China's sustained drive to eliminate neglected tropical diseases

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Non-communicable diseases dominate the public health arena in China, yet neglected tropical diseases (NTDs) are still widespread and create a substantial burden. We review the geographical distribution, prevalence, and epidemic characteristics of NTDs identified in China caused by helminths, protozoa, bacteria, and viruses. Lymphatic filariasis was eliminated in 2007, but schistosomiasis still affects up to 5% of local village residents in some endemic counties with around 300 000 people infected. China harbours more than 90% of the world's burden of alveolar echinococcosis and food-borne zoonoses are emerging. In 2010, the overall prevalence of soil-transmitted helminth infections caused by *Ascaris lumbricoides*, *Trichuris trichiura*, and hookworm was 11·4%, with 6·8% of these infections caused by *A lumbricoides*. Corresponding figures for food-borne trematodiasis, echinococcosis, and cysticercosis are more than 5%. Dengue, leishmaniasis, leprosy, rabies, and trachoma exist in many areas and should not be overlooked. Transmission of vector-borne diseases can be interrupted; nevertheless, epidemics occur in remote areas, creating a challenge for surveillance and control. Rigorous surveillance, followed by immediate and integrated response packages tailored to specific social and ecological systems, is essential for progress towards the elimination of NTDs in China.

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Introduction

Age-specific and sex-specific mortality rates in China declined by 11–71% between 1990 and 2010. A notable shift has occurred in the most common causes of hospital admissions, from communicable diseases to cancer and accidents. Eight of the top ten causes of death and disability are attributable to non-communicable diseases (NCDs) according to the disability-adjusted life-year (DALY) metrics.[1] Nevertheless, infections grouped under the term neglected tropical diseases (NTDs) still play an important part, especially because they are intimately connected with poverty.[2,3] WHO lists 17 NTDs, which are mainly parasitic worm (helminth) infections, such as lymphatic filariasis, schistosomiasis, and soil-transmitted helminthiasis.[4]

NTDs in China constitute an unacceptably high burden of disease despite recent positive changes.[5] Some NTDs are emerging or are re-emerging,[6] even though efforts to combat these infections along with social and economic developments have been implemented.[7–9] As a result, NTDs need to be contained at an early stage to further improve health and alleviate poverty in marginalised communities in China. Progress in NTD control and elimination not only depends on resource allocation and priority setting, but likewise on the understanding that any activity directed towards both disease control and elimination needs to recognise the social and ecological contexts.[10,11] Timely detection of transmission, documentation, evidence-based decisions, and interventions suited for local social and ecological systems are key to the effective control and elimination of NTDs.[11,12]

In this Review we assess the epidemiology and control of 14 selected NTDs, which are either listed by WHO or deemed to be of particular concern in China, and discuss the development of prevention and control strategies and guidance aimed at their elimination.

Overview of NTDs in China

Table 1 provides an overview of causative agents, main drivers of transmission, geographical distributions, and the number of people infected by NTDs in China. NTDs have been grouped into four classes dependent on the stage of control achieved (table 2). Lymphatic filariasis is the only NTD in the post-elimination phase with continuing rigorous surveillance.[26] Schistosomiasis, leishmaniasis, leprosy, rabies, and trachoma are regarded as in the pre-elimination phase, with targets set for their elimination by 2020.[8,30,42,43] Soil-transmitted helminthiasis, cysticercosis and taeniasis are regarded as under control.[8] By contrast, the remaining NTDs discussed in this Review are highly endemic in some areas. Transmission is ongoing and signs suggest emergence or re-emergence for many of the food-borne parasitic zoonoses, echinococcosis, and dengue.[21,40,44]

For NTDs whose transmission is strongly linked to the environment (eg, schistosomiasis and echinococcosis), an integrated, multisectoral approach is necessary to

Key messages

- Detailed data for the distribution of neglected tropical diseases (NTDs) in China are not available. A focus on disease mapping, spatiotemporal predictions of transmission dynamics, and assessment of disease burden will eventually provide specific data that are needed for effective control and elimination programmes in all parts of the country.
- Remotely sensed information gained from instruments onboard satellites, combined with geographical information systems, can be used to produce maps visualising large epidemiological datasets, and predict prevalences and future trends of NTDs. Improved diagnostics for low transmission settings will increasingly be needed. Present control and elimination activities are successful in decreasing transmission. Improved diagnostic approaches form an essential component of the effective surveillance–response systems.
- Progress in control and elimination of NTDs will not only depend on resource allocation and priority setting, but also on the understanding that the development of health information systems will have a pivotal role.
- Timely information, for evidence-based decisions and interventions, should aim to support resource allocation and strengthen the entire health system rather than focus solely on individual diseases.
- Research linking health information systems with cross-cutting themes, such as multiparasitism and comorbidity, social sciences, and capacity strengthening, need to complement current control and elimination programmes.

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achieve elimination.[24,45,46] Continuous improvements in living standards, placing an emphasis on access to clean water, adequate sanitation, and greater hygiene, will effectively contribute to the reduction of NTDs when transmission is mainly governed by social and cultural factors (eg, soil-transmitted helminthiasis).[47,48] Because the spread of many NTDs are associated with inter-related social and cultural factors and individual behaviour (eg, food-borne trematodiasis, cysticercosis, and angiostrongyliasis), the information, education, and communication (IEC) strategies and surveillance-response approaches tailored to a given setting are of utmost importance. In China, the concept of health education has now been extended to IECs to meet the challenges of working with new technologies and knowledge management in different social and economic strata of a population.

