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Preplanned Studies

Amoebic Dysentery — China, 2005–2019

Jilei Huang¹; Yingdan Chen¹; Junling Sun²; Zhongjie Li²; Shizhu Li^{1,3}; Xiao-nong Zhou^{1,3}; Men-bao Qian^{1,3,#}**Summary****What is already known about this topic?**

Amebiasis is caused by infection with *Entamoeba histolytica*. As a severe sequence in amebiasis, amoebic dysentery is tracked by China's National Notifiable Disease Reporting System.

What is added by this report?

From 2005 to 2019, a total of 28,229 cases of amoebic dysentery and 7 resulting deaths were reported in China. The annual incidence rate had significantly decreased from 0.26/100,000 in 2006 to 0.06/100,000 in 2019, and most cases were reported from southern China and in children.

What are the implications for public health practice?

Amoebic dysentery has significantly decreased in China. Continued efforts are expected to further control amoebic dysentery, and southern areas and children should be high priority groups.

Amebiasis is caused by the invasive, tissue-destroying intestinal parasite *Entamoeba histolytica* (1). Diverse sequences could be presented in amebiasis, in which amoebic dysentery is most important because of its high incidence and severe harm to health (2). Amoebic dysentery ranks among leading causes of diarrhea globally, and thus amebiasis is an important public health problem especially in developing countries (3–4). Amoebic dysentery lists among the National Notifiable Disease Reporting System (NNDRS) in China (5), and in this study, data from NNDRS on amoebic dysentery between 2005 and 2019 were analyzed to uncover the epidemiological profiles. The incident cases decreased overall from 3,308 in 2005 to 775 in 2019, cases were mainly distributed in southern China, and children were the most affected population. Significant control on amoebic dysentery has been achieved in China, but concerted efforts are needed for further control.

We extracted the cases diagnosed as amoebic dysentery (clinical-diagnosed and confirmed cases) (6) during 2005 to 2019 from the NNDRS in China. Incident cases and corresponding incidence rates were

presented by year to demonstrate long-term trend, and reported cases were presented by month to show seasonality. Cases were classified at the provincial level to demonstrate high-risk regions and by sex, age, and occupation to show high-risk populations.

In total, 28,229 cases with amoebic dysentery were reported from 2005 to 2019 and resulted in 7 deaths that all occurred before 2011. The incident cases totaled over 3,000 nationally before 2007 and then declined gradually to the lowest total of 775 in 2019 (Figure 1). Correspondingly, the annual incidence rate was 0.26/100,000 population in 2006 and decreased gradually to 0.06/100,000 in 2019. Incident cases had obvious seasonal characteristics as the incidence started increasing from January to a peak in June followed by a gradual decline. Approximately 65.5% (18,504/28,229) cases were reported between May and October. Cases have been reported in all 31 provincial-level administrative divisions (PLADs) in the mainland of China. However, besides Heilongjiang in northeastern China, cases were predominantly distributed in southern China (Figure 2). During the past 15 years, Heilongjiang reported 3,895 cases (13.8%) and were followed by 3,262 cases in Guangxi (11.6%), 3,242 in Yunnan (11.5%), 2,714 in Guangdong (9.6%), 2,396 in Jiangxi (8.5%), 2,163 in Sichuan (7.7%) and 2,129 in Henan (7.5%); these 7 PLADs accounted for 70.1% of cases nationally. Children under 14 years old accounted for 52.6% of total cases (14,838/28,229), and the number of cases decreased with increasing age in children (Figure 3). The highest number of cases was reported in children aged below 1 year (5,737 cases). The number of cases was 16,656 (59.0%) in males and 11,573 (41.0%) in females. The epidemiological profile by age for the different sexes was similar to the overall population. A higher number of cases were reported in males than females in all age groups excluding those between 50 and 59 years old. Among the different categories, unsupervised children (not in care facilities) (11,457 cases, 40.6%) were the major source, followed by farmers (6,730 cases, 23.8%), school children (2,360 cases, 8.4%), and kindergarten children (1,566 cases, 5.5%).

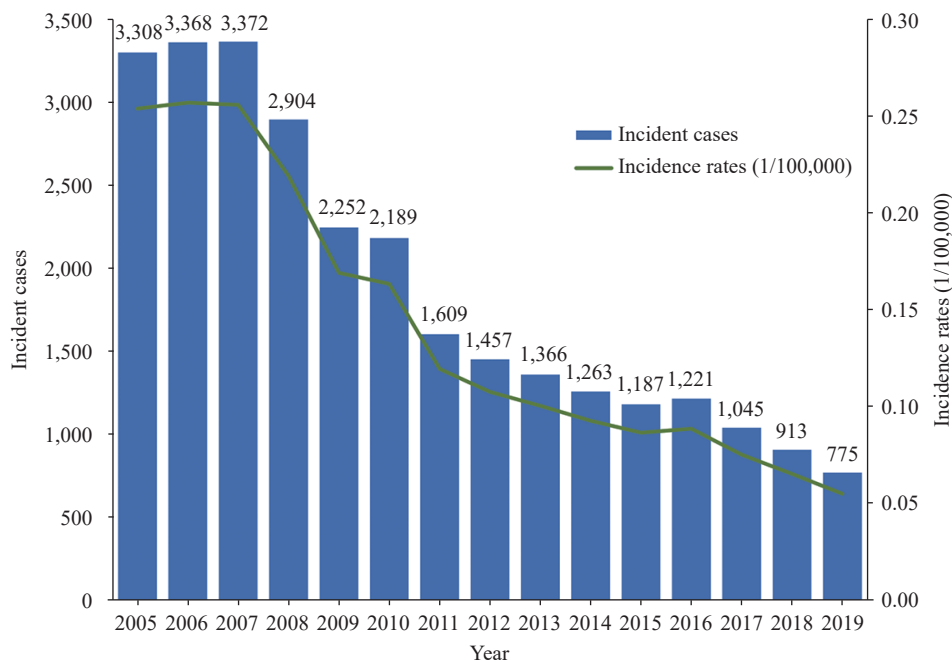


FIGURE 1. The incident cases and incidence rates attributed to amoebic dysentery in China from 2005 to 2019.

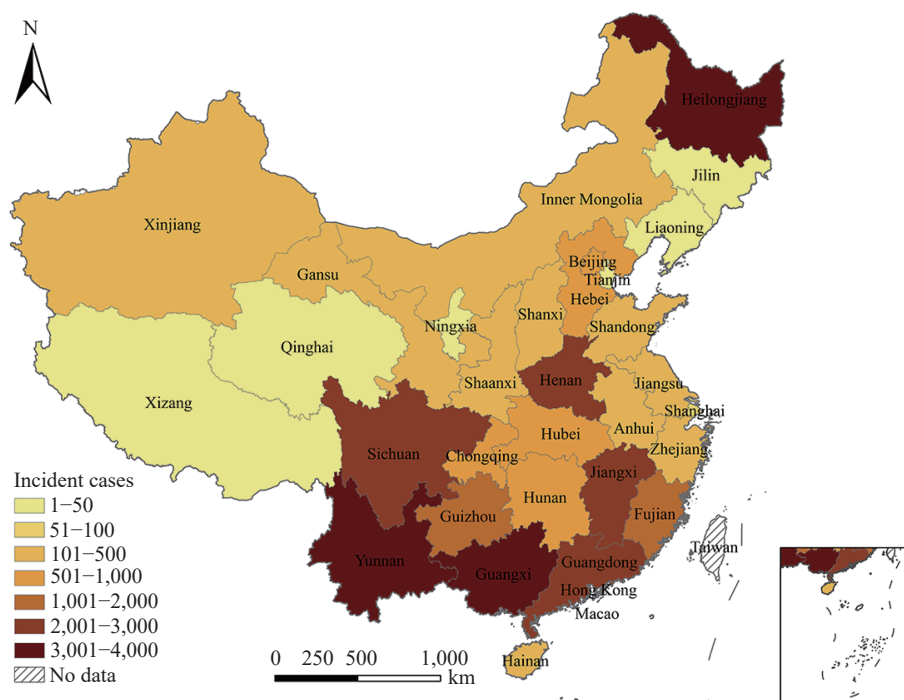


FIGURE 2. The distribution of incident cases of amoebic dysentery by provincial-level administrative divisions in China from 2005 to 2019.

