved urban design, better drainage systems, potential health screening of arriving travellers and migrant health support and management are also needed to curb dengue fever transmission (Jing et al., 2012; Tong et al., 2015).

Although participants thought the overall capacity of CDCs was excellent, some deficiencies may exist in current infectious disease and vector surveillance systems. More than 80% of participants indicated the current surveillance platforms and network-based reporting systems needed to be improved, and more than 90% declared the current disease surveillance system should be allocated with more resource and investment, which is consistent with other studies in China (Center for Strategic & International Studies, 2008; Liu, 2004; Wei et al., 2014b). Furthermore, the staff from provincial CDCs and prefectural CDCs were more likely to believe that the capacity of their CDCs, including staff and laboratory equipment are adequate in disease outbreaks. This may be because, on one hand lower organizational levels of CDCs lack high-quality laboratories, while on the other hand, higher levels of CDCs have more funding, training opportunities and better surveillance infrastructure than lower level CDCs (Center for Strategic & International Studies, 2008; Manuel, 2010). Future capacity building may consider ways to narrow the difference between higher and lower level CDCs, i.e., to provide more funding and training for county/district CDCs.

Most participants strongly suggested increasing the budget to conduct more climate and health related research and to establish early warning systems for predicting possible outbreaks in the face of climate change – these could be treated as significant climate change adaptation measures. Meanwhile, more efficacious communication and cooperation between different sectors (government organisations, health service providers and local communities, etc.), and more health promotion programs among local communities are also needed. Most participants believed that primary prevention measures, better response mechanisms, improved disease surveillance and early warning systems, collaboration with other sectors, more funding for public health education programs and better training of health workers in rural areas were very important strategies to help build capacity to meet the challenge of emerging and re-emerging infectious diseases. The results may imply a need to revise and prioritize certain adaptation measures and strategies, and develop better responses to meet the challenge of climate change and dengue fever threats.

The limitations of this study should be acknowledged. The cross-sectional study design only provides a snapshot of perceptions of the health professionals, and the results may not be generalizable and representative of all health professionals in Guangdong Province. However, this study received a strong support from CDCs which helped to ensure the high response rate and the quality of data.

5. Conclusion

Health professionals in Guangdong CDCs have a widespread awareness of climate change and its potential threat to infectious diseases, particularly dengue in this area, while knowledge of how to deal with the challenge is still limited. China's capacity for infectious disease control and prevention may need to be strengthened to meet the increasing challenge of climate change. Vigilant disease and vector surveillance, preventive practice and community health promotion programs will be required to address the threat of dengue in the future. Further efforts are required to adapt to climate change and to curb impacts of climate-sensitive infectious diseases on human health. This study directed attention where improvements may be helpful and provided baseline information for health departments and policy makers to formulate effective dengue fever prevention and control plans to improve China's capacity of coping with infectious diseases, and to ultimately reduce the adverse impacts of climate-sensitive diseases on population health. The findings of this study indicate approaches to strengthen dengue control and prevention in Guangdong which may also have potential implications for dengue control in other sub-tropical and densely populated areas such as the Asian countries.

Conflict of interest

The authors declare that they have no competing interests.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at http://dx.doi.org/10.1016/j.envres.2016.03.043.

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CHAPTER 6 PUBLIC HEALTH PROFESSIONALS' PERCEPTIONS OF CLIMATE CHANGE AND MALARIA

Statement of Authorship

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Contribution to the Paper	Collected data, performed data analysis, interpreted data, conceptualised the manuscript structure, wrote manuscript. Revised the manuscripts based on reviewers' comments and suggestions. Re-submitted for publication.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		te	10.04.2017

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Perceptions of malaria control and prevention in an era of climate change: a cross-sectional survey among CDC staff in China

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Abstract

Background: Though there was the significant decrease in the incidence of malaria in central and southwest China during the 1980s and 1990s, there has been a re-emergence of malaria since 2000.

Methods: A cross-sectional survey was conducted amongst the staff of eleven Centers for Disease Control and Prevention (CDC) in China to gauge their perceptions regarding the impacts of climate change on malaria transmission and its control and prevention. Descriptive analysis was performed to study CDC staff's knowledge, attitudes, perceptions and suggestions for malaria control in the face of climate change.

Results: A majority (79.8%) of CDC staff were concerned about climate change and 79.7% believed the weather was becoming warmer. Most participants (90.3%) indicated climate change had a negative effect on population health, 92.6 and 86.8% considered that increasing temperatures and precipitation would influence the transmission of vector-borne diseases including malaria. About half (50.9%) of the surveyed staff indicated malaria had re-emerged in recent years, and some outbreaks were occurring in new geographic areas. The main reasons for such re-emergence were perceived to be: mosquitoes in high-density, numerous imported cases, climate change, poor environmental conditions, internal migrant populations, and lack of health awareness.

Conclusions: This study found most CDC staff endorsed the statement that climate change had a negative impact on infectious disease transmission. Malaria had re-emerged in some areas of China, and most of the staff believed that this can be managed. However, high densities of mosquitoes and the continuous increase in imported cases of malaria in local areas, together with environmental changes are bringing about critical challenges to malaria control in China. This study contributes to an understanding of climate change related perceptions of malaria control and prevention amongst CDC staff. It may help to formulate in-house training guidelines, community health promotion programmes and policies to improve the capacity of malaria control and prevention in the face of climate change in China.

Keywords: Climate change, Malaria, Infectious diseases, Imported cases, Capacity building, Perception

Background

Climate change is one of the most critical challenges confronting the world today. The process of rapid development and excessive human activities have caused an increase of 0.85 ± 0.2 °C in global mean temperature over the period from 1880 to 2012 [1]. In China, the average surface temperature has increased 1.3 °C over the past 58 years (1951–2008) [4] and rapid economic development has been accompanied by landscape changes, environmental degradation, increased urbanization and frequent natural disasters [2]. Precipitation has declined in southern parts of China over the last century but increased by 22–33% in north-west China [1]. The most

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recent Intergovernmental Panel on Climate Change report (IPCC Fifth Assessment Report) in 2014 has predicted an increase of 1.1–6.4 °C in the average global land and ocean surface temperature from 1990 to 2100 and about 0.4–6 °C increase is projected for China over the period [1]. Climate change has had a negative influence on the transmission of infectious diseases [1, 3].

One of the concerns of health authorities in China is the possible influence of climate change on vector-borne diseases, especially malaria, a mosquito-borne disease which the authorities aim to eradicate by 2020 [4, 5]. Malaria is a life-threatening parasitic disease, which has been a serious public health problem in China and many other countries. *Plasmodium vivax* and *Plasmodium falciparum* are two predominant species of *Plasmodium* in China [6, 7], and the primary vectors are *Anopheles* mosquito species breeding in the streams, pools, paddy fields and other water bodies [8]. Considerable efforts have been made to address this public health issue in China, which has resulted in a significant decline in its occurrence during the 1980s and 1990s [9]. The reduction in malaria is considered to have been due to exponential improvements in the socioeconomic status and public health interventions [9]. However, early this century there was a re-emergence of the disease over several years [10]. Malaria incidence rapidly increased after 2000 and reached its peak in 2006, during which there were 64,178 cases reported in China [11]. Incidence then decreased markedly between 2007 and 2014 (Fig. 1) when there were 3078 cases reported, most being concentrated in the southwest region—Yunnan Province, central and east region—Anhui, Henan and Jiangsu provinces [6]. Possible reasons for this re-emergence may include meteorological factors, climate change, increased mosquitoes and imported cases, as studies in China have indicated that these factors could have impacts on the transmission of malaria [10, 12–14]. Given the high-density population, rapid economic development, urbanization and increasing numbers of international travelers in China, there is an urgent need to understand the effectiveness of current infectious disease control and prevention of malaria in the face of climate change.

The Center for Disease Control and Prevention (CDC) is an official health agency to protect and improve public health and safety by providing information to enhance health decisions, and promote health through partnerships with provincial health departments and other organizations [15]. One of the significant duties of CDC is infectious disease surveillance, control, and prevention [15]. There are three levels of CDCs in each Province: a provincial-level CDC, prefectural-level CDCs and county/district-level CDCs [16]. The main duties of the provincial-level CDC include the guidance of disease control and prevention across the Province, the provision of professional management, technical support and organizational coordination [15]. Prefectural-level CDCs and county/district-level CDCs are directly responsible for frontline work of infectious disease detection, response, control and elimination, and outbreak investigation in local areas [15]. Consequently, CDC staff are likely to be sensitive to emerging and re-emerging infectious disease threats, and it would be valuable to explore their perceptions of infectious disease control and prevention in the face of climate change.

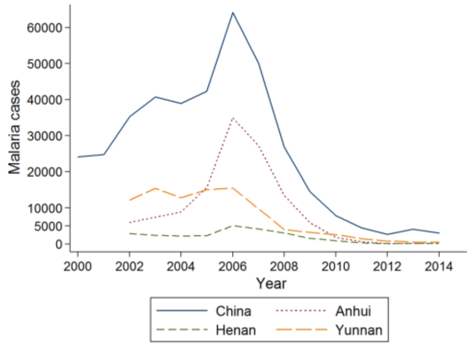

Fig. 1 Number of malaria cases in China 2000–2014. Data source was from China National CDC. http://www.chinacdc.cn

The aim of this study was to investigate perceptions of CDC staff regarding climate change and malaria control and prevention in China. The findings of this survey highlight the perceptions of China CDC staff of infectious disease control and prevention in the light of climate change. The collective knowledge and experience of the staff may prove useful in preparing for possible increases in malaria and assist policy-makers to formulate adaptation strategies for malaria in China in the context of a changing climate.

Methods

A questionnaire instrument was administrated to CDC staff in China. Questions were formulated following a review of relevant literature on climate-sensitive diseases in China [17–20]. The full questionnaire explored participants' beliefs about climate change, which infectious disease(s) would most likely be affected by climate change; perceptions of disease control and prevention; and suggested strategies to strengthen the current capacity to deal with emerging and re-emerging infectious diseases. The questionnaire also included five open-ended response questions, which provided opportunities for participants to comment more openly on infectious disease risk factors. The questionnaire was designed in English and then translated into Chinese. Experts in the China National CDC validated the draft questionnaire, and relevant revisions were made in accordance with recommendations of experts. The questionnaire was then piloted among 18 internal staff in the China National CDC. The results of the pilot testing showed that the questionnaire was clear and well understood. This study reports on a subset of questions relating to malaria and climate change. The relevant section of the questionnaire is included in Additional file 1.

Study population

The study population was health professionals in China CDCs whose roles included infectious disease control and prevention, public health, medical laboratory examination and emergency response in their CDCs. Eleven CDCs were involved in this study; three provincial CDCs in Anhui, Henan, and Yunnan Provinces, four prefectural, and county CDCs in the provinces (Fig. 2). The targeted CDCs in Anhui, Henan and Yunnan provinces were selected through discussion with key informants in the China National CDC. These provinces were selected as they had a high incidence of malaria at the time of the study and it was thought that participants could provide informed responses as they had direct experience to deal with malaria.

Study sites

Covering an area of 9.6 million square kilometres, China has a population of 1.36 billion with several climate zones [21]. Figure 2 shows the study sites.

Anhui Province, located in East China, has a total area of 139,600 km^2, a population of 60.8 million and GDP of the Province in 2015 was 2200.56 billion Yuan [22–24]. It has a warm-temperate, semi-humid monsoonal climate with an average annual temperature between 14 and 17 °C, and precipitation between 800 and 1800 mm [22]. China's largest and third largest rivers, Yangtze and Huai, run through the Province [22].

Henan Province, located in Central China, has a total area of 167,000 km^2, with a population of 106.6 million, is the most populous Province in China [25]. The GDP of the Province in 2014 was 3493.93 billion Yuan [25]. Henan has a temperate climate with four distinct seasons. The average annual temperature is between 10.5 and 16.7 °C, and precipitation varies from 407.7 to 1295.8 mm [25]. China's second and third largest rivers, Yellow and Huai, run through the Province [25].

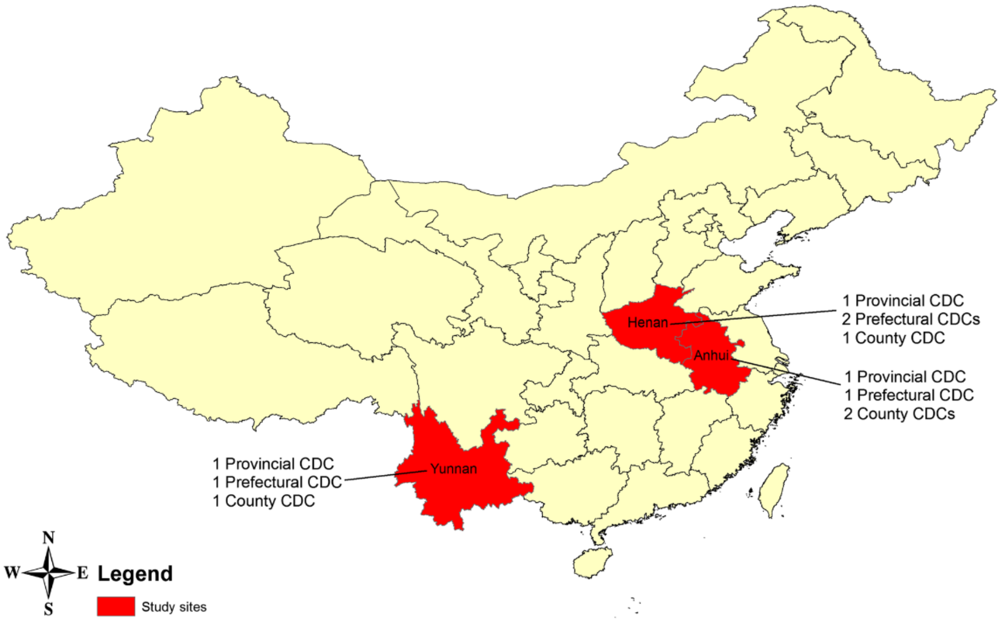

Fig. 2 Study sites and sampling CDCs in China

Yunnan Province, located in the Southwest of China and bordered by Vietnam, Myanmar, and Laos, has a total area of 394,000 km^2, a population of 46.8 million and GDP of the Province in 2014 was 1281.45 billion Yuan [26, 27]. It has a sub-tropical highland monsoonal climate. The hottest month is July (19–22 °C) and the coldest is January (6 and 8 °C) [28]. The annual precipitation is above 1000 mm in most areas of Yunnan, and 85% of the precipitation falls between May and October [28]. Six major river systems and many tributaries run through the Province [27].

Data collection

Three well-trained researchers conducted the fieldwork in China in May 2015. In order to facilitate the questionnaire distribution and to maximize response rates, investigators made contacts with the principal informants working in the selected CDCs and briefly introduced the survey's aims and main content, then invited them and their colleagues to participate. Participation was voluntary, and no incentives were offered. As responses were anonymous, participants were given clear instructions not to include any personal identifying information on the questionnaire. In total, 624 questionnaires were distributed and later collected from the participating CDCs. All questionnaires were collected, 557 were complete, 67 questionnaires were incomplete. Therefore, the response rate for this study was 89.3%.

Statistics

Data entry was facilitated using EpiData 3.1 software (EpiData Association, Odense M, Denmark). Stata 13 (Stata Corporation, College Station, Texas, USA) was used to perform all statistical analysis. The demographic characteristics of health professionals were descriptively analysed. The relationship between demographic variables and perception variables was assessed using Chi square test, or Fisher's exact tests if expected cell frequencies were less than or equal to five [18, 29]. Results were considered statistically significant at a p value <0.05.

Ethics approval

The study was approved by the University of Adelaide (Approval No. HS-2013-052), the University of South Australia (Approval No. 0000032268), Monash University (Approval No. CF13/3263-2013001642), Anhui Medical University (Approval No. 2013007) and the Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002). Informed consent was obtained from individual participants. This consent procedure was approved by the Chinese Center for Disease Control and Prevention, and conducted in accordance with its guidelines.

Results

Demographic characteristics

In this cross-sectional survey, 557 questionnaires were included (268 Males and 275 Females), ranging from 20 to 61 years of age. The demographic characteristics are described in Table 1. One hundred and fifty-four participants were from Anhui CDCs; 231 from Henan CDCs and 172 from Yunnan CDCs. There were 54.8% working in Provincial-level CDC, 27.6% working in Prefectural-level CDC and 17.6% working in District/County-level CDC. With regard to the level of education, the majority of the participants (73.5%) held university degrees. There were 42.6% of the participants who had <10 years working experience at the CDC, and 26.5% had worked for more than 20 years. Junior level staff accounted for

Table 1 Demographic characteristics of the participants (N = 557)

Characteristics	Number[a]	Percent (%)
Sites		
Anhui	154	27.6
Henan	231	41.5
Yunnan	172	30.9
Age group (years)		
20–39	301	57.8
≥40	220	42.2
Gender		
Male	268	49.4
Female	275	50.6
Levels of CDC		
Provincial	305	54.8
Prefectural	154	27.6
District/county	98	17.6
Educational level		
Below undergraduate	142	26.5
Bachelor degree	230	42.8
Master degree or above	165	30.7
Length of employment at CDC (years)		
≤9	200	42.6
10–19	145	30.9
≥20	124	26.5
Professional level		
Junior	160	28.7
Intermediate	228	40.9
Senior	106	19.1
Other	63	11.3
Specialty		
Infectious disease control and prevention	235	56.8
Public health	80	19.3
Medical laboratory	83	20.0
Emergency response	16	3.9

[a] The total number may not be equal to 557 for all items as some questions were not answered

28.7% of the total participants, intermediate level staff 40.9% and senior level staff 19.1%. More than half of the participants (56.8%) undertook duties pertaining to communicable disease control and prevention (including disinfection and vector control, and immunization), 19.3% performed other public health duties (including environmental, occupational, food and school hygiene), 20.0% worked in medical laboratories, and 3.9% worked in emergency response department.

Perceptions of climate change

Table 2 shows the participants' perception of climate change. The majority (79.8%) were either concerned or very concerned about climate change, and 18.9% were slightly concerned. Furthermore, participants in Henan were the most likely to be concerned about climate change ($p = 0.039$) (see Additional file 2). In the answer to the question "Do you think your area is becoming warmer?", 79.7% of participants said "Yes", 5.0% indicated "No" and 15.3% were "Unsure". Less than one-third of participants thought they had a good understanding of climate change, and the majority (88%) need more information about the health impacts of climate change. Additionally, male staff appeared to have a better understanding of climate change than female staff ($\chi^2 = 5.53$, $p = 0.019$). Staff who had been employed for <10 years were less likely to have a good understanding of climate change ($\chi^2 = 9.17$, $p = 0.01$) (see Additional file 2).

CDC staff's perceptions of the impact of climate change on public health are summarized in Fig. 3. Overall, 500 participants (90.3%) indicated climate change would have a negative effect on population health, 514 (92.6%) and 481 (86.8%) participants stated that predicted temperature increases and precipitation would influence the transmission of infectious diseases. Most participants (86.1%) agreed that climate change would increase the transmission of vector-borne diseases, and 83.9% expected that climate change would promote malaria transmission. Also, such perceptions were consistent across participants from different CDCs. We also found no significant difference in the perceptions of climate change between these who work in the frontline for disease control and other CDC staff.

Table 2 CDC staff's thoughts on climate change items

Thoughts on climate change items	Number[a]	Percent (%)
How concerned are you about climate change?		
Very concerned	163	29.3
Concerned	281	50.5
Slightly concerned	105	18.9
Not concerned	7	1.3
Do you think your area is becoming warmer?		
Yes	443	79.7
No	28	5.0
Unsure	85	15.3
Do you have a good understanding of climate change?		
Yes	171	31.1
No	379	68.9
Do you need more information about the health impacts of climate change?		
Yes	493	88.7
No	63	11.3

Perceptions of malaria control and prevention

As shown in Table 3, overall, about half (52.4%) of the CDC staff thought the number of mosquitoes had increased over the past 10 years—more in Yunnan, than in Henan and Anhui. There was no significant difference across these three provinces about the participants' perception ($\chi^2 = 4.57$, $p = 0.335$). However, the number of mosquito-borne diseases was perceived to be highest (55.2%) in Yunnan ($\chi^2 = 14.49$, $p = 0.006$), and correspondingly fewer participants from Yunnan CDCs claimed there were enough vector control programmes implemented, compared with those from other provinces. About 60% of those from Anhui and Yunnan indicated that mosquito-borne diseases had increased and that this was attributable to climate change while fewer (47.3%) participants from Henan held this opinion.

Participants from Anhui Province were less likely to indicate that malaria had re-emerged in their jurisdiction ($\chi^2 = 26.24$, $p < 0.001$), than those in Henan and Yunnan province. Regarding the perceived geographical expansion of malaria, about 36% of participants from Henan and Yunnan indicated that they believed malaria had moved into new geographic areas, while significantly fewer (17.4%) participants held this view in Anhui ($\chi^2 = 18.23$, $p = 0.001$). Twenty per cent of participants from Anhui indicated that malaria occurrences were arising at unusual times of the year, and more participants in Henan (26.8%) and Yunnan (33.8%) held this opinion. More than two-thirds (73.2%) of participants thought current prevention methods and the National Malaria Programme were effective in reducing the incidence of malaria, and the majority (64.5%) of participants indicated that the local residents in the population were well informed about how to reduce the risk of malaria (Table 3). Moreover, compared with other CDC staff, these who were directly related to the frontline work of disease control CDC staff were more likely to indicate that malaria had re-emerged in their regions in recent years (see Additional file 2).

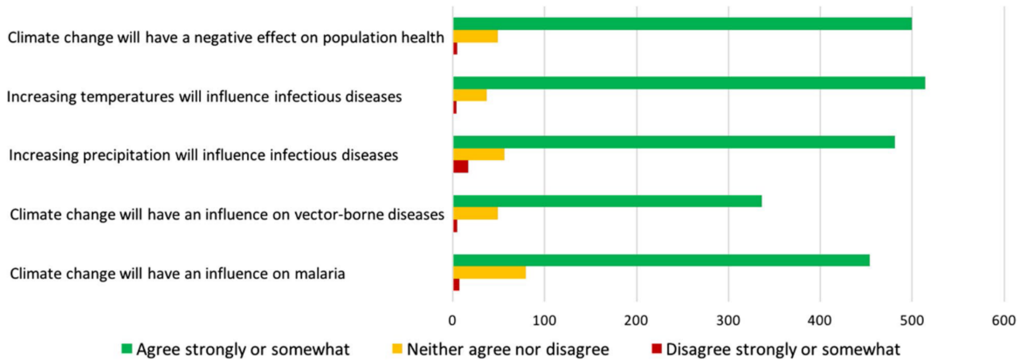

Fig. 3 Perception of impacts of public health in the face of climate change

Perceptions of the potential main risk factors for malaria

The perceived main risk factors for malaria in China were explored with an open-ended question. Participants were asked 'What do you think are the main risk factors for malaria in your region?' Table 4 summarizes these results. The most frequently reported risk factor for malaria in China was mosquitoes in high-density (23.5%), and 21.9% of participants believed imported case of malaria from overseas was a risk factor. Furthermore, 12.8% of participants implicated climate change, 10.6% thought poor environmental conditions, and 8.8% indicated internal migrant population and lack of health awareness as other significant risk factors for malaria. In addition, 12% of participants also thought insufficient control measures, numerous mosquito breeding sites, poor living conditions, poor management of imported cases and geographical factors could contribute to the transmission of malaria.