A map based on the most recent national NTD survey in 2004 (figure 1) shows areas where several NTDs coexist. For example, in the provinces of Xinjiang, Gansu, Yunnan, and Sichuan, five to six NTDs are co-endemic. Soil-transmitted helminthiasis and echinococcosis occur in overlapping foci in all provinces, showing that NTDs remain a major public health issue in China.[40]

NTDs caused by helminth infections

Lymphatic filariasis

16 Chinese provinces, municipalities, and autonomous regions were affected by lymphatic filariasis half a century ago, with the disease threatening a population of 31 million.[49] Since then, an extensive programme based on mass drug administration (MDA) with diethyl-carbamazine, followed up by meticulous post-MDA surveillance, has been undertaken.[50] China was the first country worldwide to eliminate lymphatic filariasis as a public health problem, verified by WHO in 2007,[51] and has sustained this status even though occasional imported cases are identified and immediately

	Causative agent	Number of people infected (year)	Prevalence in endemic areas (%)	Geographical distribution in China	Main drivers of transmission
Soil-transmitted helminths					
Ascariasis[13,14]	*Ascaris lumbricoides*	85·4 million (2010)	6·8	Throughout	Lack of sanitation, use of night soil*, and consumption of unwashed, contaminated vegetables and fruits
Hookworm disease[14,15]	*Ancylostoma duodenale* and *Necator americanus*	46·6 million (2010)	3·7	Mainly south and west	Lack of sanitation, use of night soil, and contact with contaminated soil
Trichuriasis[14,15]	*Trichuris trichiura*	22·1 million (2010)	1·8	Mainly central and eastern regions	Lack of sanitation, use of night soil, and consumption of unwashed, contaminated vegetables and fruits
Schistosome					
Schistosomiasis[16]	*Schistosoma japonicum*	286 800 (2011)	0·14	Seven provinces along and south of the Yangtze valley	Contact with water containing *S japonicum* cercaria
Food-borne trematodes					
Clonorchiasis[15,17]	*Clonorchis sinensis*	12·5 million (2004)	2·4	26 provinces	Consumption of raw or undercooked freshwater fish
Paragonimiasis[15]	*Paragonimus* spp	3 million (2004)	1·7	24 provinces	Consumption of raw or undercooked freshwater crabs
Fascioliasis[18,19]	*Fasciola gigantica* and *Fasciola hepatica*	No data available	No data available	Mainly in the south	Consumption of undercooked freshwater plants and contaminated water
Cysticercosis/taeniasis[15]	*Taenia solium*, *Taenia saginata*, and *Taenia asiatica*	7·0 million (cysticercosis) 0·55 million (taeniasis) (2004)	0·58 (cysticercosis) 0·28 (taeniasis)	29 provinces, particularly in the west	Consumption of undercooked contaminated beef or pork
Echinococcosis[15]	*Echinococcus granulosus* and *Echinococcus multilocularis*	0·38 million (2004)	1·08	West China	Contact with livestock or consumption of contaminated vegetables or water
Protozoal infections					
Visceral leishmaniasis[20]	*Leishmania donovani* and *Leishmania infantum*	402 new cases (2010)	No data available	Six provinces north of Yangtze valley	Sandfly bites
Bacterial infections					
Trachoma[21]	*Chlamydia trachomatis*	No data available	No data available	Throughout	Eye contact with contaminated water or dirty hands
Leprosy[22]	*Mycobacterium leprae*	6032 (2010)	<0·001	Throughout, especially in the south	Contact with individuals with leprosy
Viral infections					
Dengue[23,24]	Dengue virus serotypes 1–4	120 new cases (2011)	No data available	South	High density of aedes mosquitoes, frequency of travel to transmission areas
Rabies[25]	Lyssavirus Rhabdoviridae	1917 new cases (2011)	No data available	Throughout	Dog bite (dependent on site of bite and wound depth, treatment, and delayed immunity)

* Night soil is the application of fresh faeces from human beings as fertiliser in agriculture.

Table 1: **Key neglected tropical diseases in China**

managed.[52,53] However, many NTDs result in long-term morbidity that can progress even after successful interruption of transmission. An estimated 400 000 patients with lymphatic filariasis with post-transmission lesions remain in areas where the disease once was endemic. As a result, 562 medical care centres were established in 2009 to provide disease management and care.

Soil-transmitted helminthiasis

Soil-transmitted helminthiasis is caused by a chronic infection most often from the roundworm (*Ascaris lumbricoides*), whipworm (*Trichuris trichiura*), and the hookworms (*Ancylostoma duodenale* and *Necator americanus*).[54] Threadworm (*Strongyloides stercoralis*) belongs to the soil-transmitted helminths too and is endemic in China.[55,56] Strongyloidiasis will not be discussed in further detail because of the paucity of epidemiological data. The second national survey of parasitic diseases, conducted from 2001 to 2004, reported an overall soil-transmitted helminth infection prevalence of 19·6%, with *A lumbricoides* as the most common type of infection (85·4 million people).[13,15] Model-based estimates derived from more than 1100 geo-referenced survey data points that were collected between 2000 and 2013, showed an overall prevalence of soil-transmitted helminth infections as 11·4% in 2010.[14,15]

Chronic soil-transmitted helminth infections are widely believed to be associated with malnutrition and iron-deficiency anaemia, thus negatively affecting the physical and cognitive development of children.[35,57,58] The endemicity of soil-transmitted helminthiasis has therefore been proposed as an indicator of overall child development. As a result, regular deworming of school-