DISCUSSION

Based on the NNDRS, cases of amoebic dysentery had reportedly significantly decreased in China during the past 15 years from 3,308 in 2005 to 775 in 2019.

Overall, 65.5% of cases were reported between May and October, and a high imbalance was demonstrated in areas and populations.

The significant decrease of amoebic dysentery was consistent with decreases in intestinal protozoan

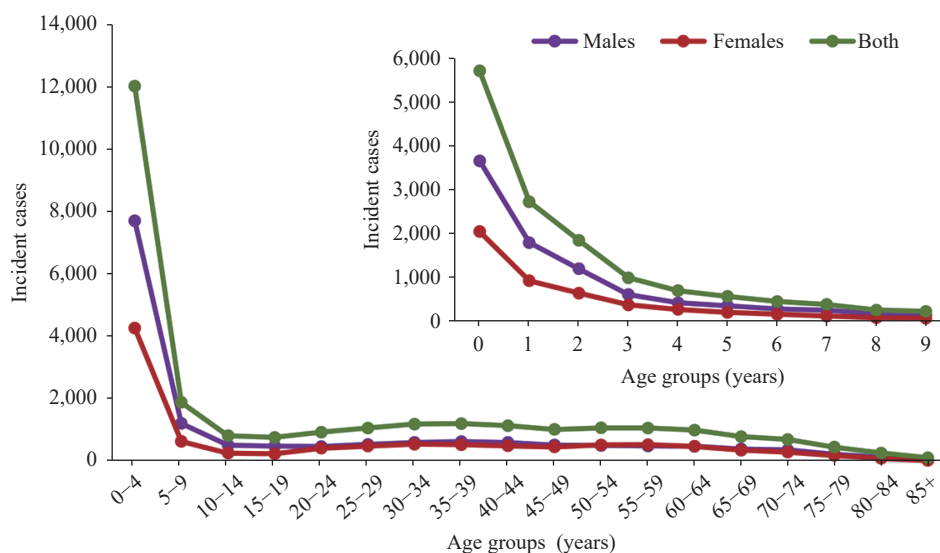


FIGURE 3. The incident cases of amoebic dysentery by sexes and age groups in China from 2005 to 2019.

infection in China in 2 national surveys (3–4). The national prevalence of intestinal protozoa was 10.3% in 1988–1992, in which *E. histolytica* infection was 0.95%. Although the separate prevalence of *E. histolytica* was not provided, the total prevalence of intestinal protozoa was only 0.99% during 2014 to 2016, which indicated the significant decrease of amebiasis in China. Social development, provision of safety water, and establishment of sanitation are relevant to the endemicity of amebiasis (1). Thus, the decrease of amoebic dysentery was consistent with the significant improvement of above conditions in China (7). Seven deaths were caused by amoebic dysentery and all occurred before 2011, which was consistent with the overall decrease in reported cases. Additionally, advances in medicine, e.g. timely diagnosis and treatment, should also contribute. Significant seasonality was demonstrated in amoebic dysentery with most cases reported in summer and autumn, which was consistent with previous reports (8–9) as high temperatures promote the survival of *E. histolytica* and raw water (i.e. not boiled) is more often consumed.

Analysis at the provincial level showed major regional variation. Most cases were reported from southern China, especially southwestern regions, which was also consistent with the higher temperatures in southern China. Furthermore, the supply of safe water and sanitation in southwestern China lags behind other areas (7). However, a high number of cases was reported in Heilongjiang in northeastern China while cases were relatively lower in adjacent PLADs, which requires further investigation to explore the

epidemiological factors. Based on a national survey in 1988–1992, the prevalence of intestinal protozoan infection including amebiasis was high in middle-aged populations and relatively low in children (3). However, it was found that the prevalence of intestinal protozoa was higher in children during 2014 to 2016 (4), which was consistent to the finding in this study. Children are possibly less resistant to *E. histolytica* infection and more likely to present morbidity after infection, and vigilant childcare from parents might contribute to higher rates of doctor visits and diagnosis.

This study has one limitation. Because of relative neglect and challenge in diagnosis, the reported cases of amoebic dysentery in NNDRS were probably underestimated. Thus, the epidemiological burden of amoebic dysentery as well as amebiasis should be higher than that indicated by the reported cases in this study. However, the reported cases in NNDRS still demonstrate the epidemiological profiles. Although cases of amoebic dysentery decreased significantly in China during the past 15 years, it still causes a high burden in some areas and populations. Further action is needed to promote the control of *E. histolytica* infection including the persistent improvement on the provision of safe water and sanitation in less developed areas.

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Preplanned Studies

Distribution of Suitable Environments for *Phlebotomus chinensis* as the Vector for Mountain-Type Zoonotic Visceral Leishmaniasis — Six Provinces, China

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Zhengbin Zhou^{1,2}; Yi Zhang^{1,2}; Shizhu Li^{1,2,#}

Summary

What is already known on this topic?

Phlebotomus chinensis (*P. chinensis*) is a sandfly and the main vector of mountain-type zoonotic visceral leishmaniasis (MT-ZVL) in China. However, the distribution of suitable environments for the vector has not been studied yet.

What is added by this report?

This study found that temperate hilly zones in midwestern China are suitable for *P. chinensis* survival with appropriate environmental factors such as moderate normalized difference vegetation value (NDVI), land use type, landform, temperature, and vegetation. Suitable living conditions for the high-density *P. chinensis* that caused the reemergence of MT-ZVL already existed.

What are the implications for public health practice?

Targeted strategies should be implemented to control the vector and the reemergence of MT-ZVL, such as by strengthening key environment monitoring and taking accurate measures for residents, mobile and migrant populations.

Phlebotomus chinensis (*P. chinensis*) is a sandfly that is the main vector of mountain-type zoonotic visceral leishmaniasis (MT-ZVL) in China, an endemic infectious disease caused by *Leishmania* spp. parasitizing in the human lymphocyte system (1–2). To analyze the distribution of suitable environments for the *P. chinensis* vector and control the reemergence of MT-ZVL, the distribution data of *P. chinensis* that were previously documented and a national survey in 2016 were input into MaxEnt software to calculate the ecological suitability results. The impact of key environmental factors on the vector were determined, and suitable living conditions for high-density *P. chinensis* that caused the reemergence of MT-ZVL

already existed. Strengthening key environment monitoring and taking accurate measures for residents, mobile and migrant populations will help control reemergence of the disease.

Ecological niche models can calculate the potential distribution of the species based on geographical location of species and environmental resources variables (3). The maximum entropy model had been widely used to predict the distribution conditions of species among all ecological niche models. Given that the suitable distribution of *P. chinensis* demonstrated a great possibility for MT-ZVL reemergence, MaxEnt software (Version 3.4.1; Phillips et al. 2020) was used to calculate distribution of suitable environments for the vector. The study area consisted of 6 endemic provinces: Gansu, Shanxi, Shaanxi, Sichuan, Henan, and Hebei. These provinces are located between latitude 26.05°–42.79° N and longitude 92.34°–119.85° E. A completed survey on historical literatures was conducted, which were published on CNKI (<https://www.cnki.net/>) and Wanfang Data (<http://www.wanfangdata.com.cn/index.html>) between 1950 and 2017, and the distribution points of *P. chinensis* were collected. The national field survey data of *P. chinensis* in 2016 was collected from national repository. The environmental variables included 24 datasets of bioclimatic and geographical data (Table 1), which was generally recognized as important factors for sandfly survival (3–4). ArcGIS10.7 was used to construct and process the environmental variable datasets, and the distribution datasets of *P. chinensis* were then imported into MaxEnt software as the biological training data. Overall, 75% of the data served as the training dataset, and the remaining 25% of the sample points were randomly selected as test data. The results of the model displayed the potential ecological suitability of the vector to survive as a range from 0 (unsuitable) to 1 (suitable), and we defined

TABLE 1. Environmental variables used in MaxEnt model.