Discussion

This is the first study to explore CDC staff's views and understanding of climate change and the transmission of malaria in China. Results showed most participants in our survey were either concerned (50.5%) or very concerned (29.3%) about climate change, and about 19% of participants were slightly concerned. The majority (79.7%) of participants indicated they thought the weather was becoming warmer. However, perceived knowledge of climate change was limited. Less than one-third of participants (31.1%) reported they had a good understanding of climate change and nearly 90%, especially females and new staff, indicated they need more information about climate change impacts. Further in-house training activities could be promoted to improve staff's knowledge and understanding of climate change. This is consistent with other studies highlighting the need for training and education among CDC staff [29–31].

The vast majority of participants indicated climate change would have an adverse impact on population health, and increase the transmission of infectious diseases, which is line with other studies [32–34]. In particular, 92.6 and 86.8% of participants indicated increasing temperatures and rainfall would influence infectious disease transmission. Furthermore, over 80% of participants believed that climate change would affect vector-borne diseases, including the transmission of malaria. These findings suggest that more attention needs to be paid to malaria control and prevention in the face of climate change to meet the goal of the China National Malaria Elimination Programme by 2020 [5].

About half of the participants indicated they thought the number of mosquitoes had increased over the past 10 years in their regions, despite some vector control programmes being implemented in place. This increase could be due to different reasons, such as urbanization, landscape changes, and the reduction of biodiversity [35]. It may also indicate that current vector control programmes need to be further improved. Some participants stated that mosquito-borne diseases had increased over the period, and this perception was highest in Yunnan Province compared to the other two provinces. This could be due to hotter, more humid weather in Southwest China and numerous imported cases from neighbouring epidemic countries such as Vietnam, Myanmar, and Laos [36, 37], suggesting regional cooperation such as data sharing and information exchange is imperative for malaria and other vector-borne diseases control. Among those participants who believed mosquito-borne diseases had increased, more than half considered the increase was associated with climate change. Studies have found

Table 3 Local CDC staff's perceptions of malaria control and prevention

	Anhui			Henan			Yunnan			Statistics	*p*
	Yes N (%)	Unsure N (%)	No N (%)	Yes N (%)	Unsure N (%)	No N (%)	Yes N (%)	Unsure N (%)	No N (%)		
Is the number of mosquitoes increased?	81 (53.0)	38 (24.8)	34 (22.2)	106 (47.5)	56 (25.1)	61 (27.4)	95 (56.9)	40 (23.9)	32 (19.2)	$\chi^2 = 4.57$	0.335
Are mosquito-borne diseases increased?	52 (34.2)	53 (34.9)	47 (30.9)	98 (42.8)	69 (30.1)	62 (27.1)	91 (55.2)	41 (24.8)	33 (20.0)	$\chi^2 = 14.49$	0.006
Would you attribute these to climate change	38 (58.5)	23 (35.4)	4 (6.1)	70 (47.3)	72 (48.6)	6 (4.1)	55 (61.1)	24 (26.7)	11 (12.2)	Fisher's exact	0.005
Are there vector control programmes in place?	107 (71.3)	31 (20.7)	12 (8.0)	175 (76.4)	47 (20.5)	7 (3.1)	107(64.1)	41 (24.5)	19 (11.4)	$\chi^2 = 12.83$	0.012
Has malaria re-emerged in this area in recent years?	51 (39.8)	39 (30.5)	38 (29.7)	105 (57.4)	60 (32.8)	18 (9.8)	77 (55.4)	46 (33.1)	16 (11.5)	$\chi^2 = 26.24$	<0.001
Are some malaria outbreaks occurring in new geographic areas?	21 (17.4)	72 (59.5)	28 (23.1)	65 (35.9)	95 (52.5)	21 (11.6)	51 (36.7)	70 (50.4)	18 (12.9)	$\chi^2 = 18.23$	0.001
Are some outbreaks occurring at unusual times of the year?	24 (20.0)	71 (59.2)	25 (20.8)	48 (26.8)	99 (55.3)	32 (17.9)	47 (33.8)	76 (54.7)	16 (11.5)	$\chi^2 = 8.43$	0.077
Have current prevention methods and the National Malaria Programme been effective in reducing incidence in this area?	99 (80.5)	23 (18.7)	1 (0.8)	127 (70.2)	54 (29.8)	0	96 (69.0)	40 (28.8)	3 (2.2)	Fisher's exact	0.034
Is the population in general well informed about how to reduce the risk of malaria?	86 (70.5)	30 (24.6)	6 (4.9)	118 (64.8)	51 (28.0)	13 (7.2)	81 (58.3)	46 (33.1)	12 (8.6)	$\chi^2 = 4.49$	0.343

Table 4 Potential main risk factors of malaria

Potential main risk factors	Frequency	Percent (%)
Mosquitoes in high-density	71	25.1
Imported cases	62	21.9
Climate change	36	12.8
Poor environmental conditions	30	10.6
Internal migrant population	25	8.8
Lack of health awareness	25	8.8
Others	34	12.0

Risks were explored by open-ended questions. Keywords of risks were listed in the table. The frequency did not equal to total 557 as some participants either did not answer the questions or answered unclear/unsure about the potential main risk factors

that climate change-induced warmer weather accelerates mosquito life cycles, hastens the development of the malaria parasite within the vector, and contributes to mosquito breeding and biting, and thus disease transmission [10, 12, 38]. Furthermore, warmer weather may have also changed human behavior that could contribute to disease transmission [38].

More than half the participants from Henan and Yunnan CDCs indicated malaria had re-emerged in recent years. This may be due to the increased number of imported malaria cases from overseas (foreign nationality or Chinese workforce infected overseas) and the risk of transmission of infected individuals present to the local population [6, 7]. Furthermore, more participants in Henan and Yunnan thought malaria was occurring in new geographic areas, which are consistent with other studies showing that malaria was emerging and re-emerging in these regions [8, 36, 37]. Greater prevention and control efforts should aim to inhibit malaria transmission in these areas. Although other studies also found malaria had re-emerged in Anhui Province since 2000 [10, 39], participants from Anhui CDCs in this survey were less likely to claim that malaria re-emergence and geographic expansion had occurred. This could be due to the great reduction of malaria cases in Anhui Province from 34984 in 2006 to only 144 in 2014 [11]. Hence, CDC staff in Anhui may be less likely to have observed that malaria had re-emerged compared with the other two Provinces. In addition, the current National Malaria Programme and other related prevention and control measures were thought to be effective in reducing malaria incidence by most of the participants in this survey, which could affirm the overall effectiveness of current control plans. However, in other regions such as Yunnan there may be a need for plans to be further improved to meet the aim of malaria elimination. Furthermore, it will be interesting to know the reasons for the different perceptions of the CDC staff between Henan and Anhui Provinces in terms of malaria emergence and re-emergence, and expansion of epidemic foci, because the two Provinces, especially the malaria epidemic foci are next to each other. In addition, frontline CDC staff were more likely to indicate that malaria re-emerged which could be due to the fieldwork experience they had, compared with other workers. More relevant research among frontline staff in the prefecture and county lower-level CDCs should be conducted to assess the re-emergence of malaria in the context of climate change in China.

The perceived risk factors yielded from open-ended questions are consistent with other studies showing risk factors associated with emergence and re-emergence of malaria in China [35, 38, 40, 41]. High densities of infected *Anopheles* mosquitoes would significantly contribute to the transmission of malaria, and this has been considered one of the most important factors leading to increased incidence of malaria worldwide [38, 40]. Moreover, CDC staff indicated that malaria control and prevention has been severely jeopardized by the growing number of imported cases of malaria, which has also been highlighted by other studies [42–44]. This trend of imported malaria to China has increased gradually since 2006. In 2014, the imported cases of malaria accounted for 98.1% of all malaria cases in China [6]. This implies that action is needed to curb the increasing numbers of imported cases by warning outgoing travelers to avoid potential risk areas or take necessary preventive measures, screening incoming international travelers and returning Chinese workers from overseas to detect and treat cases, and identify types of imported cases [6]. In addition, regional cooperation at the policy level, especially between China and its neighbouring countries, such as Vietnam, Myanmar, and Laos, is very important, in terms of establishment of a similar surveillance system for information exchange, regional collaboration for vector control [45]. Furthermore, more attention to climate change, environmental improvement, internal migrant populations, and health education programmes would also be necessary to reduce the incidence of malaria in China.

This study has several limitations. Firstly, the study participants were from 11 selected CDC, and the result may not be entirely representative of all CDC staff. Secondly, although the study started with a relatively large number of health professionals, the county-level and prefectural-level CDC sample was comparatively small compared with the provincial-level CDC. Future studies could enlarge the samples to recruit more county-level and prefectural-level CDC staff who are working on the frontline for disease control and prevention. Thirdly, the questionnaire survey was conducted in Chinese, and there may be some minor anomalies in translation. Fourthly, response biases may happen as participants may overestimate or underestimate their knowledge and competence. Furthermore, as malaria cases have decreased in China between 2007 and 2014 (Fig. 1) the terms “re-emerged” and “in recent years” in the questionnaire could be viewed subjectively by participants and could be taken to mean the last 15 years or since the 2006 peak. Nevertheless, this study represents health professionals’ perception of infectious disease control and prevention in the face of climate change and also indicates a significant finding that CDC staff may benefit from more scientific information on climate change that, in turn, may help improve the capacity for malaria control and prevention in the face of climate change in China.

Conclusions

This study found most CDC staff endorsed the statement that climate change has had a negative impact on infectious disease transmission. Malaria is reportedly re-emerging in some areas. However, high densities of mosquitoes and the continuous increase in imported cases of malaria in local areas are critical challenges to malaria control. Further efforts in mosquito density control, imported case surveillance and management, regional cooperation for malaria control and information sharing, climate change-related research and monitoring of potential re-emerging malaria areas are urgently needed. Additionally, comprehensive response measures considering issues of urbanization, internal migrant population, working and living conditions and optimized health promotion strategies are likely to be fruitful in building the capacity of infectious disease control to curb the possible health impact of emerging and re-emerging malaria in China.

Additional files

Additional file 1. Questionnaire.
Additional file 2. Supplementary tables.

Abbreviations

CDC: Center for Disease Control and Prevention; IPCC: Intergovernmental Panel on Climate Change.

Authors’ contributions

MXT analysed and interpreted the data, and drafted the manuscript. AH designed the questionnaire. MXT, JX, and XL conducted the field survey. AH, SHE and PB revised and edited the manuscript. SC, JX, QL, YS, PW, GSH, and CW reviewed the document. All authors contributed to the final version of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets during and/or analysed during the current study available from the corresponding author on reasonable request.

Ethics approval and consent to participate

The study was approved by the University of Adelaide (Approval No. HS-2013-052), the University of South Australia (Approval No. 0000032268), Monash University (Approval No. CF13/3263-2013001642), Anhui Medical University (Approval No. 2013007) and the Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002). Informed consent was obtained from individual participants. This consent procedure was approved by the Chinese Center for Disease Control and Prevention, and conducted in accordance with its guidelines.

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CHAPTER 7 PUBLIC HEALTH PROFESSIONALS' PERCEPTIONS OF CLIMATE CHANGE AND HFRS

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Contribution to the Paper	Collected data, performed data analysis, interpreted data, conceptualised the manuscript structure, wrote manuscript. Revised the manuscripts based on reviewers' comments and suggestions. Re-submitted for publication.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
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By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Health professionals' perceptions of hemorrhagic fever with renal syndrome and climate change in China

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A B S T R A C T

Background: Hemorrhagic fever with renal syndrome (HFRS) is a serious public health problem in China. Although the incidence of HFRS sharply reduced towards the end of the twentieth century, there has been a re-emergence of the disease after 2008 in some parts of China. The aim of this study was to gauge the perceptions of health professionals in China concerning HFRS control and climate change.
Methods: A cross-sectional survey about HFRS and climate change was conducted among staff in the Centers for Disease Control and Prevention (CDC) in Liaoning and Anhui Provinces, where HFRS is still a public health concern. Descriptive analyses were performed to assess survey results.
Results: In total, 412 questionnaires were distributed, and 381 participants completed the survey. >80% of participants thought climate change would have an influence on population health and infectious diseases. However, fewer participants (<60%) indicated that climate change would affect rodent-borne diseases, such as hantavirus infections. More than 40% of participants in Liaoning Province thought rodent populations had increased over the last ten years while 25.5% held this opinion in Anhui Province. Sixty-seven percent of participants in Liaoning indicated that HFRS had re-emerged, whereas <40% of participants in Anhui endorsed the statement. The majority of participants (70.9%) indicated there were rodent control programs in their area. However, less than half of participants thought these were effective in reducing HFRS incidence. Participants viewed the main risk factors for HFRS in China as being increased rodent density and infected rodents, contact with rodents, and lack of health awareness among the population.
Conclusions: Although most participants thought that climate change would have negative impacts on population health and infectious diseases, fewer participants believed it would contribute to the transmission of rodent-borne diseases, such as hantavirus infections. More participants in Liaoning indicated that HFRS had re-emerged, and current prevention programs, especially rodent control programs, need to be improved. Furthermore, more climate change-related research, health promotion programs, extended vaccination coverage, and better environmental management will likely be vital in addressing the threat of HFRS in the face of climate change. The results will be useful to inform HFRS control and prevention strategies.

1. Introduction

Hemorrhagic fever with renal syndrome (HFRS) is a dangerous zoonotic disease caused by hantaviruses and is a serious public health problem in China in past decades (Zhang et al., 2010b; Liu et al., 2012). The disease is transmitted to humans via rodents and symptoms include fever, hemorrhage, hypotension and renal dysfunction (Xiao et al., 2014b; Zhang et al., 2011). About 90% of the world's cases are reported in China (Xiao et al., 2014b). Two species of hantavirus – Hantaan virus (HTNV) and Seoul virus (SEOV) are predominant in China (Zhang et al.,

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2011). The hosts for these viruses are *Apodemus agrarius* and *Rattus norvegicus* respectively. Humans can be infected by inhaling aerosols that are contaminated with the virus shed in excreta, saliva and urine of infected animals or by contact with contaminated food, water, and infected rodent hosts (Bi et al., 2002; Hansen et al., 2015). *Apodemus agrarius* is prevalent in agricultural regions of China while *Rattus norvegicus* is prevalent in urban areas (Xiao et al., 2013a).

There were >1 million HFRS cases reported between 1931 and 1995 in China (Bi et al., 2002). Male farmers aged 30–50 years were the most vulnerable population (Liu et al., 2012). The incidence of HFRS peaked in 1986 (115,807 cases) and then declined in the late 1990s (about 20,000–50,000 cases annually) (Zhang et al., 2014a, 2014b). This reduction could be due to numerous control measures such as deratization strategies, an introduced vaccination program, better health care access and health education. However, the incidence once again rebounded after 2008 (Zhang et al., 2014b). The majority of these cases in China are concentrated in north-eastern, central and eastern China, in the provinces of Liaoning, Heilongjiang, Shanxi, and Anhui (Zhang et al., 2014b; Bi et al., 2005; Liu et al., 2011). During 2004 and 2005, Liaoning had the highest incidence of HFRS in China, and is still one of the high-risk areas (Liu et al., 2011). Before that period, the incidence rate of HFRS was very high in Anhui - >10 per 100,000 population during the 1980s and 1990s, and nowadays there are still a number of cases reported annually (Zou et al., 2016). Fig. 1 shows the annual incidence of HFRS from 2002 to 2013 in Liaoning and Anhui (National Health and Family Planning Commission of the PRC, 2016). In both provinces, the incidence of HFRS reduced gradually after 2004. However, there has been an increasing trend of HFRS cases in those regions since 2008. In Liaoning, for example, the incidence increased from 1.71/100,000 in 2008 to 2.96/100,000 in 2013. In Anhui the incidence of HFRS rose from 0.17/100,000 in 2008 to 0.32/100,000 in 2013. Although continuous control and prevention measures have been implemented in these provinces, there are still about 30,000 to 60,000 HFRS cases reported annually in China (Hansen et al., 2015; Xiao et al., 2013a).

There are a number of studies indicating the increasing number of HFRS cases is associated with climatic variables and possibly climate change, such as increasing temperature, precipitation and relative humidity (Hansen et al., 2015; Liu et al., 2011; Li et al., 2013; Zhang et al., 2010a; Guan et al., 2009; Bi et al., 2005). According to the most recent Intergovernmental Panel on Climate Change report (IPCC Fifth Assessment Report) in 2014, the average global land and ocean surface temperature is predicted to increase 1.1–6.4 °C from 1990 to 2100 (Intergovernmental Panel on Climate Change, 2013). This may have an influence on the ecology of the rodents, and increase the

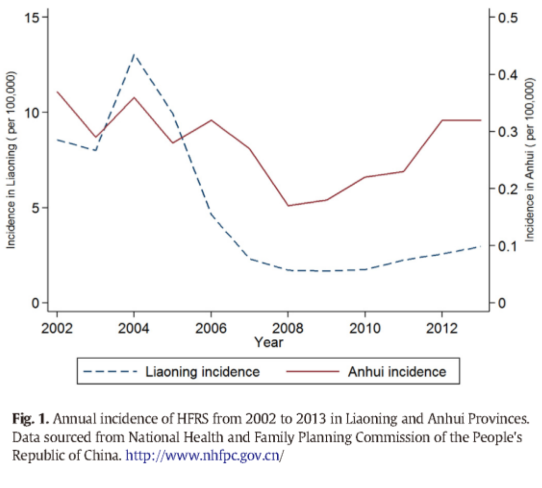

Fig. 1. Annual incidence of HFRS from 2002 to 2013 in Liaoning and Anhui Provinces. Data sourced from National Health and Family Planning Commission of the People's Republic of China. http://www.nhfpc.gov.cn/

reproduction rate, and thus contribute to rodent-borne disease transmission (Xiao et al., 2014b; Hansen et al., 2015; Li et al., 2013; Liu et al., 2013).

In China, the Centers for Disease Control and Prevention (CDC) work to protect and improve population health and safety, and to control and prevent potential infectious disease threats (Chinese Center for Disease Control and Prevention, 2015). Although CDC health professionals are likely to be knowledgeable about HFRS and possible associations with climate change, to our knowledge there are no studies investigating health professionals' perceptions of this disease under the climate change scenario, which would contribute to our understanding of the relationship between climate change and HFRS.

The aim of this study was to gauge the perceptions of CDC health professionals in China concerning HFRS control and climate change. An examination of CDC professionals' understanding of the association between HFRS and climate change, and the main reasons responsible for HFRS emergence and re-emergence, will enhance understanding of this phenomenon, while providing policy makers and stakeholders with an evidence-base on which to formulate effective and feasible adaptation strategies for the control and prevention of HFRS in the future.

2. Methods

2.1. Study areas

A CDC-based cross-sectional survey was conducted in Liaoning and Anhui Provinces. These provinces were chosen as they historically have been high-risk areas for HFRS. They are also located in two different geographical areas of China and are in different climate zones.

Liaoning Province, located in Northeast China (Fig. 2), has a total area of 145,800 km^2, a population of 42.7 million (The People's Government of Liaoning Province, 2016b). There are 4.09 million hectares of agricultural areas and 5.69 million hectares of forestland areas, accounting for 27.6% and 38.5% of land size respectively in this province (The People's Government of Liaoning Province, 2016d). Liaoning has a temperate continental monsoon climate with four distinctive seasons (The People's Government of Liaoning Province, 2016c). The precipitation averages roughly 400 to 970 mm annually, and the average annual temperature is between 5.2 and 11.7 °C (The People's Government of Liaoning Province, 2016c). Liaoning can be divided into three areas according to the terrain: the east and west mountains, the central plain and the south coastal plain. The Liao River and about 300 small tributaries run through the province. There are 14 prefecture-level divisions, 17 county-level cities, 27 counties and 56 districts in Liaoning Province (The People's Government of Liaoning Province, 2016a).

Anhui Province, located in East China (Fig. 2), has a total area of 139,600 km^2 and a population of 60.8 million (The People's Government of Anhui Province, 2015b; The People's Government of Anhui Province, 2015c). There are 5.71 million hectares of agricultural land and 4.18 million hectares of forestland areas, accounting for 40.9% and 29.9% of land size respectively in this province (The People's Government of Anhui Province, 2016). Anhui has a warm-temperate, semi-humid monsoonal climate with an average annual temperature between 14 and 17 °C, and average annual rainfall between 800 and 1800 mm (The People's Government of Anhui Province, 2015b). Anhui can be divided into three areas according to the terrain: the north plain, the north-central Huai plain, and the west and south mountains. China's largest river the Yangtze, and the third-largest the Huai River run through the Province (The People's Government of Anhui Province, 2015b). There are 16 prefecture-level divisions, comprising 62 counties and 43 districts in Anhui Province (The People's Government of Anhui Province, 2015a). There is a CDC in each county/district, prefecture, and province nationwide.

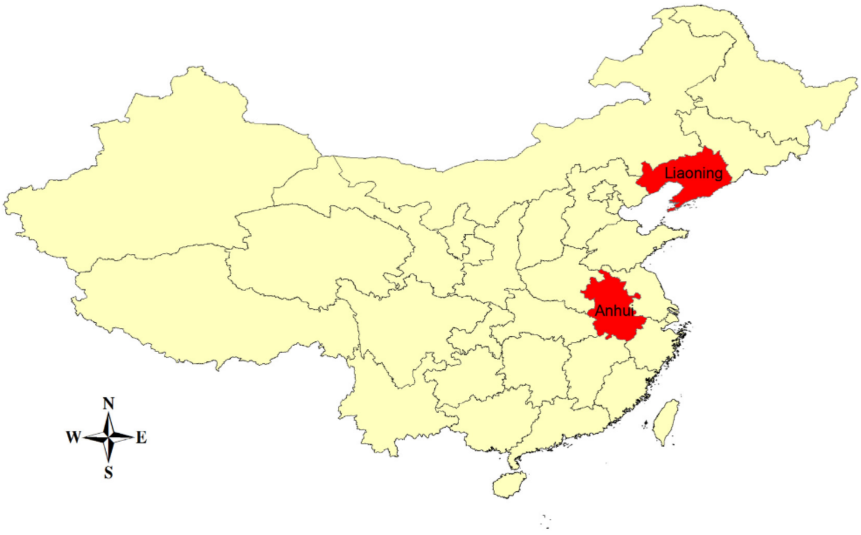

Fig. 2. Location of Liaoning and Anhui Provinces in China.

2.2. Study population

The study participants were health professionals in eight selected CDCs – one provincial, one prefectural and two county CDCs in Liaoning and Anhui Provinces, where HFRS has historically been a public health problem. Staff who were undertaking work in the field of infectious disease control and prevention, public health, medical laboratory testing and emergency response were recruited.

2.3. Study design

A cross-sectional descriptive design was employed in this study, and a questionnaire was developed for distribution to health professionals in selected CDCs as a data collection tool. Questions were formulated following a review of relevant literature (Wei et al., 2014b; Wei et al., 2014a; Semenza et al., 2012; The National Development and Reform Commission, 2014; The National Development and Reform Commission, 2013; Center for Strategic, and International Studies, 6 October, 2008). The full questionnaire has been described previously (Tong et al., 2016). This study reports on a subset of questions relating to HFRS and climate change. The relevant section of the questionnaire is included in Appendix A.

Researchers distributed the questionnaire to CDC staff in May 2015, with the assistance of the China National CDC. All participants were informed of the survey's aims and objectives. Participation was voluntary, and no incentives were offered. All responses were anonymous. In total, 412 questionnaires were distributed and later collected from the participating CDCs, 381 questionnaires were completed. The response rate was 92.5%.