	WHO goal(s)	Chinese national programme goals	Control measures
Post-elimination			
Lymphatic filariasis[26,27]	Eliminate lymphatic filariasis globally by 2020	Announced elimination of lymphatic filariasis as public health problem in 2007 (achieved)	Care for post-transmission patients, and surveillance and control of imported cases
Pre-elimination			
Schistosomiasis[8,28]	Eliminate schistosomiasis in the Americas and the western Pacific region by 2020	Elimination as public health problem by 2015 (outline of mid-term and long-term national programme on control and prevention of schistosomiasis in 2004–15)	Enhanced surveillance, establishment of 80 monitoring sites, use of sentinel mice* in selected areas, snail control, improved sanitation and water supply, and free treatment
Leishmaniasis[8,29]	Regional elimination of visceral leishmaniasis (Indian subcontinent) by 2020	Achieve very low transmission by 2015 (National Control Programme of Key Parasitic Diseases in 2006–15)	Control of vectors and sources of infection, IEC, screening of high-risk populations, and provision of treatment
Leprosy[8,30,31]	Global elimination of leprosy by 2020	Achieve elimination by 2020 (National Implementation Plan to Eliminate Leprosy as a Social Problem in 2011–20)	IEC and establishment of an integrated, efficient system for surveillance and control
Rabies[8,25,32,33]	Elimination of rabies in Latin America by 2015 and in southeast Asia and the western Pacific region by 2020	Elimination of human rabies by 2020	Public education, pet vaccination programmes, elimination of stray animals, and enhanced post-exposure management
Trachoma[8,21,34]	Global elimination of trachoma by 2020	Achieve elimination of blinding trachoma by 2016 (National Blinding Trachoma Elimination Programme, National Programme to Control and Cure Blindness in 2012–15)	IEC, improved sanitation and water supply, and treat patients
Under control			
Soil-transmitted helminthiasis[6,8,35]	Regular treatment of 75% of school-aged children (<16 years old), 75% coverage achieved in all endemic countries	Reduction of the burden by at least 40% by 2015 (National Control Programme of Key Parasitic Diseases in 2006–15)	Drug administration, IEC, and improved sanitation in some regions
Cysticercosis/ taeniasis[8,36,37]	Interventions scaled up in selected countries for control and elimination of *Taenia solium* and taeniasis/cysticercosis	Achieve under control status (National Control Programme of Key Parasitic Diseases in 2006–15)	Drug administration, IEC, toilet amelioration, and quarantine livestock
Transmission			
Food-borne parasitic zoonoses[8,38,39]	75% of population at risk reached by preventive chemotherapy, morbidity caused by FBT controlled in all endemic countries	Reduction of prevalence for clonorchiasis in highly endemic areas by 50% by 2015 (National Control Programme of Key Parasitic Diseases in 2006–15)	Keep people and pets away from water and raw or undercooked food, and kitchenware should be well sanitised
Echinococcosis[8,40]	Validated strategy available for both echinococcosis and hydatidosis, and interventions scaled up in selected countries for their control and elimination	Reduction of the infection rate in children by 60% by 2015 (Action Plan to Prevent and Cure Echinococcosis 2010–15)	Control infection sources and intermediate hosts, IEC, patients' management, improved sanitation and water supply, and surveillance
Dengue[8,41]	Number of cases reduced by more than 25% (2009–10 as baseline) and deaths by 50%	Reduction of incidence by at least 20% for 2013–15 average by comparison with 2010–2012 (The Dengue Strategic Plan for the Asia Pacific Region 2008–15)	Enhanced surveillance and quarantine, and control vectors, and cooperation with neighbouring countries

IEC=information, education, and communication strategies. FBT=food-borne parasitic trematodes. *Mice not infected but exposed to water suspected to contain infective schistosome cercariae.

Table 2: **Control and elimination measures and programmes for neglected tropical diseases in China**

aged children (<16 years old) has been embraced as the worldwide strategy against soil-transmitted helminthiasis.[4] However, a 2012 systematic review and meta-analysis noted only a small or no benefit of regular deworming on children's weight, haemoglobin levels, cognition, school attendance, and school performance.[59] Farmers have the highest infection prevalence of hookworm, attributed to the use of night soil—the application of fresh faeces from human beings as fertiliser in agriculture. The prevalence of hookworm increases with age, peaking in people aged around 60 years,[15,60] whereas the peak prevalence of *A lumbricoides* and *T trichiura* is usually in school-aged children and adolescents.[13,15]