Variable Classification	Variable Name	Definition	Units	Variable Type	Source
Bioclimatic Data					
	BIO_01	Annual mean temperature	°C		
	BIO_02	Mean diurnal range	°C		
	BIO_03	Isothermality	–		
	BIO_04	Standard deviation of temperature seasonality	–		
	BIO_05	Max temperature of warmest month	°C		
	BIO_06	Min temperature of coldest month	°C		
	BIO_07	Temperature annual range	°C		
	BIO_08	Mean temperature of wettest quarter	°C		
	BIO_09	Mean temperature of driest quarter	°C		
	BIO_10	Mean temperature of warmest quarter	°C	continuous	https://www.worldclim.org/data/worldclim21.html
	BIO_11	Mean temperature of coldest quarter	°C		
	BIO_12	Annual precipitation	mm		
	BIO_13	Precipitation of wettest month	mm		
	BIO_14	Precipitation of driest month	mm		
	BIO_15	Coefficient of variation of precipitation seasonality	–		
	BIO_16	Precipitation of wettest quarter	mm		
	BIO_17	Precipitation of driest quarter	mm		
	BIO_18	Precipitation of warmest quarter	mm		
	BIO_19	Precipitation of coldest quarter	mm		
Geographical Data					
	LU	Land use	–	categorical	
	LF	Landform	–	categorical	
	NDVI	Annual normalized difference vegetation index	–	continuous	http://www.resdc.cn/
	VEG	Vegetation	–	categorical	
	ELV	Elevation	m	continuous	https://www.worldclim.org/data/worldclim21.html

areas with ecological suitability values of 0–0.3, 0.3–0.6, and 0.6–0.98 as being at low, medium, and high-risk survival area, respectively.

The average area under the curves (AUC) was 0.936 (with a standard deviation of 0.011), which indicated excellent prediction accuracy and effect. The results of the jackknife test of variable importance revealed that annual normalized difference vegetation index (NDVI) was the most important factor and contributed the most to the model when the other variables remained stable. Other important individual factors were land use (LU), annual mean temperature (BIO_01), vegetation (VEG), landform (LF), and mean temperature of coldest quarter (BIO_11) (Figure 1A). Response curves showed the ecological suitability of *P. chinensis* was relatively high when the NDVI was \geq

0.2; when the land consisted of forests, rural agricultural areas, and mining areas; when the average annual temperature was ≥ 10 °C; when the vegetation was shrubs or meadow; and when the mean temperature during the cold and dry quarter was between -5 °C and -10 °C (Figure 1B).

According to the result, the suitable distribution of *P. chinensis* presented wide spatial distribution and high indigenous spatial clustered characteristics, which indicated high survival probability. They would survive in the following suitable high-risk areas: the temperate hills of northern Sichuan and southern Gansu, the Loess Plateau region (eastern and central Gansu, Guanzhong area in Shaanxi, and most areas of Shanxi and northwestern Henan) and southern Hebei (Figure 1C).

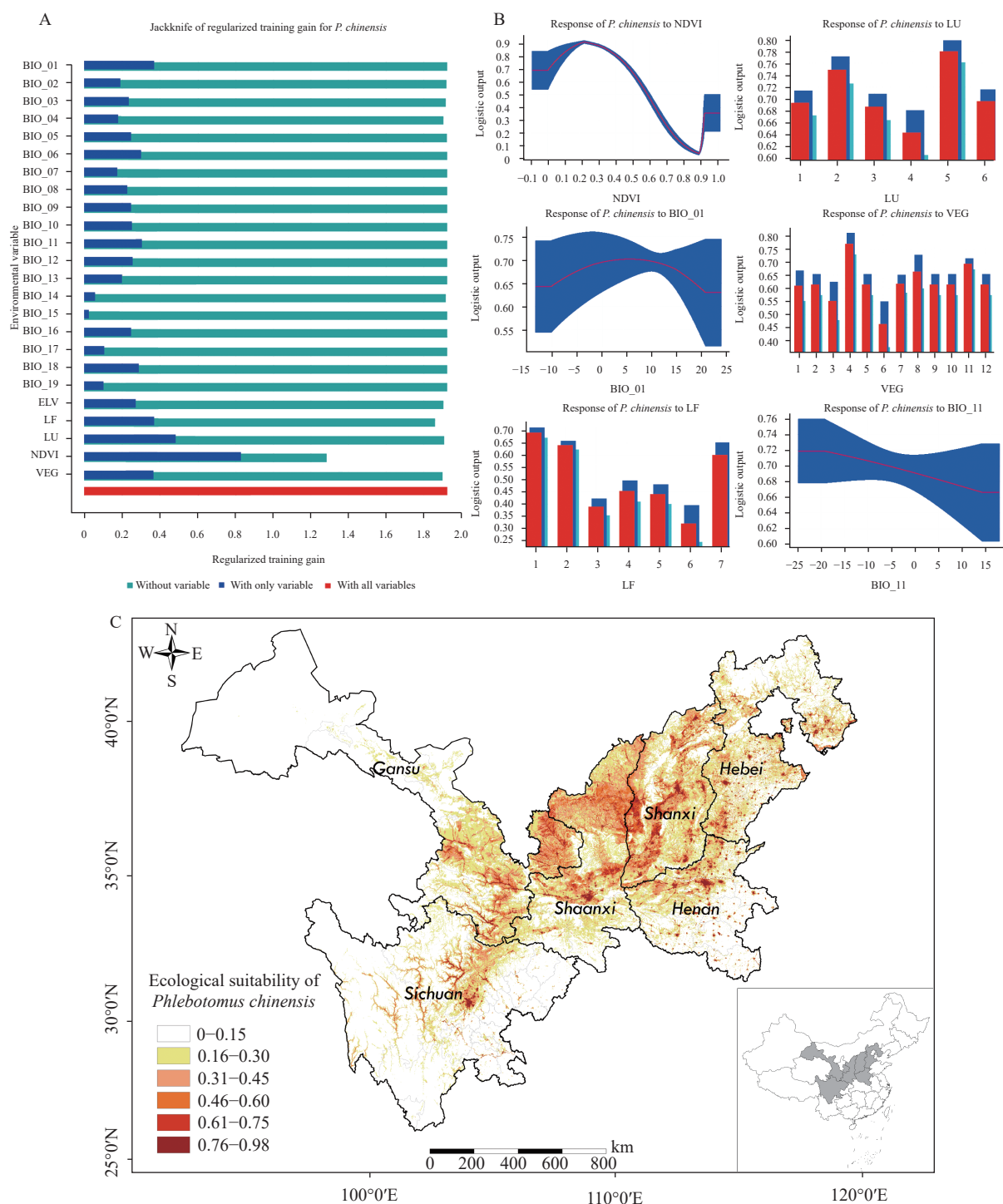


FIGURE 1. Results of the MaxEnt model: Analysis of environmental variable contributions and point-wise mean ecological suitability of suitable distribution for *Phlebotomus chinensis* (*P. chinensis*). (based on *P. chinensis* distribution data documented in literatures between 1950–2017). (A) Jackknife test results of regularized training gains for *P. chinensis*; (B) Response curves of 6 major environmental variables (NDVI, LU, BIO_01, VEG, LF, and BIO_11); (C) The distribution of suitable environments for *P. chinensis* in MT-ZVL endemic provinces in China. Abbreviations: NDVI=Annual normalized difference vegetation index, LU=Land use, BIO_01=Annual mean temperature, VEG=Vegetation, LF=Landform, BIO_11=Mean temperature of coldest quarter. In Figure 1A, blue and red bars showed training gain of variables if the model was run in isolation and of all variables, respectively. In Figure 1B, the response curves showed how each environmental variable affected the MaxEnt prediction when all other variables kept average value plotted by the value of each variable on the horizontal axis and training gain on the vertical.