2.4. Statistics

Collected data were entered into EpiData 3.1 software (EpiData Association, Odense M, Denmark) and transferred to Stata 13 (Stata Corporation, College Station, Texas, USA) for data cleaning and data analysis. Descriptive analysis was conducted using simple frequency calculations to describe the demographic characteristics of the health professionals and categorical variables. The association between demographic variables and perception variables was assessed using Chi-square test (χ^2) or Fisher's exact tests (Wei et al., 2014a). The null hypothesis of no differences was rejected when the p-value was <0.05.

2.5. Ethical approval

The study was approved by the ethics committees of the University of Adelaide (Approval No. HS-2013-052), the University of South Australia (Approval No. 0000032268), Monash University (Approval No. CF13/3263-2013001642), Anhui Medical University (Approval No. 2013007) and the Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002). Informed consent was obtained from individuals. This consent procedure was approved by the Chinese Center for Disease Control and Prevention, and conducted according to its guidelines. The participants were free to decline to answer any question if they did not wish to do so.

3. Results

3.1. Demographic information

In this study, 381 participants who undertook duties such as communicable disease control and prevention, public health, medical laboratory testing and emergency response completed the questionnaires. Table 1 shows the demographic characteristics of participants. Of the total cohort, 59.6% were from Liaoning CDCs and 40.4% were from Anhui CDCs. More than half of the participants were from provincial CDCs, and others were from CDC in counties and prefectures within the provinces. Participants were aged between 20 and 60 years, and 47.5% were male. A majority (67.1%) of participants were educated to bachelor degree or above. There were 144 (40.1%) participants who had been employed for less than ten years at the CDC, and 103 (28.7%) participants had been employed at their CDC for more than two decades. Senior and intermediate-level staff accounted for 61.5% of the total. In addition, there were a greater proportion of male participants from Anhui CDCs (55.3%) than Liaoning CDCs (42.3%) (See Supplementary Table S1).

Table 1
Demographic characteristics of participants (N = 381).

Characteristics	Number* (n)	Percent (%)
CDC		
Liaoning	227	59.6
Anhui	154	40.4
Levels of CDC		
Provincial	204	54.3
Prefectural	79	21.0
County	93	24.7
Age group (years)		
20–39	221	59.7
≥40	149	40.3
Gender		
Male	180	47.5
Female	199	52.5
Educational level		
Below bachelor degree	123	32.9
Bachelor degree or above	251	67.1
Length of employment at CDC (years)		
≤9	144	40.1
10–19	112	31.2
≥20	103	28.7
Professional level		
Junior	119	31.2
Intermediate	166	43.6
Senior	68	17.9
Other	28	7.3

* The number of participants may not add up to 381 as some questions were not answered.

3.2. Perceptions of the likely impact of climate change in Liaoning and Anhui

The perceptions of CDC staff from Liaoning and Anhui regarding the likely impact of climate change are shown in Table 2. Over 86% of participants thought climate change would have a negative effect on population health in Liaoning and Anhui. Specifically, 87.2% and 94.8% of participants in Liaoning and Anhui, respectively, indicated increasing temperatures would influence the transmission of infectious diseases, and around 83% of participants indicated increasing precipitation would also affect infectious diseases. Furthermore, 55.0% and 59.5% of participants in Liaoning and Anhui stated that climate change would have an impact on rodent-borne diseases, but comparatively fewer participants agreed on the negative impact of climate change on hantavirus infections. There were no statistically significant differences between the respective groups' perceptions, except for participants from Anhui, who were more likely to believe that increasing temperature would influence infectious diseases ($p = 0.03$). Moreover, compared with staff from county-level CDCs, provincial and prefectural CDC staff were more likely to indicate that increasing temperatures and precipitation would influence the transmission of infectious diseases (see Supplementary Table S2).

3.3. Perceptions of HFRS control and prevention in Liaoning and Anhui

Table 3 shows the CDC staff's perceptions of rodent control and rodent-borne diseases in Liaoning and Anhui. Participants from the two provinces held different opinions on whether rodent populations had increased. In Liaoning, 41.1% of participants indicated the size of rodent populations had increased over the past ten years, while 18.3% held the opposite view, and 40.6% were unsure. Comparatively, participants from Anhui were less likely to indicate that rodent populations had increased ($\chi^2 = 11.6973$, $p = 0.003$). Moreover, in both provinces more participants indicated rodent populations had increased in rural areas than metropolitan areas. The majority of participants (more from Liaoning than Anhui) indicated there were rodent control programs in place in their region. More participants in Liaoning than Anhui considered there had been an increase in rodent-borne diseases over the past ten years ($\chi^2 = 12.2125$, $p = 0.002$). In Liaoning, 33.7% indicated there had been an increase in rodent-borne diseases, while 27.4% of participants disagreed. In Anhui, a large majority (82.4%) of respondents indicated that there has not been an increase in rodent-borne diseases, or were 'Unsure'.

More participants from Liaoning (more than two-thirds) than from Anhui (<40%) believed that HFRS had re-emerged in recent years ($\chi^2 = 30.0896$, $p < 0.001$). Specifically, in Liaoning there were more participants indicating some HFRS outbreaks were occurring in new geographic areas ($\chi^2 = 19.7632$, $p < 0.001$) and at unusual times of the year ($\chi^2 = 13.6188$, $p = 0.001$) compared with those in Anhui. Most Anhui participants neither agreed nor disagreed that there had been changes in spatial or temporal trends in HFRS outbreaks. There were more participants indicating HFRS was increasing in both urban areas ($\chi^2 = 16.2415$, $p < 0.001$) and agricultural areas ($\chi^2 = 30.9173$, $p < 0.001$) in Liaoning compared to Anhui. However, there were 44.5% and 57.8% of participants in Liaoning and Anhui, respectively, who neither agreed nor disagreed that there had been an increase in agricultural areas, and even more were undecided about an increase in urban areas (Table 4). In addition, staff from the two provincial CDCs were less likely to indicate HFRS had re-emerged and increased in both urban and agricultural areas compared with those from lower level CDCs in the two Provinces (see Supplementary Table S3).

About one-third of participants in Liaoning and one-quarter in Anhui indicated that they believed increasing urbanization had impacted HFRS incidence, but the majority of participants in Liaoning (53.7%) and Anhui (61.1%) neither agreed nor disagreed. In Liaoning, there were significantly more (49.4%) participants who considered the local residents to be well-informed about how HFRS was transmitted compared with those (24.5%) from Anhui ($\chi^2 = 22.13$, $p < 0.001$). In Anhui, only 24.4% judged that the local community was well informed about transmission, while the majority of participants (62.2%) were unsure. More participants in Liaoning thought current prevention measures, deratization and immunization programs had been effective in reducing HFRS incidence, compared with those in Anhui (Table 4). Furthermore, staff from provincial CDCs were less likely to believe that local residents

Table 2
CDC staff's perceptions of the likely impact of climate change in Liaoning and Anhui*.

Climate change	Liaoning			Anhui			Statistics test	p
	Agree N (%)	Neither agree nor disagree N (%)	Disagree N (%)	Agree N (%)	Neither agree nor disagree N (%)	Disagree N (%)		
Will have a negative effect on population health	197 (86.8)	25 (11.0)	5 (2.2)	133 (86.4)	21 (13.6)	0	Fisher's exact	0.146
Increasing temperatures will influence infectious diseases	198 (87.2)	26 (11.5)	3 (1.3)	146 (94.8)	8 (5.2)	0	Fisher's exact	0.03
Increasing precipitation will influence infectious diseases	189 (83.3)	33 (14.5)	5 (2.2)	129 (83.8)	24 (15.6)	1(0.6)	Fisher's exact	0.567
Will have an influence on rodent-borne diseases	111 (55.0)	81 (40.1)	10 (4.9)	66 (59.5)	35 (31.5)	10 (9.0)	$\chi^2 = 3.523$	0.172
Will have an influence on hantavirus infections	113 (50.2)	99 (44.0)	13 (5.8)	86 (57.3)	52 (34.7)	12 (8.0)	$\chi^2 = 3.471$	0.176

* Categories 'Agree strongly' and 'Agree somewhat' were collapsed into 'Agree', categories 'Disagree somewhat' and 'Disagree strongly' were collapsed into 'Disagree'.

Table 3
Perceptions of rodent control and rodent-borne diseases in Liaoning and Anhui.

	Liaoning			Anhui			Statistics test	p
	Yes N (%)	No N (%)	Unsure N (%)	Yes N (%)	No N (%)	Unsure N (%)		
Has the size of rodent populations increased over the past ten years?	92 (41.1)	41 (18.3)	91 (40.6)	39 (25.5)	45 (29.4)	69 (45.1)	$\chi^2 = 11.6973$	0.003
Is this increase in rural areas?	82 (53.9)	24 (15.8)	46 (30.3)	47 (47.5)	14 (14.1)	38 (38.4)	$\chi^2 = 1.7776$	0.411
Is this increase in metropolitan areas?	67 (45.3)	29 (19.6)	52 (35.1)	30 (31.3)	24 (25.0)	42 (43.7)	$\chi^2 = 4.7843$	0.091
Are there rodent control programs in place?	170 (75.2)	5 (2.2)	51 (22.6)	100 (66.7)	17 (11.3)	33 (22.0)	$\chi^2 = 13.7508$	0.001
Have rodent-borne diseases increased over the past ten years?	76 (33.7)	62 (27.4)	88 (38.9)	27 (17.6)	57 (37.3)	69 (45.1)	$\chi^2 = 12.2125$	0.002

were well informed about HFRS transmission modes and preventive measurements, compared with those from lower level CDCs (see Supplementary Table S3).

3.4. Potential main risk factors for HFRS in China

In this survey, an open-ended question 'what do you think are the main risk factors for HFRS in your region?' was used to explore perceptions of potential risk factors. Fig. 3 shows the participants' answers. The most prevalent response from 31.7% of participants was 'increased rodent-density'. Furthermore, about 10% of participants mentioned 'increased infected rodents', 'lack of health awareness' and 'contact with rodents, contaminated food or water' were risk factors associated with HFRS incidence. Moreover, other risk factors, such as poor sanitary conditions, low vaccination coverage, climate change, unhealthy habits, ineffective control measures and urbanization were considered to be associated with HFRS in China.

4. Discussion

To our best knowledge, this is the first study to gauge the perceptions of CDC staff about the transmission of HFRS in relation to climate change in China. Results will provide scientific evidence to inform the capacity for improvement in control and prevention measures of HFRS in the face of climate change.

Most participants (>80%) considered that climate change would have a negative effect on population health, and indicated that increasing temperature and precipitation would influence infectious diseases, especially those from prefectural or provincial level CDCs. More than half the participants thought climate change would have an impact on rodent-borne diseases and hantavirus infections (Table 2). Furthermore, there were many participants in Liaoning and Anhui who either held a neutral opinion about this or disagreed that climate change would have an influence on rodent-borne diseases and hantavirus infections. This implies that although participants thought climate change would have negative impacts on population health and infectious diseases, they did not believe that climate change affecting rodent-borne diseases and hantavirus infections, specifically. However, reports suggest climate change could have a significant impact on the occurrence of hantavirus infections (Kim and Jang, 2010; Klempa, 2009), although more evidence is needed to draw firm conclusions on this association due to the complicated ecology of the diseases. This suggested that professional development is needed for CDC staff.

Significantly, more participants in Liaoning than Anhui held the belief that rodent populations had increased over the past ten years, despite the fact that more than two-thirds of participants in each province indicated there were some rodent control programs in place in their region. The disparity could be attributed to differences between the provinces in geography and climate, and that a significantly lower proportion of respondents thought current prevention methods and deratization programs had been effective (Table 4). Furthermore, in both provinces participants indicated there has been an increase rodent population in rural areas, more than in metropolitan areas. This may imply that unless human exposure to rodents can be reduced using pest control methods, better housing or safe storage of crop yields, the likelihood of acquiring HTNV-associated HFRS may increase for vulnerable people in farming communities. Similarly, more participants in Liaoning than in Anhui indicated rodent-borne diseases had increased over the past ten years. The majority of Anhui participants were either unsure about this or disagreed that rodent-borne diseases had increased. This suggests that further interventions are required in Liaoning, and that eradication programs need to be adjusted according to rodent characteristics in local areas.

Additionally, more participants in Liaoning than in Anhui indicated HFRS had re-emerged in their regions and some outbreaks were occurring in new geographical regions and at unusual times of the year. These views are consistent with other studies showing that the emergence and re-emergence of HFRS have been mostly reported in Northeast China where there have been more HFRS cases than in other areas (Zhang et al., 2014a, 2010b). Furthermore, significantly more participants in

Table 4
Perceptions of HFRS control and prevention in Liaoning and Anhui.

	Liaoning			Anhui			Statistics test	p
	Agree N (%)	Neither agree nor disagree N (%)	Disagree N (%)	Agree N (%)	Neither agree nor disagree N (%)	Disagree N (%)		
HFRS has re-emerged in this area in recent years	152 (67.0)	67 (29.5)	8 (3.5)	37 (38.1)	44 (45.4)	16 (16.5)	$\chi^2 = 30.0896$	<0.001
Some HFRS outbreaks are occurring in new geographic areas	104 (45.8)	104 (45.8)	19 (8.4)	18 (20.0)	56 (62.2)	16 (17.8)	$\chi^2 = 19.7632$	<0.001
Some HFRS outbreaks are occurring at unusual times of the year	80 (35.3)	112 (49.3)	35 (15.4)	13 (14.8)	61 (69.3)	14 (15.9)	$\chi^2 = 13.6188$	0.001
HFRS in urban areas is increasing	84 (37.0)	113 (49.8)	30 (13.2)	13 (14.5)	57 (63.3)	20 (22.2)	$\chi^2 = 16.2415$	<0.001
HFRS in agricultural areas is increasing	108 (47.6)	101 (44.5)	18 (7.9)	16 (17.8)	52 (57.8)	22 (24.4)	$\chi^2 = 30.9173$	<0.001
Increasing urbanization impacts on HFRS incidence	79 (34.8)	122 (53.7)	26 (11.5)	23 (25.6)	55 (61.1)	12 (13.3)	$\chi^2 = 2.5287$	0.282
The population in general is well informed about how HFRS is transmitted	112 (49.4)	107 (47.1)	8 (3.5)	22 (24.5)	56 (62.2)	12 (13.3)	$\chi^2 = 22.1300$	<0.001
Current prevention methods and deratization programs have been effective in reducing HFRS incidence	125 (55.1)	91 (40.1)	11 (4.8)	35 (38.9)	51 (56.7)	4 (4.4)	$\chi^2 = 7.3179$	0.026
Current immunization programs have been effective in reducing HFRS incidence	118 (52.0)	100 (44.0)	9 (4.0)	26 (28.9)	50 (55.5)	14 (15.6)	$\chi^2 = 21.3019$	<0.001

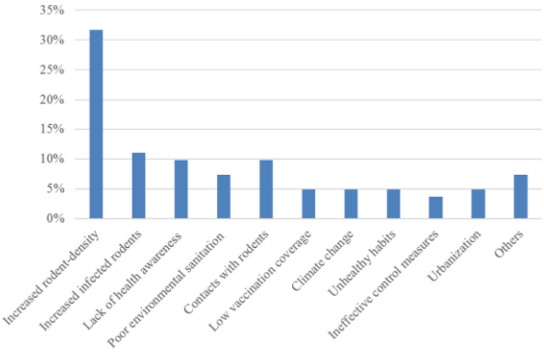

Fig. 3. Participants' perceptions of the main risk factors for HFRS in China.

Liaoning indicated that HFRS was increasing in both urban and agricultural areas compared with those in Anhui. This further affirms the necessity and urgency to intensify HFRS control and prevention efforts in Liaoning.

The majority of participants in both provinces were undecided about whether increasing urbanization has an effect on HFRS incidence, and most participants gave neutral responses to the statement 'Increasing urbanization impacts on HFRS incidence'. While urbanization generally provides improved housing conditions and hence less chance for human-rodent interaction, the increased population density and generation of waste and rubbish can provide food and breeding sites for *Rattus norvegicus*. The development of transportation routes in association with urbanization could also enable greater movement and dispersion of rodents through cities, thereby increasing the chances of contact with humans (Zhang et al., 2014c). Thus, there may be positive and negative influences of urbanization on HFRS incidence. Notwithstanding, some studies have found increasing numbers of HFRS cases reported in urban areas, with endemic areas extending into urban areas and even into city centers (Zhang et al., 2010b; Zhang et al., 2014c; Wu et al., 2009; Zuo et al., 2011). This trend implies that vigilance and preventive control measures against HFRS in urban areas should be reinforced. More health education campaigns in local communities and improved preventive measures are needed to enhance the capacity of HFRS control and prevention from the community engagement perspective.

The perceived main risk factors for HFRS in China were also explored by an open-ended question. The most commonly stated risk factor was 'increased rodent-density', which is consistent with other studies (Bi et al., 2002; Guan et al., 2009; Mills and Childs, 1998; Xiao et al., 2013b). Moreover, the contact rate with rodents was reported to be another pivotal risk factor, this being a consequence of increased rodent density. Studies have found an association between HFRS incidence in China and both rodent density and the rate of human contact with rodents (Bi et al., 2002; Li et al., 2009). A small peak in incidence occurs in China during spring and summer (between April and June), and this could be attributed to the reproduction of rodents during this period and potentially increased contact with rodents or rodent contaminated food (Li et al., 2009; Huang et al., 2012). The second (and main) peak in incidence occurs during autumn and winter (between November and January) in agricultural areas (Huang et al., 2012). This is associated with the harvest activities when farmers work and sleep in the fields and thereby increase their contact rate with rodents (Bi et al., 2002). More recently, however, transformations in farming practices have led to more mechanized forms of harvesting in certain areas, which could reduce the likelihood of human-rodent contact and the risk of HFRS transmission.

Moreover, participants in this study frequently reported 'low vaccination coverage' as a risk factor. Since the 1990s, China has offered free HFRS vaccination to people aged 16 to 60 years to assist in reducing the incidence of HFRS (Xiao et al., 2014a). However, recent studies have found an increasing number of cases outside of this age range (Xiao et al., 2014a; Tan et al., 2012). Hence, this may indicate a need to expand the coverage of the vaccination program to other age groups, and to farmers who may have limited health awareness. This is particularly important in current rural areas which many youth and adults work in urban areas due to urbanization while the elderly undertake farming duties in the rural areas. Health education to focus on these vulnerable populations should be further strengthened.

In addition, climate change and increased urbanization may affect HFRS incidence. It is likely that environmental and ecological changes will force rodents from traditional habitats into urbanized areas in search of new food sources and lead to an increase in HFRS incidence (Xiao et al., 2014b; Bi et al., 2002; Bi et al., 1998; Li et al., 2014b; Li et al., 2014a). More climate change related research is needed together with further improvements in housing conditions, farming practices and comprehensive preventive strategies, such as expanded immunization coverage, more effective rodent control measures, and more health education programs as mentioned above.

The limitations of the study are acknowledged. Given the sample size, the perceptions of climate change and HFRS gained from the study participants in Liaoning and Anhui Provinces cannot be generalized as being representative of all CDC staff in these provinces or in China as a whole. However, a range of responses from CDC staff in two high incident provinces where HFRS is a public health issue provides the insights of health professionals about the disease, prevention methods and climate change in China.

5. Conclusions

Most CDC staff endorsed the statement that climate change would have an influence on population health and infectious disease transmission. However, many participants either did not think climate change would have an influence on rodent-borne diseases including hantavirus infections, or were undecided about the issue, indicating the uncertainties and lack of evidence that exists in this area. Further climate change related research concerning rodent-borne disease transmission is required to aid future planning for HFRS control and prevention. As Liaoning province experienced more serious epidemics of HFRS than Anhui, comprehensive HFRS control strategies and more effective rodent control measures are required in Northeast China. Furthermore, improvements in domestic environmental conditions, extended vaccination coverage and more health promotion campaigns should be conducted to control the transmission of HFRS in the regions.

Competing interests

The authors declare that they have no competing interests.

Abbreviations

HFRS	Hemorrhagic fever with renal syndrome
CDC	Center for Disease Control and Prevention
HTVN	Hantaan virus
SEOV	Seoul virus
IPCC	Intergovernmental Panel on Climate Change

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Appendix A. Supplementary data

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CHAPTER 8 CLINICAL HEALTH PROFESSIONALS' PERCEPTIONS OF CLIMATE CHANGE AND INFECTIOUS DISEASES

Statement of Authorship

Title of Paper	Hospital Clinical Professionals' Perceptions of Infectious Diseases in the Context of Climate Change in Anhui Province, China
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Principal Author

Name of Principal Author (Candidate)	Michael Xiaoliang Tong		
Contribution to the Paper	Performed data analysis, interpreted data, conceptualised the manuscript structure, wrote manuscript. Revised the manuscripts based on reviewers' comments and suggestions. Re-submitted for publication.		
Overall percentage (%)	75%		
Certification:	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature and is not subject to any obligations or contractual agreements with a third party that would constrain its inclusion in this thesis. I am the primary author of this paper.		
Signature		Date	12.04.2017

Co-Author Contributions

By signing the Statement of Authorship, each author certifies that:

i. the candidate's stated contribution to the publication is accurate (as detailed above);

ii. permission is granted for the candidate in include the publication in the thesis; and

iii. the sum of all co-author contributions is equal to 100% less the candidate's stated contribution.

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Contribution to the Paper	Helped to evaluate and edit the manuscript. Provided feedback, comments and suggestions.		
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Clinical Professionals' Perceptions of Infectious Diseases in the Context of Climate Change in Anhui Province, China

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Running head: Clinicians' Views of Infectious Diseases and Climate Change

Summary

Infectious diseases are still a major cause of morbidity and mortality in China. The capacity of hospitals to deal with the challenge from emerging and re-emerging infectious diseases due to climate change is of great importance to population health. A questionnaire survey was conducted among 611 clinical professionals including doctors and nurses in three major hospitals in Anhui Province, China. Descriptive analysis and logistic regression analysis were performed. More than 90% of participants indicated climate change would have an adverse influence on population health and present a challenge for infectious disease control in China. Most thought that their hospitals were well prepared for emerging infectious diseases, although they indicated hospital's logistical support should be strengthened. The majority of participants suggested that effective prevention and control measures, better collaboration with Centers for Disease Control and Prevention, more funding for rural health care, and better online reporting facilities for rural hospitals, were extremely important strategies. Clinical professionals recognized that climate change will increase the transmission of infectious diseases, and believed their hospitals to be capable of dealing with such a challenge. They thought that interdisciplinary and cross-regional collaborations, together with necessary resource support would be important control strategies.

Keywords: Climate change; Infectious diseases; Clinical professionals

INTRODUCTION

Currently there are roughly 7 million cases of notified infectious diseases in China, which result in approximately 17000 deaths annually [1]. Previous studies have found the incidence of infectious diseases has been sharply reduced due to great improvements in healthcare services [2]. However, emergence and re-emergence of some climate-sensitive diseases, such as malaria, dengue and hemorrhagic fever with renal syndrome (HFRS) have occurred in recent decades in China [3-5]. Malaria was a serious public health problem during the 1970s with an incidence of approximately 2800 per 100000 population [6]. In 2001, the incidence was only 2 per 100000 with about 20000 cases reported [6]. However, malaria cases in China increased to 64178 in 2006 [7]. Moreover, no dengue cases were reported prior to 1977, but frequent outbreaks occurred during the last few decades in China [8]. HFRS, a serious zoonotic disease caused by hantaviruses, can be transmitted to humans by contact with infected rodents or their excreta [9]. The disease is frequently reported in China where roughly 90% of the world's cases occur [10]. Although the incidence of HFRS significantly declined during the 1990s, there has been an increasing trend since 2008 [10, 11]. The possible reasons for the emergence and re-emergence of these infectious diseases may be linked to climate change, population movement and rapid urbanization [12, 13].