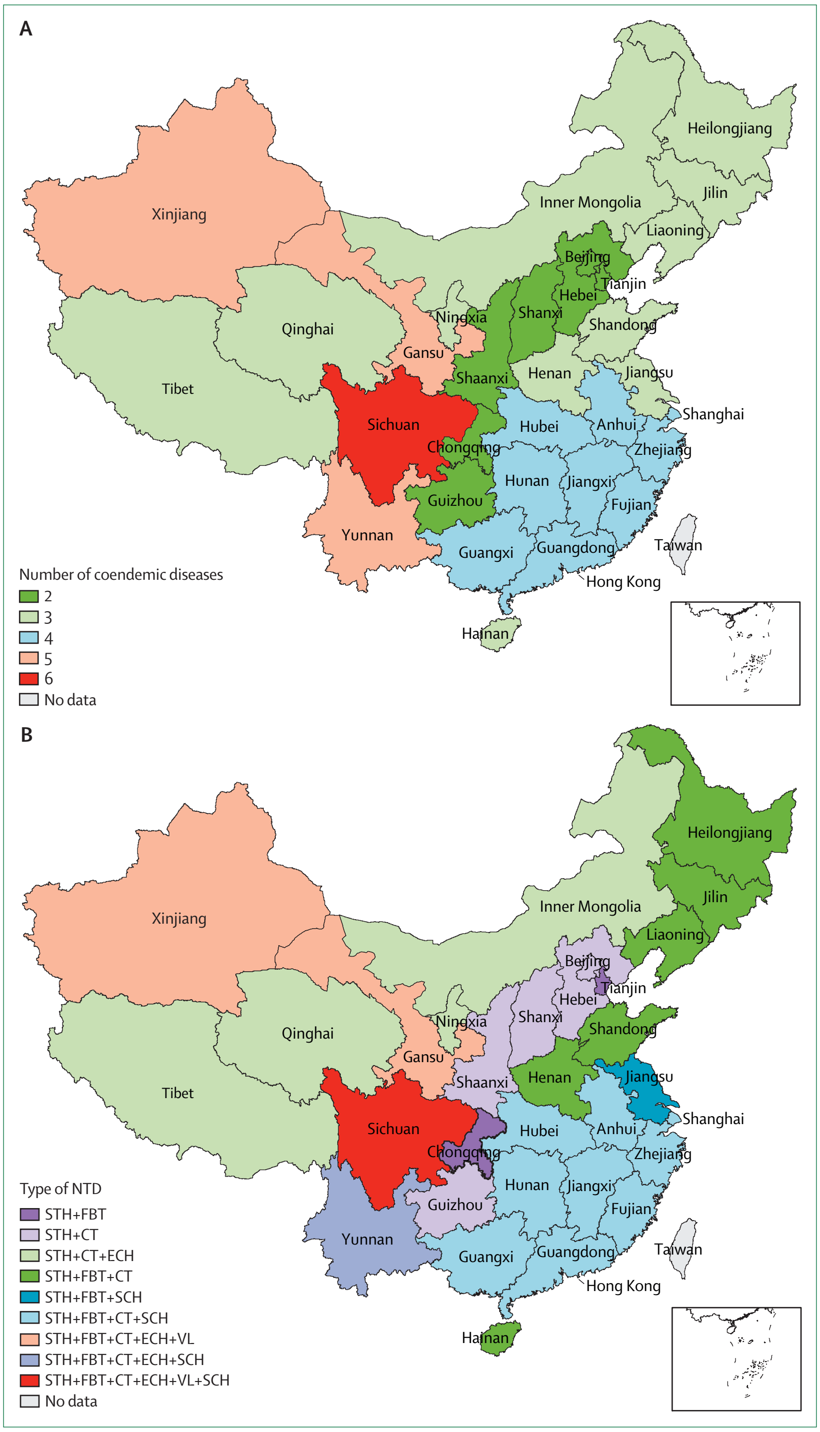

***Figure 1*: Overlapping distributions of neglected tropical diseases in China at provincial level**
(A) Number of endemic neglected tropical diseases (NTDs) in each province. (B) Disease-specific endemicities. Inset shows the South China Sea. Data derived from the second National Survey of human parasitic diseases in 2004.[15] STH=soil-transmitted helminthiasis (ascariasis, hookworm disease, and trichuriasis). CT=cysticercosis and taeniasis. FBT=food-borne parasitic zoonosis (clonorchiasis, paragonimiasis, trichinellosis, toxoplasmosis). ECH=echinococcosis. SCH=schistosomiasis. VL=visceral leishmaniasis.

The Ministry of Health has established 22 surveillance sites for soil-transmitted helminthiasis.[8] Endemicity is stratified into three prevalence ranges: less than 5%, 5–20%, and more than 20%. The declared aim for 2015 is to decrease these infection rates by 60% for the lowest prevalence group, 70% for the intermediate prevalence group, and 80% for the highest prevalence group, by use of data from the second national survey of parasitic diseases as a benchmark.[8]

Schistosomiasis

Although schistosomiasis is neglected at the global level, this problem is not the situation in China.[61] Political will, coupled with financial, human, and technical resources, has successfully controlled schistosomiasis in most parts of the country.[61–64] The number of people infected with *Schistosoma japonicum* decreased from an estimated 11·6 million in 12 provinces, municipalities, and autonomous regions in the mid-1950s to an all-time low of 286 800 in seven provinces in 2011 (figure 2).[16] Review of the national surveillance data over the past 15 years shows that the areas infested by *Oncomelania hupensis,* the intermediate

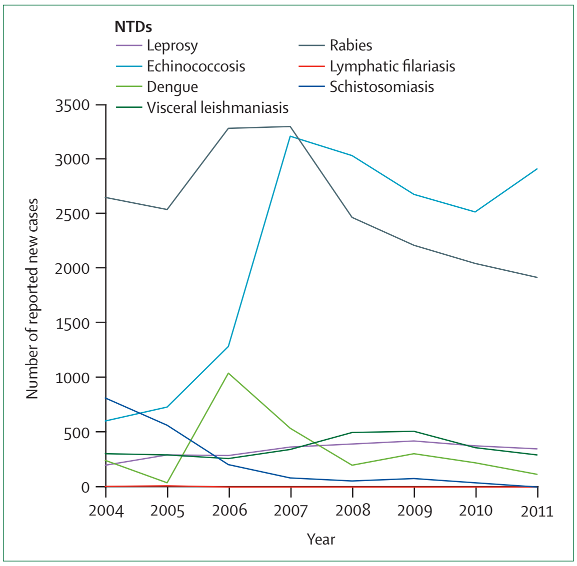

***Figure 2*: Annual reported new cases of leprosy, echinococcosis, dengue, visceral leishmaniasis, rabies, lymphatic filariasis, and schistosomiasis from 2004 to 2011 in China**

host snail of *S japonicum*, has increased, particularly in 2002–04, and presently have stabilised to around 3720 km².[16] Fluctuation, even resurgence of the national disease burden, was noted after completion of the World Bank loan project on schistosomiasis control in 2002,[65] resulting in the calls for new research to better understand the patterns of disease transmission. Bovines were found to account for 75–90% of the transmission of schistosomiasis.[66] Restriction of the grazing of cattle and water buffaloes to fenced areas, the mechanisation of agriculture and other control measures (ie, improving of water supply, sanitation, IEC, and snail control) were highly effective.[67,68] China continues to invest substantially in control activities with the aim to eliminate schistosomiasis by 2020 because of the serious consequences of this infection, both economically and in terms of the public health burden. After the infection rate in all endemic counties in 2008 decreased to less than 5%,[16,67] the goal was altered to reduce this further to less than 1% by 2015.[28] With the continued support from the Chinese Government and enhanced inter-sector cooperation, the goal of interruption of schistosomiasis transmission by 2020 might now be achieved.