DISCUSSION

MT-ZVL and the main vector, *P. chinensis* have been controlled successfully since the 1970s in China. However, the reported numbers of MT-ZVL indigenous cases increased gradually in recent years (1–2). The prediction results showed a wide spatial distribution of suitable environments for *P. chinensis* in China with high indigenous clustered characteristics. The most suitable areas for *P. chinensis* were generally temperate hilly zones with a moderate NDVI value; where the land mainly consisted of forests, suburban agricultural, and industrial land; with an average annual temperature of about 10 °C; where shrubs or meadows were the main vegetation; and where the mean temperature during the cold and dry quarters were –5 °C to –10 °C. This suggested that suitable living conditions for the high-density *P. chinensis* that caused the reemergence of MT-ZVL already existed. The study aimed to identify key environmental factors for *P. chinensis* surviving and to control reemergence of MT-ZVL in China. Key environments should get more attention and monitoring. Furthermore, this study provided more evidence to discover the potential risk of MT-ZVL transmission to concentrate resources for accurate prevention and control.

Research showed that bioclimatic factors such as temperature and precipitation changes caused by climate warming could allow *P. chinensis* to survive at higher latitudes and altitudes (3). Different bioclimatic and geographical factors in various regions have a vital influence on the distribution of sandflies (4). The policies of returning farmland to forests and closing hills for afforestation have increased the density of wild *P. chinensis*, and the natural foci in hilly zones has further spread the transmission risk of MT-ZVL to surrounding areas. Therefore, understanding the influence of bioclimatic and geographical factors on the suitable distribution of the vector can scientifically explain the reemergence of MT-ZVL to a certain extent.

High temperatures will lead to excessive larval metabolic consumption and death, and larvae at higher altitudes will take longer to develop (5). Vegetation and NDVI have important influences on the reproduction and development of wild-type *P. chinensis*. The development of females depends on absorbing the blood of livestock grazing in meadows, whereas that of males mainly depends on soft-stemmed plants (4). Suburban agricultural, industrial, and mining lands have proven suitable as temporary

habitats for semi-wild-type *P. chinensis* vectors (6), and this factor has also led to an increased ecological suitability of the vector in some large cities.

Monitoring key environments suitable for *P. chinensis* surviving should be strengthened in southern Gansu and northern Sichuan, and spraying the wild-type *P. chinensis* in key natural caves (the natural foci for MT-ZVL) with residual insecticides is recommended (7). Combining insecticide spraying measures for the semi-wild-type *P. chinensis* in cave-houses that are abandoned or in use and livestock compounds would be effective in endemic areas in the Loess Plateau region (6,8). Second, accurate prevention and control measures should be taken in high-risk areas. Residents should be reminded to strengthen protective measures to avoid being bitten by *P. chinensis*. Diagnosis, screening, and health education should also be enhanced among mobile and migrant populations, considering frequent population movements increase the risk of MT-ZVL importation in non-endemic areas (9).

However, the present study has some limitations. Most of the historically-endemic counties with reemergent MT-ZVL were predicted as high-risk areas for *P. chinensis* surviving, but the vector's high ecological suitability value in some large cities deviated from the actual distribution of the disease. One possible reason is that the distribution points of the vector in suburban and rural areas has been eliminated during the Patriotic Health Campaign and previous urbanization of rural areas. Moreover, socioeconomic factors like population density and gross domestic product (GDP) were not considered, and canines were not addressed. These factors should be included in the future to more comprehensively assess the distribution of the *P. chinensis* vector.

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Perspectives

China-UK-Tanzania Pilot Project on Malaria Control

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KEY APPROACHES OF THE PILOT PROJECT

The China-UK-Tanzania Pilot Project on Malaria Control supported by the China-UK Global Health Support Programme and funded by the UK Department for International Development (DFID) is the first pilot project of its kind for the Chinese government in Africa. The encouraging results of this pilot project demonstrated that the malaria burden could be reduced by 81% (1) when China's experience with malaria control was shared in Tanzania through interactions between health officials from China and Tanzania. The pilot strategy concept was implemented after China's process for malaria control and elimination was shared with Tanzania's health experts. This study's purpose was to document the essential approaches of the pilot strategy including local-oriented interventions, onsite technical support from Chinese staff who worked with local health staff, and grassroots capacity-building through the sharing of China's village-doctor model anchored in African local contexts.

In the pilot project, China's experience with malaria control was shared via local-oriented and evidence-based interventions (2). The baseline survey conducted in Rufiji District of Tanzania in 2015 was implemented by local health staff with the guidance of onsite Chinese staff, who also helped to identify the malaria prevalence in the community and weaknesses in the local health system. In the baseline survey, 13 health facilities (HFs) were surveyed, of which 10 were dispensaries and 3 were health centers. Only 15.38% of the HFs were found to have stocked Dihydroartemisinin/Piperaquine. The incompleteness of HFs' routine data was also a challenge to local malaria control. Moreover, the 4,685 participants in the intervention communities had a malaria prevalence of 25.7% based on a rapid diagnostic test (RDT), in contrast with the locally reported malaria prevalence rate of 16.0% (3). This data discrepancy provided crucial evidence that additional information was

necessary regarding the local surveillance system.

Following the baseline survey, Chumbi and Ikwiriri were selected as intervention communities while Bungu and Kibiti served as control communities (4). The locally-tailored 1,7-Reactive Community-Based Testing and Response (1,7-RCTR) was the main intervention in the selected communities that was administered in addition to existing malaria control and prevention implemented by the Ministry of Health through the National Malaria Control Program (NMCP). Two control communities were monitored that received no interventions beyond those provided by the NMCP. The pilot project was designed to improve rather than to alter the existing processes in the local health systems of the intervention communities. Specifically, the 1,7-RCTR implemented at the village level entailed reporting all confirmed malaria cases at the HFs within 24 hours followed by screening and treatment of identified hotspots within the next week to reduce malaria burden. This targeted intervention aligns with the World Health Organization (WHO)'s high-impact initiative for countries with moderate and high transmission by tailoring the Chinese experiences and WHO-T3 initiative (Test, Treat, Track.) to the local settings of Tanzania (5). In the intervention communities, locally tailored interventions based on the 1,7-RCTR were designed and implemented, including onsite Chinese technical support, capacity building for local community health workers (CHWs), and multilateral collaboration.

Unlike some international projects, the onsite Chinese staff for technical support were dispatched to work with local stakeholders for the duration of the pilot project in a mutual learning-by-doing approach. Chinese staff trained in malaria epidemiology, laboratory systems, vector control, and information systems were selected to collaborate with the Ifakara Health Institute (IHI) and other local partners (6). Each Chinese staff member was paired with a local staff member to work on a discreet aspect of the intervention and make implementation decisions in

the field, mainly by supervising and guiding local training and field operations. The teams conducted community mobilization campaigns with over 500 local stakeholders including local government leaders and health staff from 36 administrative villages in the 4 communities (6). Additionally, the teams ensured the steady progress of the project's implementation in the field. Capacity-building through the sharing of China's village-doctor model cultivated a local team of 35 CHWs, who were trained and supervised and ensured the success of the implementation process. The training included case management, vector control, and health education. China's village-doctor model was shared in such a way that CHWs could provide basic malaria diagnosis, drug treatment, and primary health education to members of the community, even reaching previously under-served patients. Multilateral collaboration and resource integration were key drivers in maximizing all parties' efforts. In the pilot project, resources from China were integrated with Tanzania NMCP for efficient utilization. For example, although long lasting insecticidal nets (LLINs) delivery was not supported by the project funding, around 50,000 LLINs were allocated by NMCP to reduce the risk of local malaria transmission (7).

To evaluate the pilot strategy in Tanzania, the endline survey was conducted in 2018 with 4,406 people in the intervention communities and 5,728 in the control communities. The malaria infection rate in the intervention communities was 4.9%, representing a decline of 81%, while the malaria infection rate decreased by 52% in the control communities. The dramatic reduction in the intervention wards compared to the control areas produced clear evidence that the malaria prevalence was reduced beyond the impact of NMCP alone. Currently, other malaria interventions, including the most advanced novel vaccination approaches, have only reported limited effects beyond that of LLIN use (8).