Climate change has and will continue to impact the transmission of vector and rodent-borne diseases by affecting the growth and development of the vectors or hosts, shortening the incubation period of the pathogens within the vectors, and impacting human behavior, e.g. more time spent outdoors [14-19]. The projected temperature increase and change in rainfall patterns may bring about an increase in cases of infectious diseases such as malaria, dengue and HFRS.

In the Chinese healthcare system, both clinical medicine and preventive medicine play important roles in the protection of population health. In terms of infectious diseases, hospital-based clinical professionals undertake diagnosis, treatment and management of cases and report cases of notifiable diseases to the local Center for Disease Control and Prevention (CDC) [20]. From the public health perspective, the main duties of the CDC professionals include disease prevention, control and surveillance. Therefore, hospital staff and public health professionals perform different roles, and may have different views on infectious disease control and prevention. Given the wide reach of infectious diseases in the healthcare system, an investigation of perceptions of hospital-based clinical professionals about infectious diseases and climate change is pertinent as informed clinicians are in a position to detect and report unusual disease occurrences.

The study employs a cross-sectional questionnaire survey to examine clinical professionals' perceptions of climate change and infectious diseases. Further, the study explores participants' views on capacity building in the hospital sector to curb potential emerging and re-emerging infectious diseases due to climate change in China, using malaria, dengue and HFRS as case study diseases.

METHODS

Questionnaire

A questionnaire was administered to clinical professionals in November 2015. The questionnaire instrument design was informed by previous studies and relevant literature on climate-sensitive diseases [21-24]. The questions asked about clinicians' thoughts on climate change, disease occurrence, the capacity of hospitals to deal with infectious diseases, and strategies to build the capacity of the hospital sector and curb the health impact of climate change on infectious diseases. An open-ended question was included to explore in greater depth, participants' understandings of disease control, diagnosis, treatment and management in the context of climate change. The questionnaire is included in Appendix 1.

Study site and participants

The study site of Anhui was selected because it is a salient site to study infectious disease transmission, especially malaria and HFRS, due to a high incidence and suitable climatic and geographic conditions for these diseases [25-27]. Anhui is located in East China, and has a warm-temperate, semi-humid monsoonal climate with an average annual temperature between 14 and 17 °C, and annual precipitation between 800 and 1,800 millimeters [27].

Participants were clinical professionals from three major hospitals in Anhui. Two hospitals were located in the capital city of the Province (Hefei) and one located in a prefectural level city (Fuyang). The clinical

138 professionals included both doctors and nurses whose roles pertained to infectious disease diagnosis, treatment, and management.

Data collection

Investigators administered the questionnaire in the three hospitals. To maximize the response rate, the principal researchers selected six key senior contacts from hospitals to assist with the distribution of questionnaires to potential participants. The process of participation was voluntary, and no incentives were offered. In total, 650 questionnaires were distributed, and after omitting incomplete questionnaires, 611 were analyzed, with a response rate of 94%.

Statistical analysis

All returned questionnaires were entered using EpiData 3.1 software (EpiData Association, Odense M, Denmark) to create a database. Statistical analyses were performed with Stata 13.1 (Stata Corporation, College Station, Texas, USA). Participants' demographic characteristics were descriptively analyzed. Ordinal logistic regression was used to explore the association between ordinal responses and demographic variables. The demographic variables were age, gender, professional level, length of employment, education, and occupation. All statistics were analyzed with a two-sided test and p-values less than 0.05 were considered statistically significant.

Ethical approval

This study obtained ethical approvals from the Human Research Ethics Committee of the University of Adelaide (Approval No. HS-2013-052), the University of South Australia (Approval No. 0000032268), Monash University (Approval No. CF13/3263-2013001642), Anhui Medical University (Approval No. 2013007) and the Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002). Informed consent was obtained from individuals.

RESULTS

Demographic information

Table 1 shows the demographics of the participants. Forty-four percent of the clinical professionals who participated were doctors, and 46.3% were nurses. While ages ranged from 20 to 70 years, most (64.6%) professionals were aged below 30 years, with the mean age being 28.4. The majority (70.1%) were female. Junior level professionals accounted for 43.9%, intermediate level professionals 19.8% and senior level 4.6% of the total participants. Over 40% of the participants had worked in hospitals more than five years. The majority (60.5%) held a university degree or higher qualifications, especially the doctors who were mostly highly educated (see Supplementary Table S1).

Perceptions of climate change

As shown in Table 2, more than 75% of the professionals were either very concerned or concerned about climate change. There was a statistically significant association between age group, gender and the concern about climate change (see Supplementary Table S2). Those who were over 30 years (OR=1.979, 95% CI: 1.010-3.878, p=0.047) and the male staff (OR=1.977, 95% CI: 1.236-3.163, p=0.004) were more likely to be concerned about climate change. The majority (71%) agreed with the statement that the weather was becoming warmer, especially the professionals who had been employed more than ten years. Nearly all (95.6%) believed climate change would have an adverse influence on population health. Furthermore, 94.9% and 91.3% of professionals agreed that predicted increasing temperatures and changes in precipitation patterns would affect infectious disease transmission. Specifically, 83.8%, 74.3%, and 69.9% of professionals were either extremely or very likely to believe that there was an association between climate change and malaria, dengue, and HFRS, respectively. Additionally, no significant differences in perceptions of climate change between doctors and nurses were found.

Perceptions of infectious diseases

Table 3 shows that about 20% of participants thought that there had been an increasing number of patients with malaria, dengue, and HFRS, and roughly 45% and 30% of professionals thought that climate change and population migration, respectively, were contributing factors. More than 81% of participants believed that malaria and HFRS hospital-reporting protocol was in place, and 75.8% believed so for dengue.

In terms of the diagnostic capability of hospital laboratories, 76.9%, 67.3% and 76.6% of professionals believed, either always or mostly, that their hospital laboratories were able to rapidly provide diagnostic test for malaria, dengue, and HFRS, respectively. Some 84% of participants rated diagnostic and treatment capacity as excellent/good for malaria and HFRS, while 75% thought this was the case for dengue. Moreover, if an unusual cluster of cases was noticed, most professionals would take actions such as discussing with colleagues (80.2%) and laboratory technicians (72.5%), informing the public health officer (86.4%), and consulting with the CDC (76.9%). In addition, there were no significant differences in these perceptions of infectious diseases between doctors and nurses.

Perceptions of capacity building to deal with infectious disease risks

Clinical professionals' perceptions of the current capacity of their hospitals to deal with infectious diseases are shown in Table 4. Specifically, 95.3% of participants agreed that they had sufficient staff to deal with disease outbreaks. Also, the majority (>90%) believed that their staff were well informed about current infectious disease trends, and that the quality of reported data from their hospitals to the CDC was excellent. However, most (96.5%) professionals thought that hospital's logistical support needed to be strengthened. Overall, 94.2% either agreed strongly or somewhat that hospitals were well prepared for the challenge from emerging infectious diseases. There were no significant differences between perceptions of doctors and nurses regarding the current capacity of the hospital. Additionally, 95.5% agreed that more research needs to be done focusing on the health impacts of climate change.

Concerning strategies in building capacity to meet the challenge of emerging and re-emerging infectious disease due to climate change, 75.9% of participants thought that prevention and control measures were extremely important strategies, and 73.7% believed more collaboration with local CDC was extremely important (Table 5). Furthermore, multivariate ordinal logistic regression analysis showed that compared to those under 30 years, professionals aged over 30 years, were more likely to indicate that prevention and control measures are extremely important (OR=2.370, 95% CI: 1.099-5.107, p=0.028). Senior level staff were more likely to believe that more collaboration with the CDC was extremely important (OR=8.307, 95% CI: 1.063-64.948, p=0.044) (see Supplementary Table S3). About 70% believed more funding was required for rural health care and that improving the accessibility of the online infectious disease reporting system for rural hospitals was also extremely important. More than 65% of those surveyed believed that the health impact of emerging and re-emerging infectious diseases due to climate change could be addressed with strategies such as: better response mechanisms; strengthening the monitoring of infectious diseases; having early warning systems; more health education programs; and increasing laboratory diagnostic ability in rural hospitals (Table 5). Moreover, improving environmental health, more health education, staff training and financial support were frequently reported in an open-ended question (see Supplementary Table S4).

DISCUSSION

Climate change poses a significant threat to global population health [28]. Clinical professionals are at the frontline of healthcare provision to the population and are likely to witness firsthand the health impacts of a changing climate [29]. They, therefore, provide a unique perspective on the health impacts of climate change and an in-depth understanding of local community health [29]. To the best of our knowledge, this study is the first of its kind to gauge clinical professionals' perceptions of the capacity of China's hospitals to manage infectious diseases under the scenario of climate change and provide useful insights for policy-makers, practitioners and medical educators regarding climate change adaptation in the health sector.

Concern about climate change was acknowledged by most professionals, especially among the group aged over 30 years and male staff. The majority of professionals, particularly those with longer terms of employment, indicated that the weather was getting warmer, perhaps because they have more experience of the impacts on health that may be caused by climate change. Nearly all respondents indicated climate change would adversely affect population health, and most indicated it would facilitate infectious disease transmission. Less than 10% of participants thought climate change was unlikely to be associated with malaria incidence compared to 12% for dengue and HFRS. The results were consistent with our previous studies among CDC staff who indicated climate change was more likely to have an influence on malaria than HFRS, whilst the perception of an association between climate change and dengue was not as clear as in a previous study conducted in Guangdong [24]. This is likely due to Guangdong having the highest incidence of dengue in China, whilst in Anhui there are fewer dengue cases reported [8]. Moreover, compared with previous studies, clinical professionals were more likely to indicate that climate change would have an influence on HFRS [30]. However, the overall consistency between the perceptions of CDC and hospital staff suggests that the public health and clinical health sectors share concerns about potential emerging and re-emerging climate-sensitive diseases, which imply it is necessary to strengthen capacity of both the public and the clinical health systems to curb the adverse impact of climate change on population health.

The majority of professionals indicated that climate change and population migration were considered as the most significant factors associated with the increase of these infectious diseases. This is in line with other studies that indicated the impact of climate change and migration would affect infectious disease transmission [31-33]. Higher temperatures can contribute to the increasing population of vectors/rodents and more frequent contacts with humans. Simultaneously, population movement can facilitate disease transmission from one region to another, and the "floating population" often lack health insurance and defer seeking health care [34]. Future infectious disease control should be cognizant of climate change impacts and population movements on these disease transmissions. Building a more comprehensive national health insurance system covering the internal migrant population's health expenses in any parts of China may provide benefits for population health [34].

Most professionals claimed that there was a hospital protocol in place for the reporting of notifiable diseases and believed that the capacity for disease diagnosis and treatment was either excellent or good, especially for malaria and HFRS. Anhui historically has a high incidence of malaria and HFRS [14, 35]. Therefore, we argue that professionals are more likely to have experience and confidence in dealing with malaria and HFRS. However, this could be a challenge for dengue for the Province where historically there has been a low incidence so relevant actions should be taken. The majority of professionals indicated that their hospital laboratories were able to rapidly provide diagnostic test results. Additionally, most professionals purported they would take comprehensive actions if they detected an unusual cluster of cases. This indicates there is a strong likelihood that outbreaks of emerging or re-emerging diseases would be detected early by the clinical professionals or the CDC. This detection of unusual trends could aid in curbing transmission if preventive measures are activated early.

Regarding the capacity of hospitals to deal with disease risks, most participants believed they were well prepared for the challenge from emerging infectious diseases. Of particular note, participants indicated there was a need to strengthen the hospital's logistical support. This is in line with another study conducted by Xu and Chu in 2010 focusing on logistics capacity in hospitals, which advocated that a reliable logistical support system is one of the most important components in modern healthcare systems and should be given higher priority to sustain and promote better healthcare services in the long-term [36]. Currently, the main obstacles to improving logistical support systems in China is the lack of high-quality staff and regulatory frameworks for logistics management within hospitals [37]. Promoting specialized training for logistics staff and implementing management and quality control guidelines would be important.

Moreover, the problems in rural areas were highlighted, especially regarding the funding for rural healthcare support and accessibility to an online reporting system. The Severe Acute Respiratory Syndrome (SARS) outbreak demonstrated that rural health care was the weakest component of the China's disease control and prevention system [38]. More resource allocation to rural areas would be a vital step in advancing China's capacity building in response to emerging infectious diseases.

In this study, older and senior staff were more likely to indicate primary prevention measures and interdisciplinary collaboration were important, compared with the younger or non-senior staff. Such differences could be due to the rich working experience of the group, who may have a better understanding of the infectious disease control and prevention strategies. Additionally, although we did not find significant differences in perceptions between doctors and nurses, most doctors were highly educated and either held a bachelor degree or higher qualification while only one-third of nurses held a bachelor degree or above. Further promotion of higher nursing education would improve the capacity of the hospital healthcare system [39]. Most participants also suggested a need for improved environmental health, more health education programs, staff training and financial support.

Some limitations of this study deserve mention. Firstly, this study was conducted in one province. The results may not be generalizable to other clinical professionals in China. Secondly, as dengue is an emerging and uncommon disease in Anhui, participants in this region may be less likely to have hands-on experience in dealing with dengue cases. Nevertheless, these findings may provide information for policy makers and clinical professionals pursuing initiatives to strengthen the capacity for hospitals to cope with potential upswings in the numbers of patients with infectious diseases.

This study revealed that most clinical professionals thought climate change would have an impact on infectious diseases. Although they thought the number of cases had not changed significantly over the past ten years, they believed climate change and population migration were significant factors associated with infectious disease transmission. Health professionals in our study thought that overall capacity of the hospital healthcare system to deal with infectious diseases was excellent. Nevertheless, findings suggest that logistical support should be strengthened in hospitals and more climate change related research is needed. Issues that could be addressed include prevention and control measures, collaboration with CDC, in-house training for the younger staff and improved healthcare system in rural areas. The multiple direct and indirect impacts of climate change will continue to threaten the health of the Chinese population. These findings may help health policy makers develop organizational adaptation policies to address the adverse impact of climate change on health.

SUPPLEMENTARY MATERIAL

Appendix 1: Questionnaire

Appendix 2: Supplementary Tables

AUTHORS' CONTRIBUTIONS

MXT analyzed and interpreted the data, and drafted the manuscript. MXT, JX, AH, PB and YS designed the questionnaire. YS and PB conducted the field survey. AH, SHE and PB revised and edited the manuscript. SC, JX, QL, YS, PW and GSH reviewed the document. All authors contributed to the final version of the manuscript. All authors read and approved the final manuscript.

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DECLARATION OF INTEREST

The authors declare no conflicts of interest.

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Table 1. Demographic characteristics of the clinical professionals (N=611)

Demographic variables	Number[a]	Percent (%)
Age group (years)		
20-29	390	64.6
≥30	214	35.4
Gender		
Male	179	29.9
Female	419	70.1
Professional level		
Junior	268	43.9
Intermediate	121	19.8
Senior	28	4.6
Other	194	31.7
Length of employment (years)		
<5	322	56.2
5-9	107	18.7
≥10	144	25.1
Educational level		
Below undergraduate	239	39.5
Undergraduate degree	302	49.9
Postgraduate degree	64	10.6
Occupation		
Doctor	269	44.0
Nurse	283	46.3
Other[b]	59	9.7

[a] The total number may not be equal to 611 as some questions were not answered.

[b] Other occupations included public health officer, lab technician and administrator.

445 **Table 2. Perceptions of climate change and its impacts among clinical professionals in Anhui, China[a]**

Opinions on climate change items	Number	Percent (%)
How concerned are you about climate change?		
Very concerned	124	20.4
Concerned	337	55.3
Slightly concerned	138	22.7
Not concerned	10	1.6
Do you think your area is becoming warmer?		
Yes	434	71.0
No	84	13.8
Unsure	93	15.2
Do you think climate change will have a negative effect on population health?		
Yes	584	95.6
No	11	1.8
Unsure	16	2.6
Do you think predicted increasing temperatures will influence the transmission of infectious diseases?		
Yes	580	94.9
No	13	2.1
Unsure	18	3.0
Do you think predicted changes in precipitation patterns will influence the transmission of infectious diseases?		
Yes	558	91.3
No	24	3.9
Unsure	29	4.8
How likely do you think there is an association between climate change and malaria?		

Extremely likely	242	39.6
Very likely	270	44.2
Somewhat likely	52	8.5
Not likely or Unsure	47	7.7
How likely do you think there is an association between climate change and dengue?		
Extremely likely	192	31.4
Very likely	262	42.9
Somewhat likely	82	13.4
Not likely or Unsure	75	12.3
How likely do you think there is an association between climate change and HFRS?		
Extremely likely	168	27.5
Very likely	259	42.4
Somewhat likely	110	18.0
Not likely or Unsure	74	12.1

446 [a] Data in this table are frequency and percentage N (%).

Table 3. Perceptions of malaria, dengue and HFRS among clinical professionals[a]

According to your work experience, what is the trend of patients with these infectious diseases over the past 10 years (or your working period if less than 10 years)?

	Increased	Decreased	Not a big change	Unsure
	N (%)	N (%)	N (%)	N (%)
Malaria	137 (22.4%)	78 (12.8%)	171 (28.0%)	225 (36.8%)
Dengue	124 (20.3%)	86 (14.1%)	83 (13.6%)	318 (52.0%)
HFRS	138 (22.6%)	84 (13.7)	150 (24.6%)	239 (39.1%)

If these infectious diseases have increased, what do you think are the contributing factors?

	Climate change	Urbanization	Population migration	Others
	N (%)	N (%)	N (%)	N (%)
Malaria	290 (47.5%)	66 (10.8%)	195 (31.9%)	60 (9.8%)
Dengue	298 (48.8%)	89 (14.6%)	161 (26.3%)	63 (10.3%)
HFRS	270 (44.2%)	63 (10.3%)	180 (29.5%)	98 (16.0%)

Is there a hospital protocol in place for the reporting of these notifiable diseases?

	Yes	No	Unsure
	N (%)	N (%)	N (%)
Malaria	500 (81.8%)	22 (3.6%)	89 (14.6%)
Dengue	463 (75.8%)	24 (3.9%)	124 (20.3%)
HFRS	496 (81.2%)	29 (4.7%)	86 (14.1%)

Is the hospital laboratory able to rapidly provide diagnostic test results for these infectious diseases?

	Always	Mostly	Rarely	Unsure or sent to CDC for testing
	N (%)	N (%)	N (%)	N (%)

Malaria	306 (50.1%)	164 (26.8%)	26 (4.3%)	115 (18.8%)
Dengue	207 (33.9%)	204 (33.4%)	23 (3.7%)	177 (29.0%)
HFRS	302 (49.4%)	166 (27.2%)	20 (3.3%)	123 (20.1%)

How do you rate the infectious disease diagnostic ability of your hospital?

	Excellent N (%)	Good N (%)	Fair N (%)	Poor N (%)
Malaria	232 (38.0%)	281 (46.0%)	83 (13.6%)	15 (2.4%)
Dengue	181 (29.6%)	274 (44.9%)	134 (21.9%)	22 (3.6%)
HFRS	274 (44.8%)	237 (38.8%)	82 (13.4%)	18 (3.0)

How do you rate the infectious disease treatment ability of your hospital?

	Excellent N (%)	Good N (%)	Fair N (%)	Poor N (%)
Malaria	257 (42.1%)	257 (42.1%)	82 (13.4%)	15 (2.4%)
Dengue	214 (35.0%)	248 (40.6%)	129 (21.1%)	20 (3.3%)
HFRS	272 (44.5%)	248 (40.6%)	75 (12.3%)	16 (2.6%)

If you noticed an unusual cluster of cases would you?	N (%)
Discuss with colleagues	490 (80.2%)
Inform the public health officer at the hospital	528 (86.4%)
Discuss with laboratory technicians	443 (72.5%)
Consult the CDC	470 (76.9%)
Notify no one or other option	32 (5.2%)

[a] Data in this table are frequency and percentage N (%). Abbreviation: HFRS, Hemorrhagic Fever with Renal Syndrome; CDC, Centers for Disease Control and Prevention.

Table 4. Perceptions of hospital capacity to deal with infectious diseases in Anhui, China[a]

Questions concerning capacity to deal with infectious diseases	Agree strongly N (%)	Agree somewhat N (%)	Disagree somewhat N (%)	Disagree strongly N (%)	Unsure N (%)
Current numbers of staff at this hospital will be adequate in the event of major disease outbreaks	316 (52.4)	259 (42.9)	16 (2.7)	1 (0.2)	11 (1.8)
Staff are kept up to date and well informed about current infectious disease trends	252 (42.1)	300 (50.2)	27 (4.5)	3 (0.5)	16 (2.7)
The quality of reported data is excellent	277 (46.2)	291 (48.5)	17 (2.8)	1 (0.2)	14 (2.3)
Logistical support in this hospital needs to be strengthened	344 (57.2)	236 (39.3)	11 (1.8)	1 (0.2)	9 (1.5)
More research needs to be done on the health impacts of climate change	295 (49.3)	276 (46.2)	18 (3.0)	1 (0.2)	8 (1.3)
This hospital is well prepared to respond to the threat of a serious emerging disease	283 (47.0)	284 (47.2)	19 (3.2)	2 (0.3)	14 (2.3)

[a] Data in this table are frequency and percentage N (%).

469 **Table 5. Perceptions of strategies to build capacity to curb the health impact of climate change on infectious diseases in Anhui, China[a]**

How important are these strategies to curb the health impact of climate change on infectious diseases?	Extremely important	Very important	Important	Less important	Not important
	N (%)	N (%)	N (%)	N (%)	N (%)
Prevention and control measures	458 (75.9)	138 (22.9)	6 (1.0)	1 (0.2)	0
Better response mechanisms when outbreaks occur	405 (67.4)	184 (30.6)	12 (2.0)	0	0
Strengthening the monitoring of infectious diseases	415 (68.8)	173 (28.7)	15 (2.5)	0	0
The ability to actively forecast disease outbreaks by early warning systems	406 (67.3)	174 (28.9)	22 (3.6)	1 (0.2)	0
More collaboration with CDC to deal with infectious disease outbreak	443 (73.7)	143 (23.8)	15 (2.5)	0	0
More affordable access to health care for the population	362 (60.5)	206 (34.5)	29 (4.8)	1 (0.2)	0
More health education programs	398 (66.7)	180 (30.1)	18 (3.0)	1 (0.2)	0
Increase laboratory diagnostic ability in rural hospitals	391 (65.1)	189 (31.4)	21 (3.5)	0	0
Improve accessibility of online infectious disease reporting for rural hospitals	423 (70.5)	154 (25.7)	21 (3.5)	2 (0.3)	0
More funding for rural health care	425 (70.7)	156 (25.9)	19 (3.2)	1 (0.2)	0

470 [a] Data in this table are frequency and percentage N (%). Abbreviation: CDC, Centers for Disease Control and Prevention.

Figure 1. Geographical location of Anhui Province in China

296x210mm (300 x 300 DPI)

BUILDING CAPACITY TO CURB THE PUBLIC HEALTH IMPACT OF EMERGING AND RE-EMERGING INFECTIOUS DISEASES DUE TO CLIMATE CHANGE IN CHINA

Purpose of the study

This study aims to investigate the risks of emerging and re-emerging vector/rodent-borne diseases in China and the capacity to respond to climate change driven threats of these diseases – in particular dengue, malaria and haemorrhagic fever with renal syndrome.