Food-borne parasitic zoonoses

Numerous trematodes (eg, clonorchis, fasciola, fasciolopsis, and paragonimus), nematodes (eg, angiostrongylus and trichinella), and cestodes (eg, echinococcus and taenia) are known sources of infection when raw food (ie, meat, freshwater fish, crabs, snail, or freshwater plants) is ingested.[69–71] Although common in China, infections with parasitic worms via food did not receive sufficient attention until recently.[36] Common risk factors for food-borne parasitic zoonoses are associated with deeply rooted traditional food preparation and low sanitation levels.[44,72] People have kept their traditional lifestyles despite the economic development.

Local outbreaks of angiostrongyliasis have occurred in Yunnan province, where the disease was previously unknown,[73] and the number of people affected by food-borne helminths in urban settings has increased. In a random sample of 200 cases of cysticercosis, almost half came from urban areas, whereas most patients with the infection had an occupational history as a farmer.[74] Data from the second national survey showed that it is not unusual that so-called white-collar staff, such as office workers and teachers, have a high prevalence of either clonorchiasis, cysticercosis, or paragonimiasis,[15] again emphasising social and cultural fixations. Food-borne parasitoses have expanded from relatively limited foci in specific geographical regions to become more dispersed. For instance, cysticercosis was previously concentrated in the northern and central parts of the country, but surveys in 2010 showed high rates of infection in the southern provinces (eg, Fujian and Yunnan).[37]

To combat food-borne zoonoses, the Ministry of Health emphasises an integrated control strategy that includes chemotherapy, IEC materials, and the safe disposal of night soil.[8]

Food-borne trematodiasis

Food-borne trematodiasis include the liver flukes (*Clonorchis sinensis* and *Fasciola* spp), lung flukes (*Paragonimus westermani* and *Paragonimus skrjabini*), and intestinal flukes (eg, *Fasciolopsis buski*).[72,75,76] Such infections account for the largest burden of food-borne parasitic zoonoses; 80% of the 15·3 million cases of *C sinensis* worldwide are concentrated in China.[15,75] The disability weights assigned to *C sinensis* infection, on a scale from 0 (perfect health) to 1 (death), are 0·10 in male individuals and 0·05 in female individuals.[76,77] Morbidity at the national level due to *C sinensis* infection was shown to have risen by 75% from the first national survey (completed in 1992) to the second survey (completed in 2004).[6] In Guangdong, the average prevalence of *C sinensis* infection in the reservoir hosts of cats was 41·8% and dogs was 20·5% in 2008.[78] Apart from the aforementioned risk factors, low educational attainment and a lack of appropriate sanitation are associated with a higher probability of infection with food-borne trematodes.[79]

From the first report of human fascioliasis in Hubei in 1986,[80] with an infection rate of 0·01% from *Fasciola hepatica* and an infection rate of 0·0006% from *Fasciola gigantica*,[18] the number of outbreaks has substantially increased. Fascioliasis was recorded in Yunnan with 15 reported cases of *F hepatica* in 2005, and 29 cases of *F gigantica* in 2012.[19,81,82] In Guangxi, 53·5% of buffaloes and 50·5% of cattle examined were affected in 2006 by fascioliasis.[83] Predictive risk mapping is limited, and hence, a new national survey is warranted to identify high-risk areas and establish an efficient surveillance system.

Taeniasis and cysticercosis

Taeniasis and cysticercosis constitute a large disease burden for people and domestic animals. According to the two national surveys, the prevalence rate of taeniasis increased from 0·18% in 1992 to 0·28% in 2004, as did the prevalence rate of cysticercosis from 0·011% in 1992 to 0·58% in 2004.[37] The biggest increase of *Taenia* spp infections were reported in the Sichuan and Tibet provinces.[15] Middle-aged populations (eg, age 45–50 years) have the highest prevalence of *Taenia* spp infections and might harbour up to a third of all these infections.[15]

The incidence of cysticercosis is closely correlated to faeces management in relation to pig-rearing activities.[84] Studies in Heilongjiang, Jilin, Liaoning, and Inner Mongolia in 1990 showed that economic losses from pig cysticercosis were as high as CNY 330 million (about US $53 million).[85] Integrated control measures, such as regular deworming, IEC campaigns, improved sanitation, and regular meat inspections are now also advocated for remote rural areas.[8] A validated strategy ought to urgently be established if the stated goals of control of taeniasis and cysticercosis by 2015 and their elimination by 2020 are to be achieved.