EXPERIENCES SHARED IN THE PILOT PROJECT

The pilot project entailed the sharing of China's experience with malaria control in African settings through the pilot strategy. The pilot strategy has been continuously used in China's malaria control and elimination process and has proved conducive to the selection of local effective measures, cultivation of the local team's capacity, and the enrichment of work experience regarding malaria control. Therefore,

China's experience on malaria control could be shared in additional settings.

Learning by doing: Learning by doing was explored in the pilot project as a problem-solving process. Chinese staff worked together with IHI field teams in the pilot communities to identify the obstacles in the malaria control process and resolve them. Onsite Chinese staff were paired with local staff from IHI, NMCP, and other partners and jointly worked on a specific aspect of the project for work plan designing, local staff training, field implementation, and supervision. The use of a collaborative model and teamwork realized through regular lectures on malaria control and internal assessments as well as quarterly stakeholders' meetings led to a mutual understanding of the goals of the pilot project. Thanks to the collaborative efforts achieved through community consent, community mobilization, and community participation, as well as the local leaders' and IHI's support, the pilot project was successfully implemented.

Sharing China's village-doctor model: Capacity building for CHWs through the community-based approach to malaria control was constructive in mobilizing community participation and project implementation. The name "barefoot doctor" was replaced by "village doctor" in China in 1981 (9). Village doctors have made great contributions to malaria control by providing primary health care to malaria patients in rural areas at relatively low costs in a door-to-door manner (10). Similarly, CHWs play important roles in delivering quality primary health care services and malaria control efforts, which are recognized by the World Health Assembly and promoted according to the WHO strategy (11). Many people do not go to health facilities due to a lack of awareness of malaria illness, accessibility of health services, and concern regarding high treatment costs. This project explored the feasibility of a community-based approach (4) through the sharing of China's village-doctor model in Tanzania. CHWs were recruited from local communities and their door-to-door healthcare services helped ensure the primary health of community members and served as an extension of the services provided by local health facilities.

Multilateral cooperation: Multilateral cooperation was indispensable for the effective implementation of the pilot project, which involved 11 main stakeholders from China, Tanzania, and international organizations. The internal evaluation was led by Duke University,

midterm and final evaluations were led by the WHO, and the external evaluation was led by the DFID. In this learning-by-doing process, the different stakeholders worked together to identify adapted approaches for sharing China's experience with malaria control and elimination (12).

The pilot project also encountered some challenges that could provide insight for future public health cooperation between China and Africa. China has no template to guide its engagement in global health initiatives (13). Therefore, two approaches should be considered: 1) fostering systematic changes in its international health cooperation system; and 2) working with other global agencies to build new global health partnerships. Future public health cooperation should be maintained and nurtured between China and Africa to benefit Tanzania and other places.

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Commentary

The Role of Standards for Communicable Disease Prevention and Control in Protecting People's Health and Safety During COVID-19

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World Standards Day was established by the International Organization for Standardization (ISO) on October 14 to enhance awareness on the significance of international standardization to respond to the needs of businesses, industries, governments and consumers worldwide. Since its rejoining the ISO in 1978, China held various presentations, symposiums, and commemorative events for World Standards Day in major and medium-sized cities nationwide to publicize the role of standardization in societal development and enhance the awareness of standardization among the people.

The theme for the 51st World Standards Day in this year is “Protecting the planet with standards”. Since the coronavirus disease 2019 (COVID-19) pandemic emerged, practitioners in standardization took immediate actions to respond. China's State Standardization Administration, National Health Commission, local governments, and social organizations took emergency actions to formulate and publish a series of relevant national standards, industry standards, local standards, and organization standards for the prevention and control of COVID-19, which played an essential role in regulating and directing efforts in the prevention and control of the outbreak and in protecting the people's health and safety.

REFLECTING ON THE COVID-19 PANDEMIC

COVID-19 has been the most serious pandemic in the last 100 years and a critical public health event affecting China's development with its fast transmission, wide range of infection, and other significant challenges for prevention and control. The pandemic has highlighted the importance of improving the standards for communicable disease prevention and control and the society's awareness of these measures. President Xi Jinping points out in his recent article, “All-around Improvement of Capability of Prevention, Control, and Governance according to Law to Build a

Sound National Emergency Management System in Public Health” in *Qiushi* Journal of May 2020, that suggests that the COVID-19 response is “a major test to the state's governance system and capacity.” President Xi also continues to call for practical experience to be summarized and shared to improve the prevention and control standards and the emergency management measures during these critical events. Public health practitioners have since prioritized the in-depth study of how to implement these instructions.

Laws and regulations provide a basis for governance and can regulate the developmental direction of the state and society. Underlying the enforcement of the laws and regulations are a series of more specific and refined standards containing many quantitative requirements, which supplement and extend the legal system. Standardization is the most effective way to realize practical experiences, avoid redundant construction, and enhance efficiency of public services. Building and improving a system of standards is “the last kilometer” in enhancing social governance capacity and accelerating the generation of results for public institutions. Improving communicable disease-related standards can enhance the emergency response capacity in public health to communicable diseases in China.

STANDARDIZING THE RESPONSE TO COMMUNICABLE DISEASES IN CHINA

Health standards are technical specifications formulated for matters involving human health and healthcare services based on research and practice in order to implement laws, regulations, and policies in healthcare and safeguard human health (*1*). The National Technical Committee on Health Standards was set up in 1981 to start standardization in healthcare by focusing on preventive medicine. Following this, seven sub-committees were established in the following areas: occupational health, environmental health, food health, diagnosis of

occupational diseases, radiological protection, diagnosis of diseases from radiation, and school health. With the development of public health and healthcare in China, the Technical Committee on Standards for Communicable Diseases was set up in the 3rd National Technical Committee on Health Standards in 1991, indicating the beginning of standardization in the field of communicable diseases in China. In the 20 years since the establishment of the Technical Committee on Standards for Communicable Diseases, 39 notifiable diseases and emerging and critical communicable diseases have had standards established. The 6th Committee on Health Standards of the Ministry of Health was then set up in March 2008 to reinforce and improve standardization of communicable diseases.

When the 8th Committee on Standards was set up In June 2019, it was renamed the Professional Committee on Communicable Disease Standards of the National Health Standards Committee, and the workplace of the Secretariat changed to China CDC of the National Health Commission (NHC). To date, 52 health standards in communicable diseases have been published, among which 49 are industry standards and 3 are national, and 42 are compulsory and 7 are recommended. There were 45 standards for diagnosis among them, which account for the highest percentage (91.8%) and provided a major basis for the prevention, treatment, and monitoring of communicable diseases. The system of standards in communicable diseases has been developed on the basis of years of practical work, international experiences, repeated research, and discussion by the experts. The current framework system of standards for communicable diseases is shown in Figure 1, which provides guidance and specifications for the future formulation of and amendment to standards for communicable diseases.

PROCEDURE OF DEVELOPING HEALTH STANDARDS IN COMMUNICABLE DISEASES IN CHINA

Health standards in China have been formulated mainly in a government-led manner, which consist mainly of state standards, industry standards, and local standards. The state standards are initiated and published by the State Standardization Administration, the healthcare standards by the National Health Commission, and the local standards by local market regulation administrations. The formulation of a standard system needs to pass a long period of inspection and administrative review and approval. For

some standards involving a wide range of technical factors, a long industry chain, and multiple authorities, it could take several years to complete the process from the project proposal to publication.

In recent years, supported by policies encouraging organization standards, significant progress has been made in organizational standards in healthcare, and nearly 40 social organizations represented by Chinese Preventive Medicine Association (CPMA) have carried out development of these standards. Since 2017 when development of organizational standards began, CPMA has reviewed 197 applications for projects of standardization with 126 projects approved. The standards in the field of communicable diseases account for the highest percentage every year.