The research questions include:
(1) What are the risks associated with emerging and re-emerging vector/rodent-borne diseases that may impact on population health in China in a changing climate?
(2) How effective have current infectious disease prevention and control been in hospitals?
(3) What is the capacity of the clinical system to deal with these diseases and are there barriers to capacity building for infectious disease surveillance, management and prevention in hospitals?

Who is conducting the study?

The study is funded by the Australian Government's Department of Foreign Affairs and Trade through its Australian Aid initiative program (http://aid.dfat.gov.au/Pages/home.aspx). The study is being jointly conducted by investigators at The University of Adelaide, The University of South Australia, Monash University, Anhui Medical University of China and the Chinese Centre for Disease Control and Prevention. The chief investigators in the study are listed over the page.

What will your participation involve?

If you would like to contribute to this research it would simply involve filling out this survey. We anticipate that this will take up to 30 minutes of your time. The questions will relate to your (or your organisation's) experience/knowledge of dengue, malaria and haemorrhagic fever with renal syndrome outbreaks in specific areas, risk factors, prevention/control programs and disease surveillance systems.

Participation is completely voluntary and you may withdraw from the study at any time without reason or answer only selected questions.

Ethics approval

The study has been approved by the Ethical Committees of the National Institute for Communicable Disease Control and Prevention Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002), the University of Adelaide, Anhui Medical University, Monash University, and the University of South Australia.

Confidentiality
Your responses will be strictly confidential and you will not be required to provide any information which may identify you.

What if I have a complaint or any concerns?
If you wish to raise concerns about the conduct of the project with an independent person or discuss matters related to the University policy on research involving human participants or your rights as a participant, contact:

The Human Research Ethics Committee's Secretary, *Ph*: +61 8 8313 6028, or visit: http://www.adelaide.edu.au/ethics/human/guidelines/applications/#complaint.

Or

The Chinese Center for Disease Control and Prevention, *Ph*: +86 1058900240 12320, or visit: web@chinacdc.cn

For further information:
Thank you for interest and possible involvement with this study. If you have any queries about the research, please contact the Chief Investigator: Professor Peng Bi, Discipline of Public Health, University of Adelaide; *Ph*: +61 8 8313 3583; *Email*: peng.bi@adelaide.edu.au, or the Research Associate, Dr Alana Hansen; *Ph*: +61 8 8313 1043; *Email*: alana.hansen@adelaide.edu.au.

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BUILDING CAPACITY TO CURB THE PUBLIC HEALTH IMPACT OF EMERGING AND RE-EMERGING INFECTIOUS DISEASES DUE TO CLIMATE CHANGE IN CHINA

Questionnaire

Thank you for completing this questionnaire, your help in this research is much appreciated. You may choose to answer all or some of the questions. Your answers will remain anonymous. There are 4 parts to this questionnaire and it should take no longer than 30 minutes to complete:

Part A – Demographics
Part B – Climate change
Part C – Future infectious disease risks in a changing climate
Part D – Capacity building to deal with disease risks

Part A – Demographics *(Please indicate your answer with a tick ✓ in the ☐)*

A1 Department: ____

A2 Occupation

☐ Doctor ☐ Nurse ☐ Public health officer

☐ Lab technician ☐ Administrator ☐ Other *(please specify)*_______________

A3 Gender: ☐ Male ☐ Female

A4 Age: _________ years

A5 Classification:

☐ None ☐ Junior ☐ Intermediate ☐ Associate senior ☐ Senior

A6 How long have you been employed in this hospital? ___________ Years

A7 Highest qualification:

☐ Senior high school certificate ☐ Technical certificate ☐ Undergraduate degree

☐ Postgraduate degree ☐ Other *(please specify)* _______________

Part B – Climate change (*Please indicate your answer with a tick✓ in the □*)

The following questions are about your thoughts on climate change:

B1 How concerned are you about climate change?

□ Very concerned □ Concerned □ Concerned a little □ Not concerned

B2 Do you think your area is becoming warmer?

□ Yes □ No □ Unsure

B3 Please answer the following questions about climate change and health

	Agree strongly	Agree somewhat	Disagree somewhat	Disagree strongly	Unsure
I have a good understanding of climate change					
I think climate change will have a negative effect on population health					
Predicted increasing temperatures will influence the transmission of infectious diseases					
Predicted changes in precipitation patterns will influence the transmission of infectious diseases					
I feel I need more information about the health impacts of climate change					

Part C – Future Infectious Disease Risks in a Changing Climate (*Please indicate your answer with a tick✓ in the □*)

C1 How likely do you think there is an association between climate change and these infectious diseases?

	Extremely likely	Very likely	Somewhat likely	Not likely	Unsure
Dengue					
Malaria					
HFRS*					
Others:___________					
Others 1:___________					
Others 2:________					

Others 3:___________					

* Hemorrhagic fever with renal syndrome

C2 According to your work experience, what is the trend of patients with these infectious diseases over the past 10 years (or your working period if less than 10 years)?

	Increased	Decreased	No a big change	Unsure
Dengue				
Malaria				
HFRS				

C3 If these infectious diseases have increased, what do you think are the contributing factors? (*You may tick more than one*)

	Climate change	Urbanization	Population migration	Other (*please specify*)
Dengue				
Malaria				
HFRS				

C4 Are the majority of cases of dengue/malaria in your area locally acquired or imported?

	Locally acquired	Imported	Neither	Unsure
Dengue				
Malaria				

C5 Are the majority of patients with HFRS from metropolitan areas or rural areas?

	Metropolitan areas	Rural areas	Both	Unsure
HFRS				

C6 In recent years have you noticed patients with these infectious diseases presenting at different times of the year to normal?

	Yes(ahead)	Yes(late)	No	Unsure
Dengue				
Malaria				

HFRS				

C7 Do you think there is a need to further strengthen community health education in relation to these infectious diseases?

	Yes	No	Unsure
Dengue			
Malaria			
HFRS			

C8 Is there a hospital protocol in place for the reporting of these notifiable diseases?

	Yes	No	Unsure
Dengue			
Malaria			
HFRS			

C9 Is the hospital laboratory able to rapidly provide diagnostic test results for these infectious diseases?

	Always	Mostly	Rarely	Unsure	Samples sent to CDC for testing
Dengue					
Malaria					
HFRS					

C10 Once a patient is diagnosed with these diseases, normally how long does it take to report the case online to the CDC?

	72hrs	48hrs	24hrs	Other *(please specify)*	Unsure
Dengue					
Malaria					
HFRS					

C11 How do you rate the infectious disease diagnostic ability of your hospital?

	Excellent	Good	Fair	Poor	Very Poor
Dengue					
Malaria					
HFRS					

C12 How do you rate the infectious disease treatment ability of your hospital?

	Excellent	Good	Fair	Poor	Very Poor
Dengue	☐	☐	☐	☐	☐
Malaria	☐	☐	☐	☐	☐
HFRS	☐	☐	☐	☐	☐

C13 If you noticed an unusual cluster of cases would you?: (*You may tick more than one*)

☐ Discuss with colleagues

☐ Inform the public health officer at the hospital

☐ Discuss with laboratory technicians

☐ Consult the CDC

☐ Notify no one

☐ Other (*please specify*): ______________________

Part D–Capacity Building to Deal with Disease Risks (***Please indicate your answer with a tick✓ in the ☐)***

D1 The following questions are specifically for staff in the hospital

	Agree strongly	Agree somewhat	Disagree somewhat	Disagree strongly	Unsure
Current numbers of staff at this hospital will be adequate in the event of major disease outbreaks	☐	☐	☐	☐	☐
More funding could be provided to strengthen disease diagnosis, treatment and management	☐	☐	☐	☐	☐
More staff training in this hospital needs to be strengthened	☐	☐	☐	☐	☐
Logistical support in this hospital needs to be strengthened	☐	☐	☐	☐	☐
Infectious disease diagnoses in this hospital needs to be improved	☐	☐	☐	☐	☐
Infectious disease treatment in this hospital needs to be improved	☐	☐	☐	☐	☐
Infectious disease management in this	☐	☐	☐	☐	☐

hospital needs to be improved					
The quality of reported data is excellent					
Hospital disease network-based reporting systems need strengthening					
Staff are kept up to date and well informed about current infectious disease trends					
More research needs to be done on the health impacts of climate change					
Better communication is needed between different sectors to effectively deal with infectious disease outbreaks					
This hospital is well prepared for the challenge from emerging infectious diseases					

D2 How important do you consider the following strategies in building capacity to curb the health impact of emerging and re-emerging infectious diseases due to climate change in China?

	Extremely important	Very important	Important	Less Important	Not important
Prevention and control measures					
Better response mechanisms when outbreaks occur					
More information sharing about climate-sensitive diseases					
Strengthening the monitoring of infectious diseases					
Improving reporting procedures for notifiable diseases					
The ability to actively forecast disease outbreaks by early warning systems					
More collaboration with CDC to deal with infectious disease outbreaks					

More affordable access to health care for the population					
More community health education programs					
Better training to identify and treat vector/rodent- borne diseases					
Increase laboratory diagnostic ability in rural hospitals					
Improve the network reporting ability in rural hospitals					
Improve accessibility of online infectious disease reporting for rural hospitals					
More funding for rural health care					

D3 Do you have any further suggestions about improving vector/rodent-borne disease control, diagnosis, treatment or management in the context of climate change?

____

____

____

____

____

____

Supplementary Table S1. The educational level of different occupations (N=605)[a].

	Educational level				
	Senior high school certificate N(%)	**Technical certificate N(%)**	**Bachelor degree N(%)**	**Postgraduate degree N(%)**	**Total**
Doctor	3 (1.1%)	18 (6.7%)	187 (69.8%)	60 (22.4%)	268
Nurse	11 (3.9%)	178 (63.6%)	90 (32.1%)	1 (0.4%)	280
Other	5 (8.8%)	24 (42.1%)	25 (43.9%)	3 (5.2%)	57

[a] Data are frequency and percentage - N (%). The total number is not equal to 611 as six participants did not indicate their educational level.

Supplementary Table S2. Multivariate ordinal logistic regression between age group, gender and the concern about climate change[a].

Dependent variables	**Independent variables**	**OR**	**95% CI**	**P**
Concern about climate change	Age group			
	Below 30 years	1	1	
	At or Above 30 years	1.979	1.010-3.878	0.047
	Gender			
	Female	1	1	
	Male	1.977	1.236-3.163	0.004

[a] Values are odds ratios (OR), 95% confidence interval (CI) and p-value from the multivariate ordinal logistic regression model. For age group, 'Below 30 years' is reference group; for gender, 'Female' is reference group. Model adjusted for professional level, length of employment, education, and occupation.

Supplementary Table S3. Multivariate ordinal logistic regression between demographic variables and strategies related to capacity building on infectious diseases[a].

Dependent variables	Independent variables	OR	95% CI	P
Prevention and control measures	Age group			
	Below 30 years	1	1	
	At or Above 30 years	2.370	1.100-5.107	0.028
More collaboration with CDC	Senior professional level			
	No	1	1	
	Yes	8.307	1.063-64.948	0.044

[a] Values are odds ratios (OR), 95% confidence interval (CI) and p-value from the multivariate ordinal logistic regression model. Model adjusted for gender, length of employment, education, and occupation.

Supplementary Table S4. Key terms about improving vector/rodent-borne disease control, diagnosis, treatment or management in the context of climate change from an open-ended question "Do you have any further suggestions about improving vector/rodent-borne disease control, diagnosis, treatment or management in the context of climate change?"[a].

Key terms	Frequency	Percent (%)
Improve environmental health	29	17.9
More health promotion/education	19	11.7
More staff training	19	11.7
More financial support	15	9.3
Strengthen prevention measures	13	8.0
Strengthen disease surveillance	12	7.4
Strengthen management	11	6.8
Improve diagnostic and treatment ability	11	6.8
Collaboration with CDC	7	4.3
Improve health awareness	7	4.3
Develop early warning system	6	3.7
More affordable health care	4	2.5
More climate change related research	4	2.5
Other	5	3.1

[a] Data are frequency and percentage. The total number is not equal to 611 as participants did not answer the open-ended question.

CHAPTER 9 CONCLUSION

9.1 Introduction

This thesis examined health professionals' perceptions of climate change and its impact on infectious diseases as well as the capacity of the health system (both public health and clinical health systems) to deal with emerging and re-emerging infectious diseases in the face of climate change in China. Emerging and re-emerging infectious diseases are considered to be of great importance to population health, and are projected to increase as a result of climate change [1]. The research explored health professionals' views of climate change, their perceptions of infectious disease risks in a changing climate, their appraisal of the current capacity of the health system to deal with emerging and re-emerging infectious diseases, and suggestions to further improvements in the health system to meet such challenges in the context of climate change. The research was conducted in five Provinces of China with different climate zones and which had experienced either emerging or re-emerging dengue, malaria or HFRS in recent years.

This chapter summarises this thesis' key findings, then discusses their implications and sets out a number of key recommendations for policy, practice and research. The chapter ends by characterising the strengths and limitations of this research, whilst suggesting future research directions.

9.2 Key findings

The following section presents a synthesis of the key findings, which is organised in the order of (both public and clinical) health professionals' perceptions of climate change; clinical health professionals' perceptions of infectious diseases; public health professionals' perceptions of dengue, malaria and HFRS; and finally (both public and clinical) health professionals' perceptions of the capacity of health systems to deal with emerging and re-emerging diseases under climate change.

9.2.1 Health professionals' perceptions of climate change

Most public health professionals indicated that they were either concerned or very concerned about climate change in general, and agreed with the statement that the weather was becoming warmer in their area. Moreover, more than 80% of public health professionals in three studies (Chapters 5-7) agreed that climate change would have a negative effect on population health. Roughly 85%-90% of public health professionals indicated that predicted increasing temperatures and precipitation would influence the transmission of infectious diseases. Furthermore, most public health professionals believed that climate change would have an impact on vector-borne diseases, and the majority believed that climate change would have an impact on rodent-borne diseases. These perceptions were generally consistent with the scientific evidence, based on projections that climate change would affect population health and facilitate the transmission of some infectious diseases [2-5].

Clinical health professionals held similar perceptions of climate change to those of the public health professionals. Most clinical health professionals were either concerned or very concerned about climate change in general. The majority also believed that the weather was becoming warmer in their area, and nearly all believed that climate change would have an adverse influence on population health. More than 90% indicated that climate change would affect infectious disease transmission, especially malaria and dengue. This may highlight that climate variation may have a stronger impact on mosquito-borne diseases compared with the rodent-borne diseases.

The results imply that public health professionals and clinical health professionals share similar views on climate change and its impact on population health and infectious disease transmission. The CDCs, hospitals, local governments and other health sectors should work together to develop a future warning system for potential outbreaks according to the climate sensitivity of the diseases.

However, it should be noted that the relationship between climate change and infectious diseases is complex with the consideration of other possible factors such as socioeconomic status, urbanisation, globalisation, and immune status of the population [6]. Therefore, health professionals' views about climate change, population health and infectious disease transmission may change in the future if, for example, vaccines become readily available, novel vector control programs are introduced, or socioeconomic conditions change dramatically in China. Nonetheless, the study findings have shown that at present most health professionals recognised the significance of climate change and its adverse impacts on population health and infectious diseases.

9.2.2 Clinical health professionals' perceptions of infectious diseases

Roughly one-fifth of clinical health professionals surveyed perceived that there had been an increasing number of infectious diseases, fewer did not believe so, and the majority clinical health professionals either reported "Not a big change" or "Unsure". The perceptions of health professionals may imply that the overall trend of infectious diseases had not significantly changed and infectious diseases were manageable by the clinical health system [7-9].

The majority of clinical health professionals surveyed believed that population migration and climate change were the most significant factors associated with the increase in infectious diseases. This aligns with other studies that have indicated that the impact of climate change and migration would facilitate infectious disease transmission [10-13]. Higher temperatures can contribute to the increasing population of vectors/rodents and more frequent contact with humans. Simultaneously, population movement can facilitate disease transmission from one region to another, and the "floating population" (e.g. highly mobile population) often lack health insurance and defer seeking health care [14]. Future infectious disease control should carefully consider vulnerable populations including the floating population, and the influence of climate change on the ecology and transmission of climate-sensitive diseases.

9.2.3 Public health professionals' perceptions of dengue

Nearly all public health professionals in Guangdong Province perceived that dengue had emerged or re-emerged in recent years, and indicated that there had been a geographic expansion of the disease. These views were consistent with findings from the scientific evidence showing dengue has been frequently reported in the south of China, and the geographic distribution of the disease has been extended to neighbouring regions and provinces [15, 16]. Moreover, from a broader perspective, other countries such as Nepal, Vietnam and Mexico have also shown the emergence and re-emergence and geographic expansion of the disease [17-19]. This highlights that dengue is a major public health issue of growing importance worldwide, particularly with climate change. WHO emphasises that dengue is a fast emerging pandemic-prone viral disease in the world, and the incidence has increased 30-fold during the last half century with up to 50-100 million infections worldwide [20]. Rapid urbanisation in China has generated a massive internal migrant population which can affect the transmission of dengue in different areas [21]. In addition to the increasing number of international travellers and workers, dengue could present a major threat to world population health [21].

As noted previously, the transmission of dengue relies on the presence of *Aedes aegypti and Aedes albopictus* mosquitoes, and vector control is a major prevention strategy. Early warning systems predicting possible outbreaks, and selecting optimal timing of insecticide fogging, are significant in reducing the number of mosquitoes and curbing potential dengue outbreaks [22]. Improved environmental health conditions and eradication of breeding sites such as discarded tyres, stagnant water, and other water containers are also very important in vector control [21]. Furthermore, genetically modified mosquitoes and *Wolbachia*-infected mosquitoes have been developed to control the population of dengue vectors and curb dengue transmission, shedding new light on dengue control and prevention [23, 24]. Finally, the introduction of a dengue vaccine can be significant in effectively preventing the disease transmission in future [25].

9.2.4 Public health professionals' perceptions of malaria

Roughly half of the public health professionals surveyed in Anhui, Henan and Yunnan Provinces indicated malaria had re-emerged in some parts of China. However, it should be noted that the overall trend in malaria cases has decreased since 2006 in China [26]. The southwest of China may face more severe malaria epidemics than central and other regions of China. This may be due to climate warming and humidity in the region and the increased number of imported cases from Southeast Asian countries, such as Vietnam, Myanmar and Laos. In the last five years more than 90% of reported malaria cases in China were imported cases from overseas [27-29]. It is therefore necessary to warn outgoing travellers via health promotion strategies to avoid potential risk areas or take necessary preventive measures (e.g. raising awareness of risk, taking antimalarial medicines, avoiding mosquito bites by using insect repellents or mosquito nets). Furthermore, it is also important to screen incoming international travellers and returning workers, and provide sufficient and appropriate treatment for identified malaria cases, to prevent ongoing transmission. Regional cooperation between the

Chinese government and neighbouring countries' governments for malaria control and information sharing is urgently needed to curb the re-emergence of malaria in the region.

Furthermore, with climate change, increasing temperature and more rainfall may facilitate malaria transmission and spread the disease beyond current distribution regions [30]. Reducing the extent of climate change and developing more effective malaria prevention and control measures are imperative to reducing malaria transmission and achieving the eradication of malaria in China [31].

9.2.5 Public health professionals' perceptions of HFRS

More than half of the public health professionals surveyed in Anhui and Liaoning Provinces perceived that HFRS had re-emerged in recent years, especially in northeast China-Liaoning Province; although the introduction of vaccination programs, social improvements and mechanisation of farming practices have made a great contribution to reducing the incidence of HFRS since the 1990s [32]. The number of HTNV-associated HFRS cases was perceived to have increased recently in agricultural areas of both northeast China and east China, and this finding is consistent with the scientific evidence [33]. Moreover, SEOV-associated HFRS cases have also been increasingly reported in urban areas [34, 35]. This suggests that vigilance and health awareness among the public about HFRS risks should be strengthened.

Furthermore, this research found that the most important perceived risk factors associated with HFRS occurrence were increased rodent density and low vaccination coverage. Hence, it is vital to effectively control and reduce rodent numbers and improve the vaccination coverage rate of at-risk individuals to curb the transmission of HFRS [36].

9.2.6 Capacity of health systems to deal with emerging and re-emerging diseases

Regarding the public health system, the majority of public health professionals surveyed indicated that the capacity of the different levels of CDCs in China for early detection of an infectious disease outbreak/epidemic was excellent in the context of climate change, and believed that laboratories could rapidly provide diagnostic support. Moreover, most participants stated that current staff numbers would be adequate in the event of major disease outbreaks, and indicated CDC staff were adequately experienced in handling complex investigations. Although public health professionals thought the current capacity of CDCs was excellent, most indicated infectious disease surveillance platforms and network-based reporting systems could be strengthened, especially in rural areas as indicated in the literature [21, 26, 36]. Significantly, although the surveillance system has been improved since the SARS outbreak in 2003 [37], nearly all public health professionals highlighted that there was a strong need to increase the funding for disease surveillance and control, particularly for extra staffing, to implement diagnosis and early detection of cases, and undertake scientific research [13]. One of the reasons restricting the funding could be the changing trend of disease patterns from infectious diseases to chronic diseases, which has led the government to put more funding towards chronic disease management. Furthermore, the findings showed participants thought the capacity of lower-level CDCs for infectious disease control and prevention needs to be improved [38]. Inadequate financial support and insufficient frontline staff at county/town-level CDCs could be the main reasons for constraining the capacity of lower-level CDCs [13].

Regarding the clinical health system, more than two-thirds of clinical health professionals from the health system indicated that their hospitals could rapidly provide diagnostic tests and appropriate treatments for infectious disease patients. Most clinical health professionals also purported that they would take comprehensive actions such as discussing with colleagues, informing the public health officer and consulting the CDC staff when needed. Most clinical health professionals believed that they were well prepared for the challenge from emerging and re-emerging infectious diseases in the context of climate change and had sufficient staff to deal with such disease outbreaks. However, it should be noted that nearly all clinical health professionals suggested that there was a need to strengthen their hospitals' logistical support in the future as part of their hospital capacity building.

Moreover, health professionals also highlighted problems and challenges such as funding for rural healthcare support and accessibility to an online reporting system in rural areas. The SARS outbreak demonstrated that rural health care was the weakest component of the China's disease control and prevention system [39]. Future capacity building to improve the health system to deal with emerging and re-emerging diseases due to climate change could focus on improving rural health care, disease surveillance and hospitals' logistical support. Additionally, although the current capacity of health system to manage emerging and re-emerging diseases is believed good so far, continuing evaluations and monitoring should be implemented over time to ensure the effectiveness and adequateness of the system to meet the future challenges from climate change.

9.3 Implications and recommendations

Climate change and its impact on infectious disease transmission are an emerging threat to global population health. Emerging and re-emerging infectious diseases may challenge the current capacity of the health system in each country of the world. The implications and recommendations for improving China's capacity of the health system to deal with emerging and re-emerging infectious diseases in the context of climate change are as follows:

9.3.1 Strengthen in-house training programs for health professionals

As mentioned previously, many participants in this research were concerned about climate change and indicated the weather was becoming warmer. However, the health professionals indicated their knowledge of climate change was limited. Less than one-third of participants reported they had a good understanding of climate change and most surveyed indicated they need more information about the health impacts of climate change. Training programs for health professionals could be developed to improve staff knowledge of climate change and present the latest findings regarding its impact on population health. This may help staff gain a better understanding of the climate change-infectious disease association and may be advantageous for controlling and preparing for potential emerging and re-emerging diseases due to climate change in China [36, 38, 40]. An education package could be developed as part of their professional development. Furthermore, curriculum development in public health for medical and nursing students may be necessary at tertiary institutions.