Echinococcosis

About 90% of all cases of echinococcosis in China are cystic echinococcosis caused by *Echinococcus granulosus*, whereas the remainder are from alveolar echinococcosis, which is caused by *Echinococcus multilocularis* and produces more severe pathological changes.[84,86] The occurrence of alveolar echinococcosis in China accounts for more than 90% of the total global burden.[87] The highest prevalence is in the Qinghai-Tibet plateau. Cases of echinococcosis from Xinjiang, Sichuan, Qinghai, Gansu, Ningxia, and Inner Mongolia amount to 98·2% of the total number reported in China.[15] The cases of infections in people mostly occur in the poor, pastoral minority populations.[84] In the reservoir hosts, the highest infection rates occurred in dogs (19·6%), and then sheep (5·7%).[88] From the increasing transportation of livestock products, echinococcosis has spread from pastoral regions into agricultural regions.[89] Moreover, the ecology of the endemic areas of echinococcosis has changed and the risk of transmission of the disease has increased.[90,91] To effectively reduce the burden of echinococcosis, an integrated control approach has been launched, consisting of treatment for patients and dogs, IEC strategies, and improved slaughter management. The goal for 2015 is to reduce the infection rate in children by 60% compared with 2005.[8]

Other food-borne NTDs

Angiostrongylus cantonensis, although not included in WHO's list of 17 NTDs, is an emerging disease, particularly in China.[73,92] Infections are transmitted through the consumption of raw snails (generally *Pomacea canaliculata* and *Achatina fulica*), uncooked vegetables, or contaminated paratenic hosts. Between 1994 and 2003, 84 cases of angiostrongyliasis were reported in China.[93] In 2006, a major outbreak of 160 cases occurred in Beijing, leading to the disease being reported by the national and international media.[94] In response, 19 sentinel sites have been established and the national angiostrongyliasis control programme emphasises the need for rigorous surveillance.[95]

NTDs caused by protozoal infections

Leishmaniasis

Visceral leishmaniasis, listed as one of the notifiable diseases in China, is transmitted by the sandfly vector *Phlebotomus* spp. The disease used to be common in areas north of the Yangtze river.[20] The national control programme, launched in the 1950s, eliminated the disease in most endemic regions.[42] The number of endemic provinces, autonomous regions, and municipalities has likewise decreased from 16 to three (Xinjiang, Gansu, and Sichuan), all situated in the western part of China where cases of visceral leishmaniasis occur sporadically.[15] On the basis of the source of infection, characteristics, and ecosystem, two epidemiological types of visceral leishmaniasis can be distinguished in China: first, the anthroponotic type caused by *Leishmania donovani* with peridomestic *Phlebotomus longiductus* as the vector, and secondly, the zoonotic type caused by *Leishmania infantum* with *Phlebotomus chinensis* as its vector.[20] Between 2005 and 2010, 2450 cases of visceral leishmaniasis were reported in China and of these, 226 were from 118 non-endemic counties within 16 provinces.[20] Infants and young children are at the highest risk and male individuals are usually infected more than female individuals.[42]

Several interconnected factors might explain why the disease has gained importance in the western part of China: dogs, the most important reservoir of zoonotic type, have high infection rates and their numbers have increased from 2002;[96] a growing human population mobility;[29] and the increased spells of warm weather have extended the activity of the sandfly vector.[97] All these factors bring new challenges, although the elimination of visceral leishmaniasis was previously deemed successful in the central region of China in the 1960s.[42] Compared with other NTDs, the control of leishmaniasis in China is lagging behind.[20] Several sentinel sites in high-risk regions in western China have been established to monitor vector density, human case distributions, treatment or elimination of infected dogs, and the ban on keeping dogs, which is regarded as an initial essential package for a surveillance-response system for leishmaniasis control and elimination.[8]

NTDs caused by bacterial infections

Trachoma

The total number of active trachoma cases (caused by the obligate intracellular bacterium *Chlamydia trachomatis*) in China was about 26 million in 2003.[98] Although trachoma is no longer the principal cause of preventable blindness worldwide,[99] this bacterial infection remains an important cause in different parts of China, with a strongly varying morbidity rate between 0·1% and 48·2% in Shanghai, Inner Mongolia, and Hubei.[100–102] Public prevention and IEC strategies constitute the most effective ways to prevent trachoma infections.[102] In 1997, WHO and the International Agency for the Prevention of Blindness (IAPB) put forward the scheme Global Elimination of Trachoma by the year 2020.[103] The corresponding Chinese national programme, National Blindness Prevention and Treatment, was instituted by the central government for a 5 year period starting in 2006, and followed up for another 4 years (from 2012 onwards) with the goal of elimination of blinding trachoma by the end of 2015.[21,103,104]

In line with WHO's SAFE (surgery, antibiotic mass treatment, facial cleanliness, and environmental improvement) strategy,[21,103] a third phase of the National

Blinding Trachoma Elimination Programme was started in 2013. The intervention target of the programme is the elimination of blinding trachoma as a public health problem by 2016, starting with the reduction of the active trachoma prevalence rate to less than 5% in children aged 1 to 9 years.[34]

Leprosy

A few decades ago leprosy was widely distributed in China, and a large amount of disability resulting from infection with *Mycobacterium leprae* still exists. For instance, the ratio of detection for new cases of people with a disability in 2010, was 29% in the eastern part of the country.[22] After the introduction of multidrug therapy in 1982, drug coverage increased from less than 81% before 1989 to 99% in 1998[31,105] and reached 100% in 2010.[30] Data from national leprosy surveillance showed 6032 registered cases of leprosy at the end of 2010, with a rate of 0·045 per 10 000 inhabitants (figure 2).[22] Among the registered cases, 1324 were new.[106] The overall incidence of new leprosy cases has dropped from 0·56 per 10 000 people in 1958 to 0·01 per 10 000 in 2010.[107] More than 20% of new cases are patients with grade 2 disability, which is classed as a patient having either a visible disability or damage to their hands or feet, or a severe visual impairment to the eyes (vision 6/60), and 120 000 people live with some disability.[108] However, by the end of 2005, China reached the target of less than one case per 10 000 people (ie, WHO criterion for elimination of leprosy as a public health problem) in 27 of 31 provinces and in 89·6% of all counties.[107] At a county level, the rate is higher than this threshold in some parts of Sichuan, Yunnan, Guizhou, Tibet, and Hunan provinces.[22] These discrepancies suggest the need for continued strengthening of the health system, including rigorous surveillance, IEC strategies, early diagnosis, and effective multidrug therapy treatment.[109] The aim is to reach the criteria of elimination at the county level, therefore reducing the number of cases to less than 3300 by 2020, and cases of grade 2 disability in high-endemicity areas to less than 23%.[108]