SHORTCOMINGS IN STANDARDIZATION REVEALED DURING THE COVID-19 PANDEMIC

Public attention was centralized following the COVID-19 pandemic and related standards came under significant scrutiny: standards for definite diagnosis of the case at the early stages; standards for protective supplies such as masks and suits during the period of rapid spread; concerns about the safe use of imported protection supplies with different standards; safeguard measures and management standards during resumption of work and production as the domestic situation of the outbreak was improved; etc. The State Administration for Market Regulation, NHC, local governments, and social organizations took emergency actions to formulate and publish several series of relevant national standards, healthcare industry standards, local standards, and standards of the organizations, and made widespread efforts to explain the standards to the public. Despite these efforts, considerable shortcomings were revealed in face of the pandemic. Considering the current state of standards for communicable diseases, the following main problems can be identified:

Inadequate Number and Structure of Standards

While the current industry standards in communicable diseases may cover 39 notifiable diseases, many only consist of a single provision with more than 90% being standards for diagnosis, which are far from meeting the demands for standards in the prevention and control of communicable diseases. While the Law of the People's Republic of China on

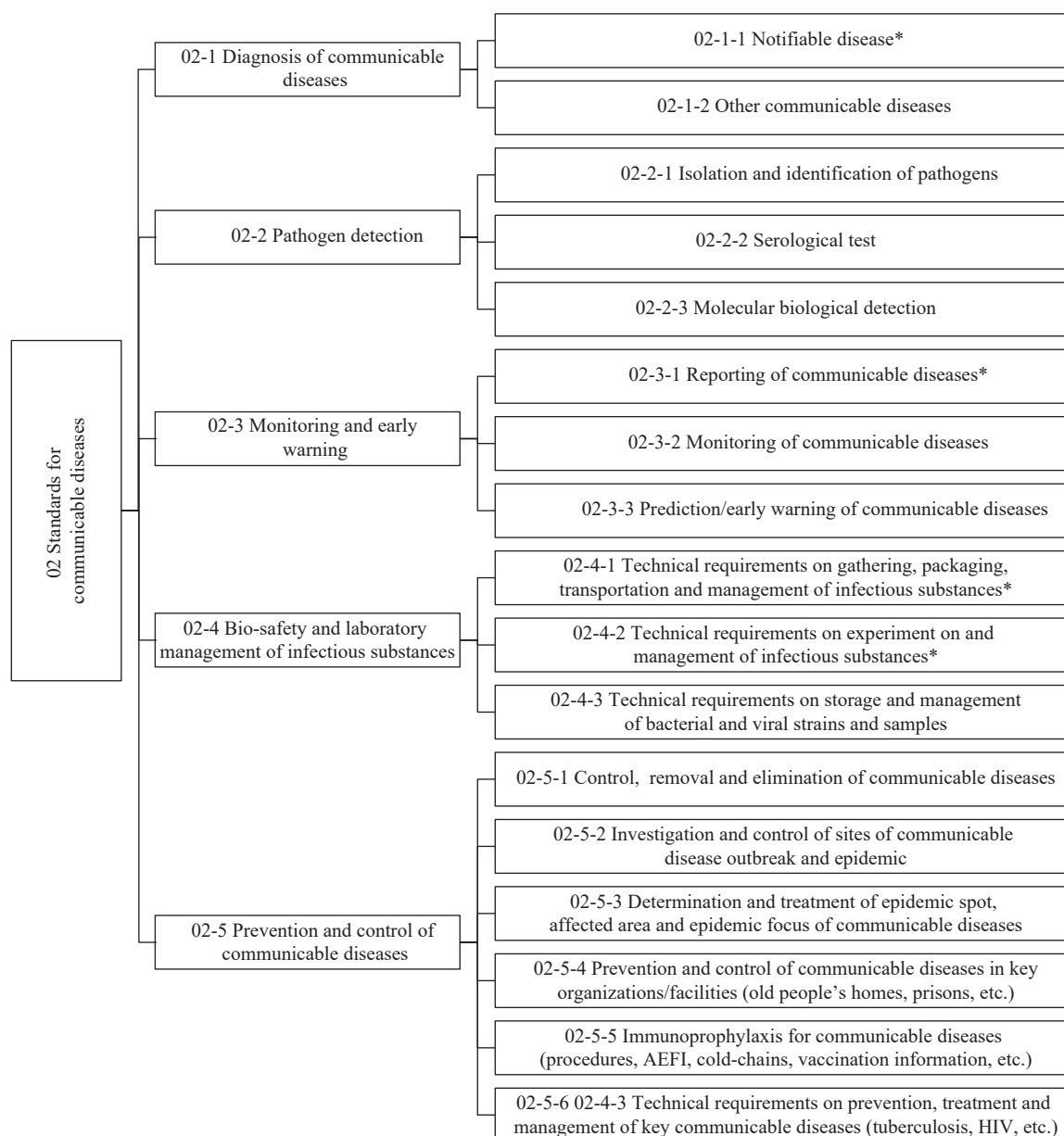


FIGURE 1. Framework system of standards for communicable diseases. Note: those with * are suggested as compulsory standards for the healthcare industry.

Prevention and Control of Infectious Diseases provides clear regulations and requirements on communicable disease monitoring and reporting, there is a lack of detailed, operable monitoring and early warning standards to provide adequate support.

Outdated Standards and Insufficient Publicity and Implementation

A substantial part of the current standards for communicable diseases are more than 10 years old with several lagging behind the most up-to-date research and technology. Although all the standards over 5 years

old were reviewed in 2019, the timely amendment and improvement to these standards is hindered because only a limited number of standards can be amended within a given timeframe. Another issue revealed during pandemic is that many basic-level organizations are not familiar with and/or do not use several published standards, so these standards cannot provide immediate and practical assistance for disease prevention and control at the organizations and neighborhoods mainly due to insufficient publicity and implementation. This situation directly leads to low awareness of the standards and unsatisfactory implementation.

IMPLICATIONS

Since the COVID-19 pandemic began, the introduction and guidance of the standardized procedures and related specifications have played an essential role in providing medical supplies, nucleic acid testing, patient treatment and cure, production of masks and protective suits, use of breathing machines and artificial lungs, and the development of vaccines and clinical trials. To achieve the goal of “building a powerful public health system” put forth by President Xi, the shortcomings in the standards for communicable diseases should be addressed so that they can guide, support, and supervise the industry and make a greater contribution to the enhancement of emergency response capacity.

Improving the System by Allowing for Adoption of New Standards and Amendment to existing Standards

Based on the experiences accumulated from the COVID-19 pandemic, the demands for standards should be further reviewed to optimize the current structure of the standard system for communicable diseases, extend the scope of the standards, and formulate new standards beyond diagnosis to cover communicable disease monitoring, treatment, prevention, result evaluation, and supervision. The strength of the academic societies should be given more authority to regulate and enhance the system of standards that organizations must follow. To practice scientific prevention and control of the outbreak and precise measures, CPMA took urgent measures to collect and approve 20 standards of the organization for prevention and control of the outbreak, which cover rapid detection of the COVID-19 virus, whole-genome sequencing, and other lab detection technologies; sample storage, transportation and other aspects of biosafety; disinfection specifications and environmental sanitation in hospitals, inpatient wards, neighborhoods, schools, mobile hospitals, temporary toilets, and other places during the outbreak; health management during quarantine; etc. Participation of members of the academic committees in standardization and other experts with wide representation should be encouraged during the drafting of the standards, consultation, technical review and other stages, and Internet-based information platforms should be used to promote wide participation, to carry out the principle of “Consultation and Consensus” in standardization.

Reinforcing the Publicity of the Standards

The impact of the standards relies on their implementation. Publicity, training, and explanation of standardization policies, compilation of standards, and standards for communicable diseases and other related areas should be conducted frequently in multiple forms and dimensions and at multiple levels to enhance standardization awareness, knowledge, and usage.