9.3.2 Strengthen interdisciplinary and cross-regional collaboration

Reducing the adverse effect of climate change on infectious disease transmission and improving the capacity of China's health system to meet such challenges need effective and efficient collaborations among different stakeholders including government organisations and departments such as agencies working in the fields of health, climatology, environment, emergency services, community services, research institutes, general communities, schools and local government. In addition, as dengue, malaria and HFRS are zoonotic diseases, cross-sectional communicable disease control and prevention promoting the cooperation between human health and animal health professionals, should be encouraged [41]. Furthermore, cross-regional collaboration with bordering Southeast Asian countries and broader international cooperation could help to curb the adverse impact of climate change on infectious disease transmission.

9.3.3 Strengthen disease and vector surveillance

The establishment of the CDC system in 2002, and the introduction of an online network-based disease reporting system have successfully contributed to enhanced disease surveillance in China [42, 43]. Controlling vectors and rodents, such as *Aedes aegypti* and *Aedes albopictus* mosquitoes for dengue transmission, *Anopheles* mosquitoes for malaria transmission, and *Apodemus agrarius* and *Rattus norvegicus* rodents for HFRS transmission is crucial in disease prevention. It should be acknowledged that the surveillance data quality still needs to be improved for communicable diseases, especially in rural and remote regions of China. It is therefore necessary to improve the disease surveillance data quality and strengthen vector surveillance to prevent and control possible emerging and re-emerging infectious disease outbreaks in early stages.

9.3.4 Strengthen community health education about climate change

There are existing gaps in knowledge about climate change and its impact on population health in the community. Many of the surveyed participants indicated that local residents were not well informed about how to reduce risks of infectious diseases. This is consistent with other studies conducted among the Chinese general population that have advocated a strong need to improve the public's knowledge of infectious diseases and health awareness [44, 45]. In order for the general population to respond effectively in the context of climate change, it is important that they have a good understanding of actions they need to take to reduce the risk of these diseases. Health practitioners, health departments, CDCs and local governments should collaborate with local groups and engage in community activities to promote health education about climate change. Knowledge and information about climate change and its impact on population health could be disseminated in a variety of ways including through the mass media (television, radio, newspapers) as well as via advertising posters, the internet and flyers.

9.3.5 Improve the healthcare service in rural areas

Health care in rural areas was an area highlighted by most participants in this research. There is a need for more funding for rural health care support, better training of rural health workers, and better accessibility to an online reporting system in rural areas. It has been reported that rural areas were the original epidemic focus in the outbreaks of SARS, swine flu and avian flu, which may imply that rural health care was the weakest component of China's disease control and prevention system [39, 46, 47]. More resource allocation, including financial assistance, technical support and personnel training to rural areas would be a vital step in advancing China's capacity of health system to meet the challenge of emerging and re-emerging infectious diseases due to climate change.

9.3.6 Strengthen logistical support in hospitals

Clinical health professionals indicated that logistical support in hospitals needs to be strengthened. The reason for this could be that this has not been given enough attention previously, while a long-term sustainable development of hospital capacity needs well-prepared logistical support to address emergency and infectious disease outbreaks in the face of climate change, e.g. suddenly increased number of patients due to extreme weather events, such as enteric infections and malaria cases after floods. In hospitals, the development of professional staff, resource supplies and effective management of logistical support has lagged behind advancements in patient care [48, 49]. A reliable logistical support system in the face of future climate challenges, including competent professional and administrative staff and transparent resource management, is one of the most important components of a modern healthcare system, and the cornerstone of a good healthcare service [48]. The lack of high-quality staff and regulatory frameworks for logistics management within hospitals are recognised obstacles in this regard [49]. It is important that logistics staff receive specific training and implement effective management and quality control procedures in order to address current inadequacies in this area.

9.3.7 Strengthen climate change and population health research

Although the issue of climate change and its negative impacts on population health was generally acknowledged by most surveyed participants, numerous knowledge gaps remain in this field, especially when the issue is complicated with other non-climate factors such as poor environmental health, rapid urbanisation and a highly mobile migrant population. Climate change research could be further conducted to quantify the health impacts, disease outcomes and disease burden, identify high-risk areas and the most vulnerable populations, build early warning systems for predicting possible disease outbreaks, and design and implement relevant public health intervention strategy for infectious disease transmission in the context of climate change. Further research will improve knowledge of climate change's interaction with, provide evidence for health professionals in the face of climate change, and mitigate the adverse impact on population health.

9.4 Strengths and limitations

This research has addressed knowledge gaps in relation to health professionals' perceptions of climate change and infectious diseases, and the capacity of the health system to deal with emerging and re-emerging infectious diseases in the context of climate change in China. The findings make an important contribution to the knowledge base on this issue and advocated for the development of adaptive strategies and policies to improve the capacity of the health system to manage climate sensitive diseases. A particular strength of the research is that both public health professionals in CDCs and clinical health professionals in hospitals were approached, providing a comprehensive overview of the perceptions of the capacity of China's health system.

The limitations of this research should be acknowledged. First, the vast majority of participants were from prefectural and provincial level CDCs and major city hospitals. Caution should be utilised when generalising the results to lower level CDCs (e.g. county level), rural hospitals and other areas of China. Second, as the participation in the questionnaire survey was completely voluntary, those who were busy, disinterested, or conducting fieldwork outside of CDCs and hospitals at the time of the survey were not included in the research, which may generate potential selection bias and therefore overestimate/underestimate participants' perceptions of climate change and its impact on infectious diseases. Lastly, for some questions/statements only a few participants answered 'disagree strongly', or 'not important'. However, statistical analysis in each chapter has considered the issue and merged relevant categories of answers.

9.5 Future research directions

This research has examined health professionals' perceptions of climate change and its impact on emerging and re-emerging infectious diseases. Using dengue, malaria, and HFRS as case study diseases it has addressed the capacity of the health system to deal with infectious diseases in the face of climate change. However, there will be a continuing need for additional research to be conducted within the following areas.

9.5.1 Frontline health professionals' perceptions of climate change

The research project recruited a broad range of health professionals to gauge the perceptions of climate change and its impact on population health and infectious disease transmission. However, the number of frontline (county/district-level) CDC staff was comparatively smaller compared with staff at higher level of CDCs. Those frontline (county/district level) staff may hold different opinions on disease emergence and re-emergence compared with other workers, which could be due to their fieldwork experience [26]. Furthermore, clinical health professionals indicated that health care in rural areas should be paid more attention to improve their capacity to deal with emerging and re-emerging infectious diseases. However, clinical health professionals in rural areas were not investigated in this study. Further in-depth research among frontline health professionals in county/district levels of CDCs and rural hospitals in China should be conducted to gauge their perceptions of health care in the context of climate change and its health impacts.

9.5.2 Capacity of rural health system in the face of climate change

This research project has demonstrated that the health professionals from lower organisational levels of CDCs had less confidence in the capacity of their CDCs in terms of laboratory diagnostic ability when disease outbreaks occur. Moreover, the research findings indicate that clinical health professionals also believed there was comparatively less capacity in the rural hospital system. Further studies could be conducted to identify the barriers existing in the rural health system and explore the approaches to improve the capacity of health care in rural areas. Qualitative research such as in-depth interviews and focus group discussions is highly recommended as this research approach could identify barriers and explore a series of improvement measures in order to strengthen the capacity of rural health system in detail and in depth.

9.5.3 Public perceptions of climate change, health and adaptive measures

The public's perceptions of climate change and its impacts on health would have an influence on the adaptive measures they would be prepared to undertake. However, findings from the present research show that less than half the health professionals indicated that the population, in general, was well informed about risks of dengue, malaria and HFRS [21, 26, 36], which implies public perceptions of climate change and its impact on health are limited in China. Understanding the public's perceptions of climate change and health may be useful in identifying the risks, and helping in health awareness and health promotion campaigns. This is particularly so for vulnerable groups such as outdoor workers including gardeners and farmers who are highly exposed to climate change and potential vector or rodent-borne diseases [50]. Further research could be conducted to gauge the public's perceptions of climate change and its impact on health in shaping current adaptive measures and improving public understandings of climate change.

9.5.4 More climate change research on rodent-borne disease transmission

Although most health professionals in this study believed that climate change would have an influence on population health and infectious disease transmission, many either did not think climate change would have an influence on rodent-borne diseases including hantavirus infections, or were undecided about the issue indicating the uncertainties and lack of evidence in this area. Further climate change related research concerning rodent-borne disease transmission is required to aid future planning for HFRS control and prevention in China.

9.5.5 Other climate-related infectious diseases and health impacts

Studies have shown that climate variation/change is likely to have an influence on vector-borne diseases, such as dengue and malaria [51, 52]. Further studies in China could be conducted to investigate health professionals' perceptions of the influence of climate change on other climate-related infectious diseases, such as water-borne and food-borne diseases, e.g. rotavirus infections and salmonella infections [53-55]. Such studies could use similar methods and survey instruments which have previously been used to explore perceptions of dengue and malaria [21, 26].

9.6 Closing remarks

There is increasing concern about climate change and its impact on population health amongst the health professionals, both in CDCs and clinical settings. Relevant adaptive strategies and measures will be required to minimise the expected adverse health impacts which include effects of the transmission of climate-sensitive diseases. This research has contributed to improved understanding of health professionals' perceptions of climate change and infectious diseases, and the capacity of the health system to deal with these diseases in the context of climate change.

Health professionals are concerned about climate change, but think that the system adequately deals with infectious diseases at present. There may be a need to build capacity in the future if greenhouse gas emissions continue to increase. Moreover, the research explores the strategies to further improve the capacity of the health system including both public health system and clinical health system to deal with the challenge from the threat of climate-sensitive diseases.

This research has identified some significant factors contributing to the transmission of infectious diseases, such as climate variation, migrant population, increasing vector/rodent density, imported cases, lack of health awareness and poor environmental conditions. Furthermore, the research has appraised current capacity of the health system to curb the adverse impact of climate-sensitive diseases, and shed light on the development of relevant adaptive strategies.

At the policy development level, these findings will inform health professionals, policy makers and other stakeholders to generate effective infectious disease prevention and control measures in the face of climate change in China. This research has shown that there is an urgent need to develop timely strategies and measures to curb the adverse impact of emerging and re-emerging infectious diseases, and improve the capacity of the health system to manage infectious diseases in the face of climate change. During the development of these strategies and measures, health professionals are key, since the extent to which relevant stakeholders feel that their perceptions are taken into account may determinate the effectiveness and practicability of the development of these strategies and measures. If these strategies and measures are in place and implemented appropriately, this would improve the capacity of the health system and curb the adverse public health impact of emerging and re-emerging infectious diseases in the context of climate change in China.

This research may also benefit the sustainable economic growth and social stability as health is one of the key concerns of social development for humans. More broadly, it may address a significant public health problem for worldwide population health as China is a major contributor to the infectious disease transmission with increasing international travellers and business trade with other nations. This research provided much-needed findings to minimise the adverse impact of emerging and re-emerging infectious diseases in a changing world, not only in China but potentially worldwide.

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APPENDICES

Appendix A: Questionnaire (CDCs)

English Version

BUILDING CAPACITY TO CURB THE PUBLIC HEALTH IMPACT OF EMERGING AND RE-EMERGING INFECTIOUS DISEASES DUE TO CLIMATE CHANGE IN CHINA

Thank you for completing this questionnaire, your help in this research is much appreciated. You may choose to answer all of some of the questions. Your answers will remain anonymous. There are 4 parts to this questionnaire and it should take no longer than 30 minutes to complete:

Part A – Climate change

Part B - Future infectious disease risks in a changing climate

Part C – Capacity building to deal with disease risks

Part D – Demographics

Part A – Climate change

The following questions are about your thoughts on climate change: ***(Please indicate your answer with a tick ✓)***

	Very concerned	Concerned	Concerned slightly	Not concerned
How concerned are you about climate change?				

	Yes	No	Unsure
Do you think your area is becoming warmer?			

	Agree strongly	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree strongly
I think climate change will have a negative effect on population health					
Predicted increasing temperatures will influence the transmission of infectious diseases					
Predicted changes in precipitation patterns will influence the transmission of infectious diseases					
I have a good understanding of climate change					
I feel I need more information about the health impacts of climate change					

Part B - Future Infectious Disease Risks in a Changing Climate

B1 Which infectious diseases do you think climate change will affect most in your area? (Tick ✓ the relevant box for each type)

	Agree strongly	Agree somewhat	Unsure/ Don't know	Disagree somewhat	Disagree strongly
Food-borne infections					
Enteric infections					
Campylobacteriosis					
Salmonellosis					
Vibrio species infections					
Norovirus infections					
Enterovirus infections					
Water-borne infections					
Rotavirus infections					
Cholera					
Cryptosporidiosis					
Giardiasis					
Legionellosis					
Vector-borne diseases					
Dengue fever					
Malaria					
Chikungunya					
Schistosomiasis					
Tick-borne encephalitis					
Lyme disease					
Rodent-borne diseases					
Hantavirus infections					
Plague					
Leptospirosis					
Unspecified:					
Viral Hemorrhagic Fevers					
HIAI*					
Hand-foot-mouth disease					
Other: __________________					

* Human Infection with Avian Influenza

B2 In your jurisdiction (province/city/county) over the past 10 years has there been:

	Yes	No	Unsure/Not applicable
Increases in *mosquito-borne* diseases?			
If yes, would you attribute these to climate change?			
Increases in mosquito numbers?			
Vector control programs in place?			
Increases in *rodent-borne* diseases?			
If yes, would you attribute these to climate change?			
Increases in the size of rodent populations			
If yes, is this in rural areas?			
Or in metropolitan areas?			
Rodent control programs in place?			

B3 The next few questions are specifically about <u>dengue fever</u> *(if there is no dengue in your jurisdiction, please move onto the next question)*

	Agree strongly	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree strongly
Dengue has re-emerged in this area in recent years					
Dengue outbreaks are occurring in new geographic areas					
Some of the outbreaks are occurring at different times of the year to normal					
The population in general is well informed about how to reduce the risk of dengue around their home					
Current prevention methods and control programs have been effective in reducing incidence in this area					

What do you think are the main risk factors for dengue in your region? (*give details*) ______________________

B4 **The next few questions are specifically about malaria** ***(if there is no malaria in your jurisdiction, please move onto the next question)***

	Agree strongly	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree strongly
Malaria has re-emerged in this area in recent years	☐	☐	☐	☐	☐
Some of the malaria outbreaks are occurring in new geographic areas	☐	☐	☐	☐	☐
Some of the outbreaks are occurring at different times of the year to normal	☐	☐	☐	☐	☐
The population in general is well informed about how to reduce the risk of malaria	☐	☐	☐	☐	☐
Current prevention methods and the National Malaria Program have been effective in reducing incidence in this area	☐	☐	☐	☐	☐

What do you think are the main risk factors for malaria in your region? *(give details)* ______________________

B5 **The next few questions are specifically about <u>haemorrhagic fever with renal syndrome</u>** ***(if there is no HFRS in your jurisdiction, please move onto the next question)***

	Agree strongly	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree strongly
HFRS has re-emerged in this area in recent years	☐	☐	☐	☐	☐
Some of the HFRS outbreaks are occurring in new geographic areas	☐	☐	☐	☐	☐
Some of the outbreaks are occurring at different times of the year to normal	☐	☐	☐	☐	☐
HFRS in urban areas is increasing	☐	☐	☐	☐	☐
Increasing urbanisation impacts on HFRS incidence	☐	☐	☐	☐	☐
HFRS in agricultural areas is increasing	☐	☐	☐	☐	☐
The population in general is well informed about how HFRS is transmitted	☐	☐	☐	☐	☐

Current prevention methods and deratization programs have been effective in reducing HFRS incidence	☐	☐	☐	☐	☐
Current immunization programs have been effective in reducing HFRS incidence	☐	☐	☐	☐	☐

What do you think are the main risk factors for HFRS in your region? *(give details)* ______________________________

Part C – Capacity Building to Deal with Disease Risks

C1 The following questions are specifically for staff at the Centres for Disease Control and Prevention (CDC) ***(if any do not apply please leave blank and move to the next question):***

	Agree strongly	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree strongly
Current levels of staffing at my organization will be adequate in the event of major disease outbreaks	☐	☐	☐	☐	☐
More funding could be provided to strengthen disease surveillance systems	☐	☐	☐	☐	☐
The CDC could strengthen vector/rodent surveillance systems to detect changes in geographic range or incidence	☐	☐	☐	☐	☐
The quality of monitored data could be improved	☐	☐	☐	☐	☐
Current vector/rodent control programs are adequate	☐	☐	☐	☐	☐
Our CDC conducts research on climate-sensitive diseases	☐	☐	☐	☐	☐
CDC staff are adequately experienced in handling complex investigations	☐	☐	☐	☐	☐
The ability of the local CDC to detect a disease outbreak/epidemic early is excellent	☐	☐	☐	☐	☐

The CDC laboratory can rapidly provide routine and diagnostic support in the case of an epidemic	☐	☐	☐	☐	☐
Disease surveillance platforms and network-based reporting systems need strengthening	☐	☐	☐	☐	☐
There needs to be more staff training on the impacts of climate change	☐	☐	☐	☐	☐
Staff are kept up to date and well informed about current infectious disease trends	☐	☐	☐	☐	☐

C2 These questions are about climate change adaptation, planning, communication and coordination

	Agree strongly	Agree somewhat	Neither agree nor disagree	Disagree somewhat	Disagree strongly
More research needs to be done to identify high-risk areas due to climate change	☐	☐	☐	☐	☐
More research needs to be done on early warning systems for disease outbreaks	☐	☐	☐	☐	☐
The budget for climate change research needs to be increased	☐	☐	☐	☐	☐
Policymakers need to revise current strategies in the face of climate change	☐	☐	☐	☐	☐
There needs to be more health promotion programs to educate the public about measures to minimise disease risks	☐	☐	☐	☐	☐
The CDC rapidly disseminates news of potential outbreaks to doctors/physicians	☐	☐	☐	☐	☐
Better communication is needed between sectors to effectively deal with zoonotic disease outbreaks	☐	☐	☐	☐	☐
China is well prepared to respond to the threat of an important emerging disease	☐	☐	☐	☐	☐

C3 How important do you consider the following strategies in building capacity to curb the population health impact of emerging and re-emerging infectious diseases due to climate change in China?

	Very important	Important	Unsure/ Don't know	Not Important	Useless
Primary prevention measures	☐	☐	☐	☐	☐
Better response mechanisms when outbreaks occur	☐	☐	☐	☐	☐
Having more staff available to undertake epidemiological investigations of disease outbreaks	☐	☐	☐	☐	☐
Strengthening international cooperation to address climate change challenges	☐	☐	☐	☐	☐
Strengthening the monitoring of infectious diseases	☐	☐	☐	☐	☐
Establishing worldwide infectious diseases surveillance and emergency systems	☐	☐	☐	☐	☐
Formulating standard reporting procedures for the health sector and CDCs	☐	☐	☐	☐	☐
Improving field data collection and reporting using new technologies	☐	☐	☐	☐	☐
The ability to actively forecast disease outbreaks by early warning systems	☐	☐	☐	☐	☐
Collaboration with the veterinary sector with regard to both surveillance and responses to an outbreak	☐	☐	☐	☐	☐
Collaboration with the hospital with regard to both lab detection and responses to an outbreak	☐	☐	☐	☐	☐
More affordable access to health care to aid in disease diagnosis	☐	☐	☐	☐	☐
More funding for public health education programs	☐	☐	☐	☐	☐

Underreporting of cases is an important issue particularly in rural areas	☐	☐	☐	☐	☐
Better training of doctors in rural areas to provide greater capacity to identify and treat vector/rodent- borne diseases	☐	☐	☐	☐	☐
Better education standards among public health and health care workers	☐	☐	☐	☐	☐

C4 What do you think will be the major barriers to effective disease control in the future?

____

____

____

____

____

____

C5 Are they any other issues that you see as important regarding China's capacity to deal with emerging and re-emerging vector/rodent-borne diseases?

____

____

____

____

____

____

Part D – Demographics

These final questions are about you and your work:

Gender: Age: ______________ years

Male	☐
Female	☐

Affiliation

Institution: ____

Classification: *(please tick)*

Junior	☐
Intermediate	☐
Associate senior	☐
Senior	☐

Other (*details*) ______________________

Current professional field: *(please tick whichever applies)*

Nursing	☐
Clinical medicine	☐
Communicable diseases control and prevention	☐
Food-borne disease control	☐
Vector-borne disease control	☐
Chronic disease control and prevention	☐
Endemic disease control and prevention	☐
Emergency response and preparedness	☐
Laboratory Science/analysis	☐
Disinfection and vector control	☐
Immunization planning programs	☐
Environmental health	☐
Nutritional health and food safety	☐
School health	☐
Occupational health	☐
Research	☐
Administrative management	☐
Informatics and data management	☐
Health assessment	☐
Preventive care	☐

Other: *(details)* ____

How long have you been employed in this profession? ________________ years

<u>Qualifications:</u>

Highest educational qualification:

Junior high school	
Senior high school	
Technical secondary school	
College	
University bachelor’s degree	
Master’s degree or equivalent	
Doctor of Philosophy	

We would very much like to discuss these issues in more detail with you and we invite you to participate in a short interview with one of our researchers. The interview will be recorded (for research purposes only) and confidentiality will be assured.

Would you be willing to take part in an interview?

Yes	☐	**Please proceed to next section**
No	☐	**Thank you for completing the questionnaire**
Unsure	☐	

Confidential information (optional)

If you are willing to participate in an interview regarding the population health impact of emerging and re-emerging infectious diseases and the role of climate change, please provide name and contact details so we can arrange a suitable time with you.

Please note this information will be removed from the survey to ensure confidentiality.

Name: …….………………………………………………………….

Email: ….………………………………………………………..…

On behalf of The University of Adelaide and the Institute for Communicable Disease Control and Prevention, Chinese Centre for Disease Control and Prevention, thank you very much for taking part in this survey.

Your help is greatly appreciated.