NTDs caused by viral infections

Dengue

Dengue is one of the most strongly emerging NTDs worldwide with presently no available drugs or vaccines. All four virus serotypes of dengue fever are prevalent in China with the first epidemic recorded in Guangdong in 1978.[110] Subsequently, a series of dengue outbreaks were reported from the provinces of Hainan, Guangxi, Fujian, Zhejiang, and Yunnan,[23,41,111,112] and in 2010, a dengue outbreak occurred in Dongguan, a city in Guangdong province that had been free of the disease for more than two decades.[112] Transmission is maintained by 13 species of mosquitoes, most often *Aedes albopictus* and *Aedes aegypti*.[23] The former is found in nearly a third of China, while *A aegypti* is primarily distributed along the southeast coast, including Taiwan, Hainan, and a few counties in Guangdong.[113] High frequencies of dengue epidemics have been reported in Guangdong province. The number of imported cases of dengue is on the rise[114] and surveillance data suggests that they mainly come from bordering countries in the south.[115] Global climate change and rapid urbanisation might account for how dengue epidemics are gradually spreading from southern (Guangdong, Guangxi, and Hainan) to slightly more northeastern (Fujian and Zhejiang) and southwestern (Yunnan) regions.[23] A surveillance system for dengue fever is the backbone for the prevention and control of transmission of this infection in China.[116]

Rabies

Rabies is an acute, invariably fatal, neuro-invasive zoonotic disease with dogs as the main reservoir.[117,118] The high mortality of rabies places it in the top three of all notifiable infectious diseases (figure 2).[119] China accounts for 80% of the world's market for vaccines against rabies, worth CNY 10 billion (around $1·6 billion).[120] About 2000–3000 rabies deaths are reported every year in China, the second largest number after India.[117,118] Transmission of rabies is at its highest during the summer and autumn seasons.[121] Rabies has re-emerged in recent years, reaching a peak of 3300 cases in 2007 with most cases recorded in the southern and eastern parts of the country.[119,122] Provinces with sustained high incidence rates for 5 consecutive years are selected for routine annual monitoring.[123] Studies show that immunisation of 70% of the dog population can effectively control rabies transmission;[124] however, less than 20% of dogs have presently been vaccinated in China.[43] There is a pressing need to further strengthen collaborations between the veterinary and medical sectors.[32,124] To achieve the worldwide goal of elimination of rabies in man by 2020, China faces a challenge.[43]

Discussion

Factors associated with transmission features of NTDs

In the past few decades, substantial progress has been made in China regarding the prevention, control, and elimination of various NTDs. China's rapid and sustained economic development provides a unique opportunity to unveil key epidemiological characteristics and to assess the contribution of specific interventions. Disease transmission is often rooted in old, prevailing customs that do not change swiftly and therefore govern the public health challenges and priorities in unexpected ways. For example, the way food is produced, prepared, and consumed is an important tradition that has the potential to disseminate and increase the prevalence and incidence of ancient diseases in modern society. Other activities that can widen the infectious panorama include greater population movements and animal trade, resulting from globalisation and the transformation of ecosystems. The end-result is often an increased transmission of NTDs.[125]

Search strategy and selection criteria

We searched in PubMed (MeSH terms), ISI Web of Science, WanFang database, China National Knowledge Infrastructure, and Chinese Scientific Journal Database for articles published up to Dec 31, 2013, in English and Chinese with the following search terms: "prevalence", "epidemiology", "distribution", "disease burden", "prevention", or "control" in combination with each of the 14 diseases listed in table 1, "soil-transmitted helminthiasis", and "food-borne parasitic zoonoses". We also assessed books and reports from WHO or the Chinese Ministry of Health, dissertations and unpublished documents (grey literature). We hand-searched reference lists in identified publications and WHO databases or Google Scholar, including Weekly Epidemiological Record. We included articles if they were about the global epidemiology of 14 neglected tropical diseases (NTDs), concerned domestic epidemiology situation of 14 NTDs at countrywide or provincial level, or reports published on official websites (eg, WHO, Chinese Ministry of Health, and Chinese Center for Diseases Control and Prevention) about the worldwide or domestic statuses of the 14 NTDs.

China is the world's largest fishery nation and freshwater aquaculture is a major part of this industry.[126] In 2008, the output of aquatic products was close to 49 million tonnes, which represents 9·7 times the volume compared with 1978.[127] However, traditional production facilitates contamination of aquatic products with pathogens, which is a major risk factor for infections in man and a key reason why food-borne trematodiasis are emerging.[128] Additionally, the environment influences parasitic diseases by affecting the behaviour of vectors and intermediate hosts. For instance, climate change might increase the geographical distribution of sandflies (the vector for leishmaniasis), aedes mosquitoes (dengue), and some bat species (rabies).[129] Flooding events enlarge snail habitats, thereby expanding the risk for schistosomiasis and food-borne trematodiasis. New suitable habitats, both for insects and snails, have been created from the re-plantation of forests and re-establishment of previously drained lakes, which is part of the present Chinese Government's policies aimed at ecological protection.[130,131] Because these policies transform the environment, they too influence the transmission dynamics of parasites and vectors, and can change distribution patterns.[131] Moreover, rapid urbanisation does not always leave the rural environment behind; sometimes even changing the countryside in ways that favour vector breeding.[132] At the same time, populations are attracted from the countryside to the cities taking traditions with them that have the potential to promote diseases, such as angiostrongyliasis, echinococcosis, food-borne trematodiasis, and schistosomiasis. The implementation and maintenance of major water-resource development projects, such as the Three Gorges dam and the South-to-North Water Transfer Project together with many plans for dams—in the face of climate change—is already having a negative effect with regards to the transmission of schistosomiasis and possibly other NTDs too.[133,134]