Promoting the Internationalization of the Standards for Communicable Diseases

As the COVID-19 pandemic spread worldwide, Chinese experiences in prevention and control were recognized and applied by many countries in international cooperative efforts. Compilation, translation, and publication of standards for communicable diseases in foreign languages should be continued and better funded, and working mechanisms for cooperation between organizations establishing health standards in China, such as the World Health Organization (WHO) and ISO be explored, to promote mutual recognition of the standards for communicable diseases in these international organizations. With standards for communicable diseases as an important starting point for the promotion of construction of the community with a shared future for mankind in terms of healthcare, plans for internationalization of the standards for communicable diseases from China in global affairs and events should be developed to play an active role in formulation of important international standards.

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Outbreak Reports

Occupational Mercury Exposure at a Thermometer Facility — Jiangsu Province, 2019

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Summary

What is already known about this topic?

Mercury is still used in the manufacture of some thermometers in China. This may pose health risks if exposure is not properly prevented and controlled.

What is added by this report?

An onsite investigation of a workplace at a thermometer facility in Jiangsu Province in 2019 found heavily elevated airborne and urinary mercury levels among a massive number of workers exposed to mercury. Traditional and obsolete technology as well as inadequate protection measures for occupational hazards caused this high level of exposure.

What are the implications for public health practice?

Employers at thermometer producing facilities need to adopt effective protection measures and implement strict management. Monitoring exposure, adopting better engineering controls, diligent cleaning, and providing recommended personal protective equipment (PPE) along with training to their workers properly can alleviate mercury exposure at their facilities. In addition, transitioning to mercury-free thermometers would eliminate the risk of mercury exposure.

On November 25, 2019, the Jiangsu Health Commission contacted the Jiangsu Provincial CDC (JSCDC) seeking assistance for an investigation of mercury exposure among workers at a thermometer manufacturing facility. For 3 consecutive years, nearly all workers who were tested had urine mercury levels far exceeding the biological exposure limit (BEL) of 35.0 µg/g creatinine (Cr) required by China's National Health Commission (NHC). Thermometers were composed of a slender glass tube containing liquid mercury. During production, inhalation of mercury vapor and direct contact of mercury via skin were likely the main routes of exposure. JSCDC investigators took industrial hygiene sampling, obtained ventilation measurements, and observed field conditions as well as

work practices. Inorganic mercury vapor concentrations were found to exceed the occupational exposure limits (OELs) at 15 of 18 workstations in the small thermometer department. Workers wore inadequate personal protective equipment (PPE). Moreover, the facilities and measures for controlling occupational hazards should be upgraded so that the released vapors can be effectively isolated or removed. Employees who are at risk for mercury exposure should have access to and consistently wear NHC-approved respirators to protect against mercury vapor and nitrile or other suitable gloves to prevent contact exposure.

INVESTIGATION AND RESULTS

On December 3, 2019, JSCDC and the local occupational health administration carried out a supervised investigation to assess the work environment, interview employees, and perform mercury monitoring at the workplace. First, the urine testing results for three consecutive years were collected. A case of mercury exposure was defined as a urinary mercury level above the NHC BEL of 35.0 µg/g Cr. Workers who received confirmation of mercury exposure were referred to an occupational disease diagnosis agency for further evaluation. Subsequently, the air mercury exposure level of workers in the workplace was tested by obtaining air samples near the individual breathing zone with a low-flow pump and analyzed using atomic fluorescence spectrometry. The NHC currently recommends that exposure to inorganic mercury be limited to 0.02 mg/m³ as an 8-hour time-weighted average (TWA), as well as 0.04 mg/m³ as a short-term exposure limit (STEL). In addition, ventilation measurements were performed using a TSI 8347 (TSI, Inc., USA) air velocity meter at workstations with local exhaust ventilation systems. All workers were required to participate in a survey including the employment history, PPE use, and medical and social history.

The enterprise under investigation was established in 2008 to manufacture glass thermometers and acupuncture needles for clinical use. The company employed approximately 120 workers involved in 2 assembly lines (trigonal and internal scaling) of glass thermometers (Table 1). Nearly 15 million small thermometers were produced each year in the manufacturing zone, which occupies 6,150 square meters (m²) covering 2 floors of the plant. Several operations were contained in the process of manufacturing thermometers except for glass tubes, which were pre-manufactured by another company and purchased for further assembly. In brief, reservoir bulbs were blown at one end of cut-glass tubes and were then filled with liquid mercury. Any excess liquid

was driven out with heat and the tubes were flame-sealed to a certain length. The sealed tubes were calibrated, mounted on a scale, assembled on or in a holder as necessary, and packaged. Trigonal and internal scaling thermometers were the two predominant models produced at this company.

Initially, urine mercury (standardized to urinary Cr) results were collected from 2016–2018 (Table 2). The median level for workers exposed to mercury was 670.4 (97.9–1705.7) µg/g Cr in 2016, 311.1 (37.3–995.2) µg/g Cr in 2017, and 160.7 (2.9–899.3) µg/g Cr in 2018. With urine mercury decreasing year by year on average, it was still far beyond the normal reference value. Evidence of chronic mercury poisoning commences at levels in excess of 35 µg/g Cr. By

TABLE 1. The results of air sampling for inorganic mercury in the thermometer factory workplace — Jiangsu Province, 2019.

Division	Job Category	Air Hg concentration (mg/m ³)		Judgement
		C _{TWA}	C _{STEL}	
Trigonal thermometer	Distillation	0.083	0.135	unqualified
	Fill and degas	0.057	0.072	unqualified
	Contractor	0.045	0.053	unqualified
	Centrifuge	0.067	0.102	unqualified
	Inspector	0.079	0.107	unqualified
	Pull-Top	0.052	0.062	unqualified
	Pointer	0.091	0.074	unqualified
	Scaling	0.066	0.074	unqualified
	Printing and baking	0.063	0.063	unqualified
	Package	0.060	0.070	unqualified
Internal scaling thermometer	Fill and degas	0.030	0.037	unqualified
	Contractor	0.028	0.028	unqualified
	Pointer	0.024	0.028	unqualified
	Scaling	0.019	0.020	qualified
	Inserting marker	0.016	0.019	qualified
	Sealing	0.020	0.024	qualified
	Inspector	0.028	0.029	unqualified
	Package	0.029	0.028	unqualified
Flat handle needle (free of Hg)	Embossing	0.010	0.022	qualified
	Pulling and cutting	0.007	0.010	qualified
	Inspector	0.009	0.011	qualified
	Storage	0.019	0.026	qualified
Hg free thermometer (free of Hg)	Glass tube	0.010	0.012	qualified
	Fill and degas	0.004	0.005	qualified
	Pointer	0.018	0.020	qualified
	Combination	0.016	0.031	qualified

Abbreviation: Hg=mercury, C_{TWA}=concentration-time weighted average, C_{STEL}=concentration-short term exposure limit.

TABLE 2. Urinary mercury levels by current job category from workers at the thermometer facility — Jiangsu, 2019.