谢谢

中国气候变化引起新发和再发传染病的公共卫生影响及能力建设研究

非常感谢您参与本次调查，对您的大力支持和帮助我们表示由衷的谢意！

本次调查是匿名的，所有数据将进行严格的保密处理，请您放心如实回答本次调查问卷的问题。本次调查问卷包括 4 个部分，大约需要花费至多半个小时的时间。

第一部分 气候变化

第二部分 气候变化对传染病的影响

第三部分 传染病防控能力建设

第四部分 人口学信息

第一部分 气候变化

以下问题是关于您对气候变化的一些看法见解。（请在选项框内打“√”）

	非常关注	比较关注	关注一点	不关注
您对气候变化的关注程度如何？				

	是	否	不确定
您是否认为自己所在的区域正在变暖？			

	非常同意	比较同意	不确定	不太同意	不同意
气候变化对人群健康会有负面影响					
气温上升会对传染病的传播造成影响					
降雨的改变会对传染病的传播造成影响					
我对气候变化有很深入的了解					
我需要掌握更多关于气候变化对人群健康影响的信息					

第二部分 气候变化对传染病的影响

1. 您认为气候变化对您所在地的以下传染病影响程度如何？（请在选项框内打“√”）

	影响很大	影响较大	不确定	影响不大	不影响
食物源性传染病……………					
肠道传染病………………					
弯杆菌病…………………					
沙门氏菌病………………					
弧菌属感染………………					
诺瓦克病毒感染…………					
肠病毒感染 ………………					
水源性传染病………………					
轮状病毒感染……………					
霍乱………………………					
隐孢子虫病………………					
贾第虫病…………………					
军团杆菌病………………					
媒介传染病…………………					
登革热……………………					
疟疾………………………					
基孔肯雅病………………					
血吸虫病…………………					
森林脑炎…………………					
莱姆病……………………					
鼠源性疾病…………………					
汉坦病毒感染……………					
鼠疫………………………					
细螺旋体病………………					
其它：					
病毒性出血热……………					
人感染禽流感……………					
手足口病…………………					
其它： ________________					

2. 过去十年，您的管辖区域（省、市、区）内是否发生以下情况（请在选项框内打“√”）：

	是	否	不确定 / 不适用
(1) 蚊媒传染病是否增多？			
如果增多，是否归因于气候变化？			
(2) 蚊子数量是否增多？			
(3) 所在地是否有媒介传染病控制管理方案？			
(4) 鼠源性疾病是否增多？			
如果增多，是否归因于气候变化？			
(5) 鼠类数量是否增多			
如果增多，是在农村郊区？			
还是在城市?			
(6) 所在地是否有鼠类控制/灭鼠方案？			

3. 以下问题特别针对<u>登革热</u>（如果您的管辖区域内没有登革热，请跳过此部分）（请在选项框内打“√”）

	非常同意	比较同意	不确定	不太同意	不同意
近些年登革热已经在本区域再度出现					
某些爆发是在新的地理区域内					
某些爆发不同于往年的正常时间					
本地人群大体上对如何做好登革热的防控工作有较好的认识					
当前的预防措施和控制方案已经有效地降低本地登革热的发病率					

您认为您所在地区登革热的主要危险因素有哪些？ ________________________________

4. 以下问题特别针对<u>疟疾</u> （如果您所在的管辖区域内没有疟疾，请跳过此部分）（请在选项框内打“√”）

	非常同意	比较同意	不确定	不太同意	不同意
近些年疟疾已经在本区域内再度出现					
某些爆发是在新的地理区域内					
某些爆发不同于往年的正常时间					
本地人群已对如何做好疟疾的防控工作有较好的认识					
当前的预防措施和国家疟疾控制方案已经有效地降低本地疟疾的发病率					

您认为您所在地疟疾的主要危险因素有哪些？ ______________________________

5. 以下问题特别针对<u>肾综合症出血热</u>（如果您所在的管辖区域内没有肾综合症出血热，请跳过此部分）（请在选项框内打“√”）

	非常同意	比较同意	不确定	不太同意	不同意
近些年肾综合症出血热已经在本区域内再度出现					
某些爆发是在新的地理区域内					
某些爆发不同于往年的正常时间					
城市中的肾综合症出血热正在增多					
城市化对肾综合症出血热发病率的影响不断增强					
农村肾综合症出血热正在增多					
本地人群大体上对肾综合症出血热的传播有较好的认识					
当前的预防措施和灭鼠方案已经有效地降低肾综合症出血热的发病率					
当前的免疫计划已经有效地降低肾综合症出血热的发病率					

您认为您所在地肾综合症出血热的主要危险因素有哪些？ ______________________________

第三部分 传染病防控方面的能力建设

1. 此部分问题由疾控中心人员作答。如果您不再此部门工作，请跳过此部分。（请在选项框内打“√”）

	非常同意	比较同意	不确定	不太同意	不同意
本单位在职人员的水平可以胜任并应对重大的传染病爆发					
本单位需要更多的财政支持加强现有的疾病监测系统					
本疾控中心可以通过加强媒介传染病监测系统强化对媒介传播疾病的监测					
现有的监测数据质量有待提高					
现有媒介传染病的控制管理方案是有效可行的					
本疾控中心有关于气候变化和传染病的研究					
本疾控中心的工作人员有经验开展深入复杂的调查研究					
本疾控中心可以迅速有效的监测到可能爆发的传染病/流行病					
本疾控中心实验室可以在流行病爆发时迅速及时的提供常规检验支持					
现有的疾病监测平台和网络报告系统有待加强					
本单位需要加强工作人员在气候变化影响方面的培训					
疾控工作人员对当前传染病的发病趋势及相关情况有较全面的认识					

2. 以下问题是关于气候变化的应对、规划以及交流合作。

	非常同意	比较同意	不确定	不太同意	不同意
我认为需要进一步研究确定气候变化引发的高危区域					

	非常重要	比较重要	不确定	不太重要	不重要
我认为需要加强对传染病早期预警系统的研究					
我认为气候变化方面的研究经费需要增加					
我认为政策制定者需要修改当前应对气候变化的政策及策略					
我认为需要加强健康宣传，教育公众如何降低疾病的危险因素					
我认为疾控中心需要及时告知医护人员潜在的疾病爆发					
各部门之间需要加强交流与合作以便有效应对动物源性传染病的爆发					
中国已经作好应对重大新发传染病的准备					

3. 针对中国气候变化引起新发和再发传染病的公共卫生影响和能力建设中，您认为以下所举出的策略重要程度如何？

	非常重要	比较重要	不确定	不太重要	不重要
加强一级预防措施					
更好的传染病爆发响应机制					
有更多的工作人员投入到疾病爆发的流行病学调查中					
加强应对气候变化的国际合作					
加强传染病的监控					
建立全球传染病的监测及应急系统					
为健康及疾控部门建立标准化的疾病报告制度					
使用新技术提高现场数据收集和汇报能力					
通过早期预警系统提高对疾病爆发的预测能力					

	非常重要	比较重要	不确定	不太重要	不重要
加强与动物检疫部门在监测和响应疾病爆发方面的合作					
加强与医院相关部门在实验室检测和响应疾病爆发方面的合作					
增加经济实用的疾病诊断技术					
增加对公共卫生健康教育的财政支持					
疾病的少报或不报是一个严重的问题，特别是在农村地区					
为农村地区的医生提供更好的培训，提高他们识别和治疗媒介传染病的能力					
提高公共卫生和医护人员的教育标准					

1. **您认为影响未来传染病防控建设的主要障碍是什么？**

____

____

____

____

____

2. **关于中国在应对新发和再发媒介传染病能力建设方面，您认为还有哪些其它的事宜需要关注？**

____

____

____

____

____

第四部分 人口学信息

以下问题是关于您的基本信息。

性别：（请打勾“√”）　　　　　　　　　年龄：_______岁

男性	
女性	

单位信息

单位名称：____

专业技术职称级别：（请打勾“√”）

初级职称	
中级职称	
副高级职称	
高级职称	

其它：____________________

您当前从事的专业领域：（请打勾“√”，可多选）

护理	
临床医学	
传染病控制和预防	
食物源性传染病控制	
媒介传染病控制	
慢性病控制和预防	
地方病控制和预防	
应急响应和处置	
卫生检验	
消毒与媒介控制	
免疫计划	
环境卫生	
营养与食品安全	
学校与少儿卫生	
职业卫生	
科研	
行政管理	
信息和数据管理	
健康评估	
预防保健	

其它：（请注明）____

您从事该专业有多久了？________________年

您的最高学历:

初中及以下	
高中	
中专	
大专	
大学本科	
硕士	
博士	

我们非常希望邀请您和我们对以上问题作进一步的讨论。如果您愿意，我们的一位研究人员将邀请您做一个简短的调查访谈，访谈记录仅用于学术研究并进行严格保密。如果您感兴趣，欢迎您的进一步参与！

您是否愿意参加我们的调查访谈？

是	☐	**请您移至下一部分**
否	☐	**非常感谢您参加此次调查**
不确定	☐	

保密信息（可选）

如果您愿意参加关于气候变化新发和再发传染病对人群健康的影响方面的访谈，请提供以下信息以便我们的研究人员联系您。

请注意，您提供的信息将从本次调查中移除以确保其隐私和保密性。

姓名：……………………………………………………………

电子邮件（请用正楷书写）：…………………………………………

在此谨代表阿德莱德大学、中国疾病预防控制中心传染病预防控制所对您参与本次调查表示由衷的感谢！

非常感谢您的大力支持和参与！

谢谢

Appendix B: Participant Information Sheet (CDCs)

English Version

BUILDING CAPACITY TO CURB THE PUBLIC HEALTH IMPACT OF EMERGING AND RE-EMERGING INFECTIOUS DISEASES DUE TO CLIMATE CHANGE IN CHINA

Purpose of the study

This study aims to investigate the risks of emerging and re-emerging vector/rodent-borne diseases in China and the capacity to respond to climate change driven threats of these diseases – in particular dengue fever, malaria and haemorrhagic fever with renal syndrome.

The research questions include:
(1) What are the risks associated with emerging and re-emerging vector/rodent-borne diseases that may impact on population health in China in a changing climate?
(2) How effective have current infectious disease prevention and control programs been?
(3) What is the capacity of the public health system to deal with these diseases and are there barriers to capacity building for infectious disease surveillance, management and prevention?

Who is conducting the study?

The study is funded by the Australian Government's Department of Foreign Affairs and Trade through its Australian Aid initiative program (http://aid.dfat.gov.au/Pages/home.aspx). The study is being jointly conducted by investigators at The University of Adelaide, The University of South Australia, Monash University, Anhui Medical University of China and the China Centre for Disease Control and Prevention. The chief investigators in the study are listed over the page.

What will your participation involve?

If you would like to contribute to this research it would simply involve filling out this survey. We anticipate that this will take up to 30 minutes of your time. The questions will relate to your (or your organisation's) experience/knowledge of dengue fever, malaria and haemorrhagic fever with renal syndrome outbreaks in specific areas, risk factors, prevention/control programs and disease surveillance systems.

Participation is completely voluntary and you may withdraw from the study at any time without reason or answer only selected questions. Please note the project may not be of any direct benefit to you or your organisation.

Ethics approval

The study has been approved by the Ethical Committees of the National Institute for Communicable Disease Control and Prevention Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002), the University of Adelaide, Anhui Medical University, Monash University, and the University of South Australia.

Confidentiality

Your responses will be strictly confidential and you will not be required to provide any information which may identify you.

What if I have a complaint or any concerns?

If you wish to raise concerns about the conduct of the project with an independent person or discuss matters related to the University policy on research involving human participants or your rights as a participant, contact:

The Human Research Ethics Committee's Secretary, *Ph*: +61 8 8313 6028, or visit: http://www.adelaide.edu.au/ethics/human/guidelines/applications/#complaint.

Or

The Chinese Center for Disease Control and Prevention, *Ph*: +86 1058900240 12320, or visit: web@chinacdc.cn

For further information:

Thank you for interest and possible involvement with this study. If you have any queries about the research, please contact the Chief Investigator: Professor Peng Bi, Discipline of Public Health, University of Adelaide; *Ph*: +61 8 8313 3583; *Email*: peng.bi@adelaide.edu.au, or the Research Associate, Dr Alana Hansen; *Ph*: +61 8 8313 1043; *Email*: alana.hansen@adelaide.edu.au.

The investigators in the project are:

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Chinese Version

中国气候变化引起新发和再发传染病的公共卫生影响及能力建设研究

研究目的

本次研究的目的是调查中国现今新发和再发媒介传染病的危险因素、气候变化对这些疾病的影响及相关能力的调查与建设。此次研究的传染病主要包括登革热、疟疾和肾综合症出血热。

研究问题

3. 针对中国气候变化，引起新发和再发媒介传染病的主要诱导因素有哪些？
4. 当前传染病预防和控制措施的效力情况如何？
5. 当前中国公共卫生系统对传染病的预防控制能力如何？以及对传染病监测、管理和预防的能力建设可能存在的障碍有哪些？

资助及研究单位

本研究由澳大利亚政府外交外贸部海外援助项目(http://aid.dfat.gov.au/Pages/home.aspx)资助。参与本研究的合作单位包括澳大利亚阿德莱德大学、南澳大利亚大学、莫纳什大学、安徽医科大学和中国疾病预防控制中心。本项目主要研究负责人列举如下：

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您的参与包括以下内容

如果您愿意参加本次调查研究，我们表示由衷的感谢！本次问卷调查大概需要花半小时，问题涉及您或您所在的工作单位对所管辖地区登革热、疟疾、肾综合症出血热的相关知识、处理经验，传染病的危险因素，疾病的预防和控制以及现有疾病监测系统的相关情况。

参与本次调查是完全自愿的，您可以随时退出本次调查或者回答部分您愿意回答的问题，当然我们对您能全程参与表示万分感谢！请注意本次调查研究也许不会对您或者您的工作单位有直接的利益，但研究对提高整个中国公共卫生系统有深远的影响。我们非常希望您能全程参与！

伦理道德委员会许可文件

本次研究已经通过中国疾病预防控制中心传染病预防控制所伦理委员会审批通过（批准文号：ICDC-2013002）,并于阿德莱德大学、安徽医科大学、莫纳什大学和南澳大利亚大学存案。

隐私及保密性

您的所有回答都将严格保密并且您不需要提供任何涉及个人身份的信息。

咨询与投诉
如果您对本次研究项目有任何疑问或者希望能够进一步了解本次研究的相关政策条例以及希望了解更多参与本次调查研究的权益，请联系：

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或者

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更多信息
首先非常感谢您的参与！如果您对本次调查研究有任何疑问，请联系项目首席科学家：

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Appendix C: Questionnaire (Hospitals)

English version

BUILDING CAPACITY TO CURB THE PUBLIC HEALTH IMPACT OF EMERGING AND RE-EMERGING INFECTIOUS DISEASES DUE TO CLIMATE CHANGE IN CHINA

Thank you for completing this questionnaire, your help in this research is much appreciated. You may choose to answer all or some of the questions. Your answers will remain anonymous. There are 4 parts to this questionnaire and it should take no longer than 30 minutes to complete:

Part A – Demographics
Part B – Climate change
Part C – Future infectious disease risks in a changing climate
Part D – Capacity building to deal with disease risks

Part A – Demographics (Please indicate your answer with a tick✓ in the ☐)

A1 Department: ____

A2 Occupation

☐ Doctor ☐Nurse ☐Public health officer

☐Lab technician ☐Administrator ☐Other (*please specify*)_______________

A3 Gender: ☐Male ☐Female

A4 Age: _________ years

A5 Classification:

☐None ☐Junior ☐Intermediate ☐Associate senior ☐Senior

A6 How long have you been employed in this hospital? ___________ Years

A7 Highest qualification:

☐Senior high school certificate ☐Technical certificate ☐Undergraduate degree

☐Postgraduate degree ☐Other (*please specify*) _______________

Part B – Climate change (*Please indicate your answer with a tick✓ in the ❑*)

The following questions are about your thoughts on climate change:

B1 How concerned are you about climate change?

☐Very concerned ☐Concerned ☐Concerned slightly ☐Not concerned

B2 Do you think your area is becoming warmer?

☐Yes ☐No ☐Unsure

B3 Please answer the following questions about climate change and health

	Agree strongly	Agree somewhat	Disagree somewhat	Disagree strongly	Unsure
I have a good understanding of climate change					
I think climate change will have a negative effect on population health					
Predicted increasing temperatures will influence the transmission of infectious diseases					
Predicted changes in precipitation patterns will influence the transmission of infectious diseases					
I feel I need more information about the health impacts of climate change					

Part C – Future Infectious Disease Risks in a Changing Climate (*Please indicate your answer with a tick✓ in the ❑*)

C1 How likely do you think there is an association between climate change and these infectious diseases?

	Extremely likely	Very likely	Somewhat likely	Not likely	Unsure
Dengue fever					
Malaria					
HFRS*					
Others:___________					
Others 1:___________					
Others 2:_________					
Others 3:___________					

* Hemorrhagic fever with renal syndrome

C2 According to your work experience, what is the trend of patients with these infectious diseases over the past 10 years (or your working period if less than 10 years)?

	Increased	Decreased	No big change	Unsure
Dengue fever				
Malaria				
HFRS				

C3 If these infectious diseases have increased, what do you think are the contributing factors? (*You may tick more than one*)

	Climate change	Urbanization	Population migration	Other (*please specify*)
Dengue fever				
Malaria				
HFRS				

C4 Are the majority of cases of dengue/malaria in your area locally acquired or imported?

	Locally acquired	Imported	Neither	Unsure
Dengue fever				
Malaria				

C5 Are the majority of patients with HFRS from metropolitan areas or rural areas?

	Metropolitan areas	Rural areas	Both	Unsure
HFRS				

C6 In recent years have you noticed patients with these infectious diseases presenting at different times of the year to normal?

	Yes(ahead)	Yes(late)	No	Unsure
Dengue fever				
Malaria				
HFRS				

C7 Do you think there is a need to further strengthen community health education in relation to these infectious diseases?

	Yes	No	Unsure
Dengue fever			
Malaria			
HFRS			

C8 Is there a hospital protocol in place for the reporting of these notifiable diseases?

	Yes	No	Unsure
Dengue fever			
Malaria			
HFRS			

C9 Is the hospital laboratory able to rapidly provide diagnostic test results for these infectious diseases?

	Always	Mostly	Rarely	Unsure	Samples sent to CDC for testing
Dengue fever					
Malaria					
HFRS					

C10 Once a patient is diagnosed with these diseases, normally how long does it take to report the case online to the CDC?

	72hrs	48hrs	24hrs	Other (*please specify*)	Unsure
Dengue fever					
Malaria					
HFRS					

C11 How do you rate the infectious disease diagnostic ability of your hospital?

	Excellent	Good	Fair	Poor	Very Poor
Dengue fever					
Malaria					
HFRS					

C12 How do you rate the infectious disease treatment ability of your hospital?

	Excellent	Good	Fair	Poor	Very Poor
Dengue fever					
Malaria					
HFRS					

C13 If you noticed an unusual cluster of cases would you?: (*You may tick more than one*)

☐ Discuss with colleagues

☐ Inform the public health officer at the hospital

☐ Discuss with laboratory technicians

☐ Consult the CDC

☐ Notify no one

☐ Other (*please specify*): ________________________________

Part D–Capacity Building to Deal with Disease Risks (*Please indicate your answer with a tick✓in the ❑*)

D1 The following questions are specifically for staff in the hospital

	Agree strongly	Agree somewhat	Disagree somewhat	Disagree strongly	Unsure
Current numbers of staff at this hospital will be adequate in the event of major disease outbreaks					
More funding could be provided to strengthen disease diagnosis, treatment and management					
More staff training in this hospital needs to be strengthened					
Logistical support in this hospital needs to be strengthened					
Infectious disease diagnoses in this hospital needs to be improved					

Infectious disease treatment in this hospital needs to be improved	☐	☐	☐	☐	☐
Infectious disease management in this hospital needs to be improved	☐	☐	☐	☐	☐
The quality of reported data is excellent	☐	☐	☐	☐	☐
Hospital disease network-based reporting systems need strengthening	☐	☐	☐	☐	☐
Staff are kept up to date and well informed about current infectious disease trends	☐	☐	☐	☐	☐
More research needs to be done on the health impacts of climate change	☐	☐	☐	☐	☐
Better communication is needed between different sectors to effectively deal with infectious disease outbreaks	☐	☐	☐	☐	☐
This hospital is well prepared for the challenge from emerging infectious diseases	☐	☐	☐	☐	☐

D2 How important do you consider the following strategies in building capacity to curb the health impact of emerging and re-emerging infectious diseases due to climate change in China?

	Extremely important	Very important	Important	Less Important	Not important
Prevention and control measures	☐	☐	☐	☐	☐
Better response mechanisms when outbreaks occur	☐	☐	☐	☐	☐
More information sharing about climate-sensitive diseases	☐	☐	☐	☐	☐
Strengthening the monitoring of infectious diseases	☐	☐	☐	☐	☐
Improving reporting procedures for notifiable diseases	☐	☐	☐	☐	☐
The ability to actively forecast disease outbreaks by early warning systems	☐	☐	☐	☐	☐

More collaboration with CDC to deal with infectious disease outbreaks					
More affordable access to health care for the population					
More health education programs					
Better training to identify and treat vector/rodent- borne diseases					
Increase laboratory diagnostic ability in rural hospitals					
Improve the network reporting ability in rural hospitals					
Improve accessibility of online infectious disease reporting for rural hospitals					
More funding for rural health care					

D3 Do you have any further suggestions about improving vector/rodent-borne disease control, diagnosis, treatment or management in the context of climate change?

____

____

____

____

____

____

气候变化引起新发和再发传染病对中国公共卫生影响及能力建设研究

非常感谢您参与本次调查，对您的大力支持和帮助我们表示由衷的谢意！

本次调查是匿名的，所有数据将进行严格的保密处理，欢迎您根据自己的了解回答本次调查问卷的问题。

本次调查问卷包括 4 个部分，大约需要 20-30 分钟的时间。

第一部分 基本信息

第二部分 气候变化

第三部分 气候变化对传染病的影响

第四部分 传染病防控能力建设

第一部分 基本信息（请在选项框打勾“√”）

A1 医院：____________________________ 科室名称 ：__________________________

A2 职业： ①医生 ②护士 ③公共卫生人员

④医学检验人员 ⑤行政管理人员 ⑥其它：______________

A3 性别： ①男 ②女

A4 年龄: _______ 岁

A5 专业技术职称级别：

无职称 ②初级 ③中级 ④副高级 ⑤高级

A6 您累计在医疗服务行业有多少年的工作经验？____________ 年

A7 您的最高学历:

①高中或卫校（中专） ②大专或高职 ③大学本科

④硕士及以上 ⑤其它：__________

第二部分 气候变化（请在选项框打勾“√”）

以下问题是关于您对气候变化的一些看法见解。

B1 请问您对气候变化的关注程度如何？

① 非常关注 ②比较关注 ③关注一点 ④不关注

B2 请问您是否认为自己所在的区域气候正在变暖？

①是　　②否　　③不清楚　　④不关心

B3 请问您是如何看待以下问题：

观点	非常同意	比较同意	比较不同意	非常不同意	不清楚
我对气候变化有良好的认识和了解					
我认为气候变化会对人群健康会有负面影响					
气温上升会对传染病的传播造成影响					
降雨的改变会对传染病的传播造成影响					
我认为我需要了解与掌握更多有关气候变化对人群健康影响的信息					

第三部分 气候变化对传染病的影响　（请在选项框打勾“√”）

C1.请问您认为气候变化和传染病的相关程度如何？

传染病	气候和传染病的关系
登革热	①非常相关　②比较相关　③有点相关　④不相关　⑨不清楚
疟疾	①非常相关　②比较相关　③有点相关　④不相关　⑨不清楚
流行性出血热	①非常相关　②比较相关　③有点相关　④不相关　⑨不清楚
其它（请填写病名）：	
其它㈠：	①非常相关　②比较相关　③有点相关　④不相关　⑨不清楚
其它㈡：	①非常相关　②比较相关　③有点相关　④不相关　⑨不清楚
其它㈢：	①非常相关　②比较相关　③有点相关　④不相关　⑨不清楚