Regional diseases have expanded their distribution as a result of transportation. A report on imported dengue fever between 2004 and 2006 in Hong Kong and Guangdong identified that the main transmission factor was frequent labour migration among southeast Asia countries in the summer.[135] One investigation shows that two-thirds of the present mobile fishing population living on boats in the Three Gorges dam reservoir areas originate from endemic areas, a risk for the introduction of schistosomiasis into non-endemic areas.[136] The implementation of intervention strategies for NTDs control or elimination are aligned with present programme planning and shows that different strategies are, and will be, adopted to tailor the intervention to the prevailing, setting-specific conditions. For example, surveillance and effective responses to environmental and climate changes are increasingly important in the elimination stage, whereas intensified control of water-borne and vector-borne parasitic zoonoses is essential in poor rural settings. A key determinant in control and elimination of NTDs in China is a rigorous and constant emphasis on surveillance, followed by prompt integrated response packages.[137]

A surveillance–response system for elimination of NTDs

Sporadic foci are the main features of NTDs in the elimination stage and therefore surveillance–response approaches hold promise as a strategy for disease elimination.[130,137] A surveillance–response approach to NTDs consists of four main components: establishment of the minimal essential data or indicator requirement in time and space; mapping and modelling of transmission patterns;[138] detection and response to low-transmission patterns by sensitive diagnostics; and validation of the approaches chosen and assessment of the elimination programme.[7,139] Mapping of the national and regional NTDs distribution based on the established database with near real-time information would ease the determination of the underlying variables, such as transmission, and allow planning for implementation of the NTD response programme.[138,140] Sparse data for trachoma is the key obstacle to elimination of preventable blindness.[98] Because many NTDs are zoonoses, surveillance mapping, agricultural activities (eg, livestock populations), consumption habits, and production systems, can help to identify high-risk communities.[103,141,142]

The sustained monitoring of environmental factors and their dynamics will play an important part in eliminating water-borne and vector-borne parasitic zoonoses, since hot spots of resurgence or the introduction of new pathogens will be able to be predicted.[129]

Annual surveillance of infection rates in pathogen hosts, including dogs, livestock, and people, is critical for the establishment of a real-time and pre-intervention baseline and to assess the efficacy of elimination programmes. National annual surveillance for schistosomiasis promoted the risk mapping and prediction of the disease leading to quick responses for this infection and other diseases.[63,143] Conversely, effective responses with regards to food security are still lagging as are the control of products with the potential contamination of infectious agents or artificial additives.[5] The infection rates of animals, which are reservoir hosts for many NTDs, have not been firmly established. For water-borne parasitic diseases, public areas of water access at lakes and rivers, which could pose a threat of parasite contamination, should be subject to local, provincial, and national monitoring. Passive surveillance, through routine health reporting systems and interrelated targeted active case detections, have another important role in disease elimination or post-elimination, such as for leishmaniasis. New techniques appropriate for diagnosis and surveillance of NTDs are essential; improving these techniques is likewise, an important task in disease elimination.[144,145]

Integrated intervention strategies for control of disease burden

Only the adoption of appropriate, integrated prevention and control measures can achieve cost-effective benefits in the control of disease burden. For example, the schistosomiasis control strategy changed from morbidity control with the anti-schistosomal drug praziquantel[143,146] during the 1990s to an integrated scheme in the new millennium that includes livestock management and snail control, improved sanitation, and intensive IEC.[28,67,147] According to available resources and practical attainable conditions, an integrated, multisectoral, multidisciplinary approach is needed to further reduce the disease burden and interrupt transmission.[129] The development and use of rapid diagnostic techniques with a high sensitivity for screening infections are critical, particularly at the elimination stage.[28,138]

Populations living in the same social-ecological settings are inevitably co-infected, often with several different parasites resulting in co-endemic NTDs, such as schistosomiasis, cysticercosis, and soil-transmitted helminthiasis. Multiparasitism needs to be better explored by the national control programmes that have partly been redesigned to meet this challenge.[148] Large-scale preventive chemotherapy programmes and mass drug administration therefore need to be built into multisectoral intervention programmes capable of reducing the comorbidity and coendemicity of NTDs.

The broad experience and lessons learned in the prevention, control, and elimination of NTDs in different social and ecological contexts merits sharing and a comparison across different endemic settings, cultures, and social systems to contribute effectively to the goals of the London Declaration, which include the elimination or control of ten neglected diseases by 2020 by providing more than $785 million to support research and development.[139] Launched on Jan 30, 2012, the London Declaration is a collaborative disease eradication programme between WHO, the World Bank, the Bill & Melinda Gates Foundation, the world's top 13 pharmaceutical companies, and governmental representatives from USA, UK, United Arab Emirates, Bangladesh, Brazil, Mozambique, and Tanzania.[139] China has accumulated expertise and experience with a host of different infectious diseases and the political commitment to move forward with design, validation, and implementation of integrated control strategies and innovative surveillance–response systems.[149] African countries are increasingly requesting effective partnerships for research and the control and elimination of NTDs. China is ready to share its expertise and novel technologies, based on 50 years' experience, in the pursuit of the goals of the London Declaration.

Contributors

G-JY, MT, RB, JU, and X-NZ conceived the paper. G-JY, LL, H-RZ, and X-NZ performed the literature search, figures, and data interpretation. G-JY, LL, and H-RZ wrote the first version of the report. MT, RB, JU, and X-NZ assisted in the restructure and in revising the manuscript. All authors read, contributed to, and approved the final version.

Declaration of interests

We declare no competing interests.

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