Division	Job category	Urine Hg (µg/g Cr): Median (Range)			Excess ratio (%)		
		2016	2017	2018	2016	2017	2018
Trigonal thermometer	Fill and degas	906.4(401.0–1460.8)	532.4(527.9–886.0)	401.7(291.4–507.6)	100	100	100
	Contractor	791.9(444.6–1705.7)	335.5(297.5–920.2)	374.1(55.6–846.7)	100	100	100
	Centrifuge	377.5	624.6	113.0	100	100	100
	Inspector	572.8(191.0–726.9)	310.8(139.4–434.7)	78.1(69.2–232.1)	100	100	100
	Pull-Top	460.4	439.6	324.1	100	100	100
	Pointer	908.9(315.3–1390.4)	208.9(80.5–726.9)	257.7(161.1–817.6)	100	100	100
	Scaling	859.4(545.8–1449.2)	364.0(66.2–995.2)	345.6(2.9–610.1)	100	100	87.5
	Printing and baking	665.0(97.9–1175.5)	318.3(95.2–639.2)	249.2(62.8–899.3)	100	100	100
	Package	404.6(347.1–526.7)	316.4(187.6–596.7)	160.3(141.8–366.3)	100	100	100
Internal scaling thermometer	Fill and degas	841.5(289.3–1440.7)	378.6(165.6–805.9)	251.3(85.9–423.3)	100	100	100
	Contractor	445.6	130.7	128.4	100	100	100
	Pointer	807.7(190.8–1393.6)	698.0(621.5–894.7)	237.8(87.1–413.2)	100	100	100
	Scaling	1210.4(260.6–1243.0)	260.0(58.4–346.6)	39.2(12.0–167.3)	100	100	71.4
Internal scaling thermometer	Inserting marker	463.8	171.2	152.1	100	100	100
	Sealing	208.5	340.3	76.3	100	100	100
	Inspector	1334.4	249.8(196.4–855.6)	108.0(17.9–159.3)	100	100	66.7
	Package	346.2(230.6–461.8)	242.9(115.4–971.0)	84.2(47.5–120.7)	100	100	100
N/A	Jobs free of Hg	N/A	N/A	0.11(0.01–1.08)	N/A	N/A	0

Abbreviation: Hg=mercury, Cr=creatinine, N/A=not applicable.

contrast, unexposed individuals rarely exhibit mercury-in-urine concentrations in excess of 1.0 µg/g Cr.

Then according to GBZ 159-2004 (Specifications of air sampling for hazardous substances monitoring in the workplace) (1) and GBZ/T 300.18-2017 (Determination of toxic substances in workplace air — Part 18: Mercury and its compounds) (2), ambient air sampling of the workplace was implemented using a GilAir-5 (Sensidyne, Inc., USA) sampler (0.5 L/min). All production areas of the facility were sampled on whether there was direct mercury exposure or not. Overall, it was indicated that inorganic mercury vapor concentrations ranged from 0.016 to 0.091 mg/m³ (median: 0.049 mg/m³) for concentration-time weighted average (C_{TWA}) and 0.019 to 0.135 mg/m³ (median: 0.058 mg/m³) for concentration-short term exposure limit (C_{STEL}) (Table 1). That is, approximately 83.3% (15/18) of the work positions exceeded the limits given by GBZ 2.1-2019 (Occupational exposure limits for hazardous agents in the workplace — Part 1: Chemical hazardous agents) (3). However, the sampling results among workers in mercury-free sites only averaged 0.01 mg/m³ for C_{TWA} and 0.016 mg/m³ for C_{STEL}.

The workshop deployed two axial fans creating rated airflows of 14,000 m³/h and 7,670 m³/h. The air purification system was formed by connecting the exhaust hoods above different positions with pipelines and equipped with active carbon to absorb mercury vapor, while waste gases from combustion were extracted and directly discharged outside. The actual airflows created by the exhaust system were found to be unsatisfactory as the wind speed at control points under each hood was far below the capture velocity of 200 fpm (1.016 m/s) necessary to control mercury vapors (Supplementary Table S1 available in <http://weekly.chinacdc.cn/>). Due to the small size and excessive height of the hood opening, the design of the exhaust hood for mercury distillation was insufficient, which affected the actual protective ability of the equipment (Figure 1A).

Other control measures applied throughout the factory include isolating equipment, submerging broken thermometers in trays of water, and conducting a continuous clean-up program. During the field investigation, some engineering facilities appeared to run in poor condition. The size of the isolation cabinet did not fit well with the degassing machine, leaving doors not fully closed (Figure 1B). Furthermore,

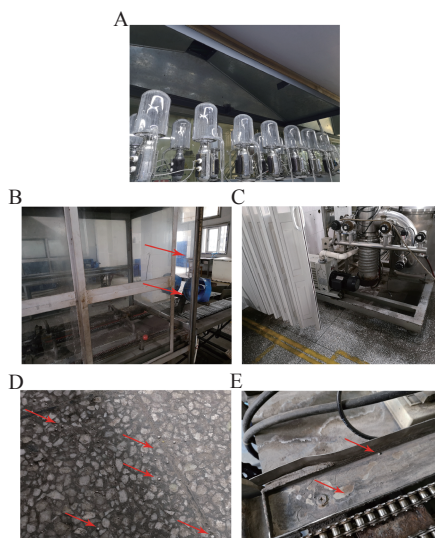


FIGURE 1. The working environment and status of engineering control measures during field investigations at a thermometer facility in Jiangsu Province in 2019. (A) Exhaust hoods for mercury distillation; (B) The door of isolation cabinet did not fit the degassing machine (red arrows indicate a large gap between the door and its frame); (C) A plastic screen was half-open in front of the filling machine; (D) Spills of mercury on the ground (red arrows indicate mercury droplets); (E) Small droplets of mercury on the machine (red arrows indicate mercury droplets)

though a plastic screen was set up in front of the filling machine, it was not effectively enclosed (Figure 1C).

The employer distributed disposable active carbon facepieces for workers exposed to mercury before 2019. Since then, half facepieces (3M Reusable Respirator 7502 adapted with 3M Mercury Vapor Cartridge 6009 and 3M Particulate Filter 5N11) were provided. The cartridge and particulate filter were planned to be replaced once a month and once a week, respectively. However, owing to a lack of supervision on PPE wearing, it was found the respiratory protective masks did not fit several workers well.

During our survey, we realized that occupational safety and health regulations were not satisfactorily implemented. Small droplets of mercury contamination were obviously visible on the grounds and machines (Figure 1D–1E).

DISCUSSION

Mercury can evaporate at room temperature and at higher rates at higher temperatures (4). Environmental data demonstrated that workers had significant exposure to inorganic mercury vapor at the

thermometer plant. Many samples, including individuals and environments, exceeded the NHC compulsory standard of 0.02 mg/m^3 (TWA) and/or 0.04 mg/m^3 (STEL). In addition, continual urinalysis accurately depicted increasing trends in an employee's mercury absorption, which manifested an increased risk of adverse health effects to workers. Thus, the occupational hazards of mercury could not be overlooked, especially in certain outdated industries.

For the sake of minimizing occupational health risks, the most effective measure was to renovate the production process, such as taking indium as a substitute for mercury (5). But the employer's top priority was to enhance engineering and administrative controls to reduce mercury contamination. Urine mercury and personal breathing-zone mercury vapor levels were recommended to be periodically monitored. Local ventilation devices need to be repositioned, better enclosed, or otherwise modified until a minimum capture velocity of 200 fpm can be achieved and maintained. When respirators were used, a formal respiratory protection program comprising of written standard operating procedures (SOP) must be established in accordance with GB 2626-2019 (Respiratory protection — Non-powered air-purifying particle respirator) (6). The procedures should cover specific requirements for respirator use, selection, cleaning, inspection, maintenance, training, and supervision. Moreover, spills or droplets of mercury must be immediately cleaned up with a vacuum system equipped with an absorbent filter. All operations involving mercury should be performed over impermeable surfaces without crevices. Most importantly, the enterprise must take the primary responsibility of occupational health management and reinforce daily supervision. Workers must receive sufficient training against the health hazards of mercury, as well as the work practices and personal hygiene measures necessary to avoid occupational hazards. This training is extremely important for new employees to prevent the development of sloppy habits in handling mercury. Through these measures, the level of mercury exposure can be lowered.

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SUPPLEMENTARY TABLE S1. Ventilation detection on local exhausting devices at the thermometer facility in Jiangsu, 2019.

Division	Job/Location	Local exhausting	Wind velocity (m/s)		
			1	2	3
Trigonal thermometer	Distillation	Exhaust hood 1	0.02	0.03	0.02
		Exhaust hood 2	0.03	0.02	0.03
		Bulb machine	0.42	0.43	0.43
	Fill and degas	Degassing machine 1	0.17	0.18	0.17
		Degassing machine 2	0.13	0.14	0.12
	Contractor	Contractor machine	0.23	0.25	0.24
	Pull-Top	Pull-Top machine	0.20	0.21	0.22
Internal scaling thermometer	Sealing	Sealing machine 1	0.03	0.04	0.04
		Sealing machine 2	0.18	0.19	0.19

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