C2.本地区过去十年间，以下传染病发病趋势如何？

	发病人数增加	发病人数没增加	发病人数减少	不清楚
登革热				
疟疾				
流行性出血热				

C3. 如果传染性疾病的发病人数增加，您认为导致这一现象的可能原因是什么？

	气候变化	城市化	流动人口增多	其它（请指明）
登革热				
疟疾				
流行性出血热				

C4. 您所在地区的登革热和疟疾病例主要是以本地源性的病例为主还是外来输入性病例为主？

	本地为主	外来为主	都不是	不清楚
登革热				
疟疾				

C5. 您所在医院的流行性出血热病例主要是以来自城市地区病例为主还是来自农村地区病例为主？

	城市为主	农村为主	都是	不清楚
流行性出血热				

C6. 您在近些年是否注意到以下传染病的发病季节发生改变， 比如有明显的提前或者延迟？

	有改变（提前）	有改变（延迟）	没改变	不清楚
登革热				
疟疾				
流行性出血热				

C7. 您是否认为有必要进一步加强以下传染病的健康宣传和健康教育工作 ？

	有必要	没有必要	不清楚
登革热			
疟疾			
流行性出血热			

C8. 您所在的医院是否根据自身情况制定了院内传染病应急管理方案或管理细则，比如对突发传染病爆发时的人员，物资，设备的应急储备管理和院内的统筹调动等？

	有	没有	不清楚
登革热			
疟疾			
流行性出血热			

C9. 您所在医院的实验室、检验科是否可以对以下传染病提供及时有效的实验室诊断结果？

	可以	大多情况下可以	少数情况下可以	不清楚	送检疾本地控中心
登革热					
疟疾					
流行性出血热					

C10.您所在的医院一旦有病人被确诊为以下某种传染病，一般情况下多长时间内该病例会在网上直报？

	72 小时	48 小时	24 小时	其它（请指明）	不清楚
登革热					
疟疾					
流行性出血热					

C11.您认为所在医院对以下传染病的诊断水平能力如何？

	非常出色	比较出色	一般	比较差	非常差
登革热					
疟疾					
流行性出血热					

C12.您认为所在医院对以下传染病的治疗水平能力何如？

	非常出色	比较出色	一般	比较差	非常差
登革热					
疟疾					
流行性出血热					

C13.您如果发现一例不同寻常或奇特的传染性病例，您将会如何处理：**（可多选）**

☐ ①与同事讨论交流

☐ ②报告给医院防保科

☐ ③与检验科讨论沟通

☐ ④咨询疾病控制中心

☐ ⑤不做任何通知，直接处理

☐ ⑥其它（请指明）：______________________________

第四部分 传染病诊断治疗管理的能力建设 （请在选项上打勾"√"）

D1.针对当前传染病情况，您认为所在医院的整体能力如何及需要做出哪些调整？

条目	非常同意	比较同意	比较不同意	非常不同意	不清楚
本医院的医务水平和人员配备可以胜任并应对本地区可能发生的传染病爆发的诊断及治疗					
本医院需要更多的财政支持加强传染病的诊断、治疗和管理能力					
本医院需要加强人员能力的建设培训					
本医院需要加强后勤保障的建设支持					
本医院在传染病方面的诊断水平有待进一步提高					
本医院在传染病方面的治疗水平有待进一步提高					
本医院在传染病方面的管理水平有待进一步提高					
本医院的传染病报告质量非常高					
现有的医院传染病网络直报系统有待进一步加强					
本医院的医务人员对当前传染病的发病趋势及相关情况有较全面的认识					
有必要进一步加强关于气候变化引起对传染病影响的研究					
本医院需要加强与其它相关部门的交流与合作以便更有效的应对传染病的爆发					
本医院已经作好应对重大新发传染病的准备					

D2. 针对气候变化可能引起新发和再发传染病的公共卫生影响和能力建设中，您认为以下所举出的策略重要程度如何？

策略	重要程度
加强预防措施	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
更好的传染病爆发响应机制	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
更多关于气候敏感性疾病的信息交流	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
加强传染病的监控	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
改善现有的医院疾病报告规程	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
通过早期预警系统提高对疾病的预测能力	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要

加强与疾控部门在传染病防控方面的合作	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
提供经济实惠的看病就医服务	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
增加对公共卫生健康教育的财政支持	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
需要更好的培训以提高媒介传染的诊治能力	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
提高偏远地区医院实验室诊断能力	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
提高偏远地区医院的传染病网络直报能力	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
增加对偏远地区医疗健康的投入	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要
增加对本院医疗队伍的建设	①非常重要 ②比较重要 ③一般重要 ④不太重要 ⑤不重要

D3.关于中国在应对气候变化可能引发新发和再发媒介传染病诊断、治疗和管理能力建设方面，您还有哪些其它的建议或看法？

谢谢您的参与！

Appendix D: Participant Information Sheet (Hospitals)

English Version

BUILDING CAPACITY TO CURB THE PUBLIC HEALTH IMPACT OF EMERGING AND RE-EMERGING INFECTIOUS DISEASES DUE TO CLIMATE CHANGE IN CHINA

Purpose of the study

This study aims to investigate the risks of emerging and re-emerging vector/rodent-borne diseases in China and the capacity to respond to climate change driven threats of these diseases – in particular dengue fever, malaria and haemorrhagic fever with renal syndrome.

The research questions include:
(1) What are the risks associated with emerging and re-emerging vector/rodent-borne diseases that may impact on population health in China in a changing climate?
(2) How effective have current infectious disease diagnosis, treatment and management been in hospitals?
(3) What is the capacity of the clinical system to deal with these diseases and are there barriers to capacity building for infectious disease surveillance, management and prevention in hospitals?

Who is conducting the study?

The study is funded by the Australian Government's Department of Foreign Affairs and Trade through its Australian Aid initiative program (http://aid.dfat.gov.au/Pages/home.aspx). The study is being jointly conducted by investigators at The University of Adelaide, The University of South Australia, Monash University, Anhui Medical University of China and the Chinese Centre for Disease Control and Prevention. The chief investigators in the study are listed over the page.

What will your participation involve?

If you would like to contribute to this research it would simply involve filling out this survey. We anticipate that this will take up to 30 minutes of your time. The questions will relate to your (or your organisation's) experience/knowledge of dengue fever, malaria and haemorrhagic fever with renal syndrome outbreaks in specific areas, risk factors, prevention/control programs and disease surveillance systems.

Participation is completely voluntary and you may withdraw from the study at any time without reason or answer only selected questions.

Ethics approval

The study has been approved by the Ethical Committees of the National Institute for Communicable Disease Control and Prevention Chinese Center for Disease Control and Prevention (Approval No. ICDC-2013002), the University of Adelaide, Anhui Medical University, Monash University, and the University of South Australia.

Confidentiality
Your responses will be strictly confidential and you will not be required to provide any information which may identify you.

What if I have a complaint or any concerns?
If you wish to raise concerns about the conduct of the project with an independent person or discuss matters related to the University policy on research involving human participants or your rights as a participant, contact:

The Human Research Ethics Committee's Secretary, *Ph*: +61 8 8313 6028, or visit: http://www.adelaide.edu.au/ethics/human/guidelines/applications/#complaint.

Or

The Chinese Center for Disease Control and Prevention, *Ph*: +86 1058900240 12320, or visit: web@chinacdc.cn

For further information:
Thank you for interest and possible involvement with this study. If you have any queries about the research, please contact the Chief Investigator: Professor Peng Bi, Discipline of Public Health, University of Adelaide; *Ph*: +61 8 8313 3583; *Email*: peng.bi@adelaide.edu.au, or the Research Associate, Dr Alana Hansen; *Ph*: +61 8 8313 1043; *Email*: alana.hansen@adelaide.edu.au.

The investigators in the project are:

Professor Peng Bi
Discipline of Public Health
The University of Adelaide
peng.bi@adelaide.edu.au
ph. +61 8 8313 3583

Professor Qiyong Liu
Department of Vector Biology and Control
National Institute for Communicable Disease Control and Prevention
China CDC
liuqiyong@icdc.cn

Professor Phil Weinstein
The University of Adelaide
Philip.Weinstein@adelaide.edu.au

Associate Professor Scott Cameron
Discipline of Public Health
The University of Adelaide
scott.cameron@adelaide.edu.au

Dr Alana Hansen
Discipline of Public Health
The University of Adelaide
alana.hansen@adelaide.edu.au
ph. +61 8 8313 1043

Associate Professor Craig Williams
Division of Health Sciences
The University of South Australia
craig.williams@unisa.edu.au

Professor Yehuan Sun
Professor of Epidemiology
School of Public Health
Anhui Medical University

Associate Professor Gil-Soo Han
School of English, Communications and Performance Studies
Monash University
gil-soo.han@monash.edu.au

中国气候变化引起新发和再发传染病的公共卫生影响及能力建设研究

研究目的

本次研究的目的是调查中国现今新发和再发媒介传染病的危险因素、气候变化对这些疾病的影响及相关能力的调查与建设。此次研究的传染病主要包括登革热、疟疾和肾综合症出血热。

研究问题

6. 针对中国气候变化，引起新发和再发媒介传染病的主要诱导因素有哪些？
7. 当前中国医院系统对传染病诊断，治疗和管理的效力情况如何？
8. 当前中国医院系统对传染病的预防控制能力如何？以及对传染病监测、管理和预防的能力建设可能存在的障碍有哪些？

资助及研究单位

本研究由澳大利亚政府外交外贸部海外援助项目(http://aid.dfat.gov.au/Pages/home.aspx)资助。参与本研究的合作单位包括澳大利亚阿德莱德大学、南澳大利亚大学、莫纳什大学、安徽医科大学和中国疾病预防控制中心。本项目主要研究负责人列举如下：

研究项目主要负责人

毕鹏
阿德莱德大学
公共卫生学院
环境卫生与流行病学教授
peng.bi@adelaide.edu.au
电话： +61 8 8313 3583

安娜拉・汉森
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环境流行病学博士
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刘起勇
中国疾病预防控制中心
传染病所媒介生物控制室主任
环境与人群健康学教授
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philip.weinstein@adelaide.edu.au

孙业桓
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流行病学教授

斯科特・卡梅隆
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公共卫生学院
环境流行病学副教授
scott.cameron@adelaide.edu.au

吉尔修・韩
莫纳什大学
媒体电影和新闻学院
沟通与媒体学副教授
gil-soo.han@monash.edu.au

您的参与包括以下内容

如果您愿意参加本次调查研究，我们表示由衷的感谢！本次问卷调查大概需要花半小时，问题涉及您或您所在的工作单位对所管辖地区登革热、疟疾、肾综合症出血热的相关知识、处理经验，传染病的危险因素，疾病的预防和控制以及现有疾病监测系统的相关情况。

参与本次调查是完全自愿的，您可以随时退出本次调查或者回答部分您愿意回答的问题，当然我们对您能全程参与表示万分感谢！请注意本次调查研究也许不会对您或者您的工作单位有直接的利益，但研究对提高整个中国公共卫生系统有深远的影响。我们非常希望您能全程参与！

伦理道德委员会许可文件

本次研究已经通过中国疾病预防控制中心传染病预防控制所伦理委员会审批通过（批准文号：ICDC-2013002）,并于阿德莱德大学、安徽医科大学、莫纳什大学和南澳大利亚大学存案。

隐私及保密性

您的所有回答都将严格保密并且您不需要提供任何涉及个人身份的信息。

咨询与投诉
如果您对本次研究项目有任何疑问或者希望能够进一步了解本次研究的相关政策条例以及希望了解更多参与本次调查研究的权益，请联系：

阿德莱德大学人类研究伦理道德委员会秘书处
电话：+ 61 8 8313 6028
网站：http://www.adelaide.edu.au/ethics/human/guidelines/applications/#complaint.

或者

中国疾病预防控制中心
电话：+ 86 10 5890 0240 12320
网站：web@chinacdc.cn

更多信息
首先非常感谢您的参与！如果您对本次调查研究有任何疑问，请联系项目首席科学家：

毕鹏 教授
阿德莱德大学公共卫生学院
电话：+ 61 8 8313 3583
电子邮箱：peng.bi@adelaide.edu.au

或者

安娜拉·汉森 博士
阿德莱德大学公共卫生学院
电话：+ 61 8 8313 1043
电子邮箱：alana.hansen@adelaide.edu.au

Appendix E: Copy of Informed Consent Form

Human Research Ethics Committee (HREC)

CONSENT FORM

1. I have read the attached Information Sheet and agree to take part in the following research project:

Title:	Building capacity to curb the public health impact of emerging and re-emerging infectious disease due to climate change in China
Ethics Approval Number:	HS-2013-052

2. I have had the project, so far as it affects me, fully explained to my satisfaction by the research worker. My consent is given freely.

3. Although I understand that the purpose of this research project is to improve the capacity for public health, it has also been explained that my involvement may not be of any benefit to me.

4. I have been informed that, while information gained during the study may be published, I will not be identified and my personal results will not be divulged.

5. I understand that I am free to withdraw from the project at any time and that this will not affect medical advice in the management of my health, now or in the future.

6. I am aware that I should keep a copy of this Consent Form, when completed, and the attached Information Sheet.

Participant to complete:

Name: ______________________ Signature:_________________________ Date:___________

Researcher/Witness to complete:

I have described the nature of the research to ____
(print name of participant)

and in my opinion she/he understood the explanation.

Signature: ___________________ Position: __________________________ Date:___________

Appendix F: Independent Complaint Form

The University of Adelaide
Human Research Ethics Committee (HREC)

This document is for people who are participants in a research project.

CONTACTS FOR INFORMATION ON PROJECT AND INDEPENDENT COMPLAINTS PROCEDURE

The following study has been reviewed and approved by the University of Adelaide Human Research Ethics Committee:

Project Title:	**Building capacity to curb the public health impact of emerging and re-emerging infectious diseases due to climate change in China**
Approval Number:	**HS-2013-052**

The Human Research Ethics Committee monitors all the research projects which it has approved. The committee considers it important that people participating in approved projects have an independent and confidential reporting mechanism which they can use if they have any worries or complaints about that research.

This research project will be conducted according to the NHMRC National Statement on Ethical Conduct in Human Research (see http://www.nhmrc.gov.au/publications/synopses/e72syn.htm)

1. If you have questions or problems associated with the practical aspects of your participation in the project, or wish to raise a concern or complaint about the project, then you should consult the project co-ordinator:

Name:	**Peng Bi; Michael Xiaoliang Tong**
Phone:	**Australia +61 8 8313 3583; +61 8 8313 3321**

2. If you wish to discuss with independent person matters related to:
   - Making a complaint, or
   - Raising concerns on the conduct of the project, or
   - The University policy on research involving human participants, or
   - Your rights as a participant,

Contact the Human Research Ethics Committee's Secretariat on phone (08) 8303 6028.

Appendix G: Ethical Approval Letter (The University of Adelaide)

THE UNIVERSITY of ADELAIDE

RESEARCH BRANCH
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY

BEVERLEY DOBBS
EXECUTIVE OFFICER
LOW RISK HUMAN RESEARCH ETHICS REVIEW GROUP (FACULTY OF HUMANITIES AND SOCIAL SCIENCES AND FACULTY OF THE PROFESSIONS)
THE UNIVERSITY OF ADELAIDE
SA 5005
AUSTRALIA
TELEPHONE +61 8 8313 4725
FACSIMILE +61 8 8313 7325
email: beverley.dobbs@adelaide.edu.au

24 September 2013

Professor P Bi
School of Discipline of Public Health

Dear Professor Bi

ETHICS APPROVAL No: HS-2013-052
PROJECT TITLE: Building capacity to curb the public health impact of emerging and re-emerging infectious diseases due to climate change in China

I write to advise that the Low Risk Human Research Ethics Review Group (Faculty of Health Sciences) has approved the above project. The ethics expiry date for this project is **30 September 2016**.

Ethics approval is granted for three years subject to satisfactory annual progress and completion reporting. The form titled *Project Status Report* is to be used when reporting annual progress and project completion and can be downloaded at http://www.adelaide.edu.au/ethics/human/guidelines/reporting. On expiry, ethics approval may be extended for a further period.

Participants in the study are to be given a copy of the Information Sheet and the signed Consent Form to retain. It is also a condition of approval that you **immediately report** anything which might warrant review of ethical approval including:

- serious or unexpected adverse effects on participants,
- previously unforseen events which might affect continued ethical acceptability of the project,
- proposed changes to the protocol; and
- the project is discontinued before the expected date of completion.

Please refer to the following ethics approval document for any additional conditions that may apply to this project.

Yours sincerely

Dr John Semmler
HREC Convenor on behalf of the
Low Risk Human Research Ethics Review Group (Faculty of Health Sciences)

THE UNIVERSITY of ADELAIDE

RESEARCH BRANCH
OFFICE OF RESEARCH ETHICS, COMPLIANCE AND INTEGRITY

BEVERLEY DOBBS
EXECUTIVE OFFICER
LOW RISK HUMAN RESEARCH ETHICS REVIEW GROUP (FACULTY OF HUMANITIES AND SOCIAL SCIENCES AND FACULTY OF THE PROFESSIONS)
THE UNIVERSITY OF ADELAIDE
SA 5005
AUSTRALIA

TELEPHONE +61 8 8313 4725
FACSIMILE +61 8 8313 7325
email: beverley.dobbs@adelaide.edu.au

Applicant: Professor P Bi

School: Discipline of Public Health

Application/RM No: 0000017188

Project Title: **Building capacity to curb the public health impact of emerging and re-emerging infectious diseases due to climate change in China**

Low Risk Human Research Ethics Review Group (Faculty of Health Sciences)

ETHICS APPROVAL No: HS-2013-052

APPROVED for the period: 24 Sep 2013 to 30 Sep 2016

Thank you for the revisions emailed 19 September, 2013. The details of the local independent complaints contacts are to be added to the participant information sheets.

Dr John Semmler
HREC Convenor on behalf of the
Low Risk Human Research Ethics Review Group (Faculty of Health Sciences)

Appendix H: Ethical Approval Letter (Monash University)

MONASH University

Monash University Human Research Ethics Committee (MUHREC)
Research Office

Human Ethics Certificate of Approval

This is to certify that the project below was considered by the Chair of the Monash University Human Research Ethics Committee. The Chair was satisfied that the proposal meets the requirements of the *National Statement on Ethical Conduct in Human Research* and has granted approval.

Project Number:	**CF13/3263 - 2013001642**	
Project Title:	**Building capacity to curb the public health impact of emerging and re-emerging infectious diseases due to climate change in China**	
Chief Investigator:	**Assoc Prof Gil-Soo Han**	
Approved:	**From: 30 October 2013**	**To: 30 October 2018**

Terms of approval - ***Failure to comply with the terms below is in breach of your approval and the Australian Code for the Responsible Conduct of Research.***

1. Approval is only valid whilst you hold a position at Monash University and approval at the primary HREC is current.
2. **Future correspondence:** Please quote the project number and project title above in any further correspondence.
3. **Final report:** A Final Report should be provided at the conclusion of the project. MUHREC should be notified if the project is discontinued before the expected date of completion.
4. **Retention and storage of data:** The Chief Investigator is responsible for the storage and retention of original data pertaining to a project for a minimum period of five years.

Professor Nip Thomson
Chair, MUHREC

cc: Prof Peng Bi

Postal – Monash University, Vic 3800, Australia
Building 3E, Room 111, Clayton Campus, Wellington Road, Clayton
Telephone +61 3 9905 5490 Facsimile +61 3 9905 3831
Email muhrec@monash.edu http://www.monash.edu.au/researchoffice/human/
ABN 12 377 614 012 CRICOS Provider #00008C

Appendix I: Ethical Approval Letter (University of South Australia)

Alana Hansen

From: Craig Williams <Craig.Williams@unisa.edu.au>
Sent: Thursday, 5 December 2013 5:03 PM
To: Alana Hansen; Peng Bi; Philip Weinstein
Subject: Fwd: Human Ethics: Application approved

FYI - final HREC approval at UniSA

Begin forwarded message:

From: "no_reply@unisa.edu.au" <no_reply@unisa.edu.au>
Date: 5 December 2013 4:44:33 PM ACDT
To: Craig Williams <Craig.Williams@unisa.edu.au>, Research Ethics <ethics@unisa.edu.au>
Subject: Human Ethics: Application approved

Dear Applicant

Re: Ethics protocol "Building capacity to curb the public health impact of emerging and re-emerging
infectious diseases due to climate change in China" (Application ID: 0000032268)

Thank you for submitting your ethics protocol for consideration. Your protocol has been considered by the E1 Committee Review Group.

I am pleased to advise that your protocol has been granted ethics approval and meets the requirements of the National Statement on Ethical Conduct in Human Research. Please note that the E1 Committee Review Group's decision will be reported to the next meeting of the Human Research Ethics Committee for endorsement.

Please regard this email as formal notification of approval.

Ethics approval is always made on the basis of a number of conditions detailed at http://www.unisa.edu.au/res/forms/docs/humanresearchethics_conditions.doc; it is important that you are familiar with, and abide by, these conditions. It is also essential that you conduct all research according to UniSA guidelines, which can be found at http://www.unisa.edu.au/res/ethics/default.asp

Please note, if your project is a clinical trial you are required to register it in a publicly accessible trials registry prior to enrolment of the first participant (e.g. Australian New Zealand Clinical Trials Registry http://www.anzctr.org.au/) as a condition of ethics approval.

Best wishes for your research.

Executive Officer
UniSA's Human Research Ethics Committee
CRICOS provider number 00121B

Appendix J: Ethical Approval Letter (China National CDC)

中国疾病预防控制中心传染病预防控制所

伦理审查委员会批准通知书

NATIONAL INSTITUTE FOR COMMUNICABLE DISEASE CONTROL AND PREVENTION CHINESE CENTER FOR DISEASE CONTROL AND PREVENTION

ETHICAL COMMITTEE APPROVAL NOTICE

NO：ICDC-2013002

PRINCIPAL INVESTIGATOR OF PROJECT: BI Peng Co-PI: LIU Qiyong

TITLE OF PROJECT: Building capacity to curb the public health impact of emerging and re-emerging infectious disease due to climate change in China

PROJECT DURATION: FROM 24 Sep 2013 TO 30 Sep 2016

DEPARTMENT/DIVISION: Department of Vector Biology and Control

FUNDING AGENCY: the Australian Government's overseas AID program AusAID(http://www.ausaid.gov.au/)

DATE SUBMITTED: 22 Nov 2013

DATE APPROVED: 27 Nov 2013

The project entitled " Building capacity to curb the public health impact of emerging and re-emerging infectious disease due to climate change in China ", submitted by investigator Dr. Liu Qiyong, Department of Vector Biology and Control, has been approved by the meeting of ethics committee of national institute for communicable disease control and prevention, China CDC, according to Chinese ethics laws and regulations. It is recognized that the right and the welfare of the subject are adequately protected. The Investigator should submit summaries of investigation to the ethics committee annually.

SIGNATURE

LU Jinxing

Deputy Director,

Department of Science, Technology and Education (substitute),

National Institute for communicable disease control and prevention,

China CDC

27 November 27, 2013

Appendix K: Ethical Approval Letter (Anhui Medical University)

编号： 2013007

安徽医科大学生物医学伦理委员会
课题论证报告
（正　本）

课 题 负 责 人：孙业桓（Yehuan Sun）

课　题　名　称：Building capacity to curb the public health impact of emerging and reemerging infectious diseases due to climate change in China

承　担　单　位：安徽医科大学

一、伦理委员会对该课题方案进行了论证，并特别对以下三方面进行了认真讨论：
1、研究对象的权利与利益；
2、确保取得知情同意的措施；
3、存在的危险与可能的受益。

二、同意实施该课题方案。实施过程中请使用经论证的知情同意书、问卷、说明信等材料。

三、课题方案如需修改，须事先经伦理委员会论证方可实施，修改内容及其原因需详细备案。

四、实施过程中如出现任何不良反应需立即向伦理委员会做出书面报告。

主席姓名：朱启星　　签　字：

生效日期：2013 年 10 月 17 日

安徽医科大学生物医学伦理委员会

Building capacity to curb the public health impact of emerging and reemerging infectious diseases due to climate change in China 负责人：

该课题伦理审查申请表、项目方案及其它伦理审批材料，已经由全会审查的方式审议通过，现批准该方案在项目正式实施之日起一年内有效。如果此课题进展过程中发生了不良事件需及时报告，研究计划有变更需要提交伦理委员会批准，若需继续开展或滚动开展此课题，请在本次审批有效期结束前 4 到 8 周重新申请审批。

安徽医科大学生物医学伦理委员会

2013 年 10 月 17 日