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Spatiotemporal variations in the incidence of bacillary dysentery and long-term effects associated with meteorological and socioeconomic factors in China from 2013 to 2017

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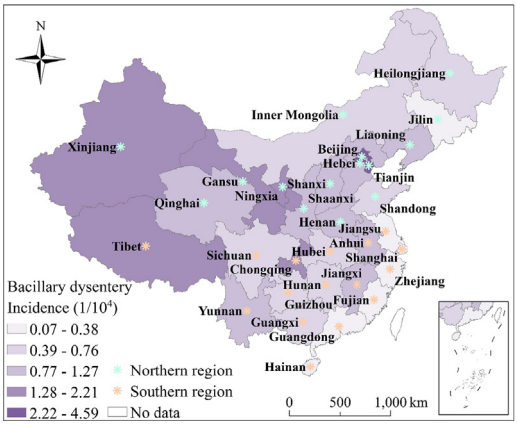
HIGHLIGHTS

- The incidence of bacillary dysentery has significant spatiotemporal heterogeneity.
- The bacillary dysentery incidence highly correlates with average temperature and per capita GDP in northern China.
- Bacillary dysentery is highly correlates with average temperature and number of health technicians in southern China.

GRAPHICAL ABSTRACT



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ABSTRACT

Bacillary dysentery is a global public health problem that exhibits manifest spatiotemporal heterogeneity. However, long-term variations and regional determinant factors remain unclear. In this study, the Bayesian space-time hierarchy model was used to identify the long-term spatiotemporal heterogeneity of the incidence of bacillary dysentery and quantify the associations of meteorological factors with the incidence of bacillary dysentery in northern and southern China from 2013 to 2017. GeoDetector was used to quantify the determinant powers of socioeconomic factors in the two regions. The results showed that the incidence of bacillary dysentery peaked in summer (June to August), indicating temporal seasonality. Geographically, the hot spots (high-risk areas) were distributed in northwestern China (Xinjiang, Gansu, and Ningxia) and northern China (including Beijing, Tianjin, and Hebei), whereas the cold spots (low-risk areas) were concentrated in southeastern China (Jiangsu, Zhejiang, Fujian, and Guangdong). Moreover, significant regional differences were found among the

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Northern and southern China
Bayesian space-time hierarchy model
GeoDetector

meteorological and socioeconomic factors. Average temperature was the dominant meteorological factor in both northern and southern China. In northern and southern China, a 1 °C increase in the average temperature led to an increase of 1.01% and 4.26% in bacillary dysentery risk, respectively. The dominant socioeconomic factors in northern and southern China were per capita gross domestic product and the number of health technicians, with *q* statistic values of 0.81 and 0.49, respectively. These findings suggest that hot, moist, and overcrowded environments or poor health conditions increase the risk of bacillary dysentery. This study provides suggestions and serves as a basis for surveillance efforts. Further, the suggestions may aid in the control of bacillary dysentery and in the implementation of disease prevention policies.

1. Introduction

Bacillary dysentery is an enteric infectious disease caused by different species of *Shigella* (*Shigella dysenteriae*, *Shigella flexneri*, *Shigella boydii*, *and Shigella sonnei*), a group of gram-negative, non-spore-forming, rod-shaped bacteria (Kotloff et al., 2018; Livio et al., 2014). This disease is mainly transmitted through the fecal-oral route contaminated food and water, or contact with an infected person (Lee et al., 1991; Mather et al., 2014). Typically, the symptoms include diarrhea, fever, tenesmus, and presence of mucus and blood in the stool (Simini, 1996).

Bacillary dysentery remains a common global public health problem in both developed and developing countries (Ombelet et al., 2018; Vincent et al., 2014). It causes approximately 125 million diarrhea episodes each year and approximately 160,000 deaths worldwide (Bardhan et al., 2010). In China, although the incidence of bacillary dysentery has declined in the past few decades, it remains the third most reported infectious disease, especially in underdeveloped areas (Liu et al., 2020). Given that the pathogenic mechanism of bacillary dysentery is not yet completely clear, it may cause an epidemic at any time. Therefore, determining the spatiotemporal heterogeneity of the influence of bacillary dysentery and quantifying the determinant powers of the meteorological and socioeconomic factors from a long-term perspective in different regions would yield suggestions for bacillary dysentery risk control and disease-prevention policies, which need to be adapted to local conditions.

Numerous studies have shown that meteorological factors have significant effects on the transmission of bacillary dysentery. For example, in Beijing, the incidence of bacillary dysentery peaks in summer (from June to September) (Xu et al., 2017). A study conducted in Jinan, a city in northern China, showed that the risk peaks in the summer and fall seasons (Zhang et al., 2008). In India, the incidence of bacillary dysentery peaks mostly in the summer season (Moors et al., 2013). In Dhaka, a city in southern Asia, the incidence peaks between September and December (Albert et al., 1999). Thus, based on these previous studies, we suggest that meteorological factors evidently have an effect on the temporal heterogeneity of the incidence of bacillary dysentery (Li et al., 2015; Liu et al., 2017; Liu et al., 2019).

Furthermore, the incidence of bacillary dysentery also presents clearly non-homogeneous spatial characteristics. Some studies have demonstrated that the incidence of bacillary dysentery is closely related to socioeconomic factors because an overcrowded environment or poor health conditions along with an inadequate infrastructure would promote an increase in the risk of bacillary dysentery. For example, Kotloff et al. (2018) reported that the incidence of bacillary dysentery in China was higher than that in many developed countries, such as the United States, England, Australia, and France. Chang et al. (2016) found that the incidence of this disease was higher in northwestern China (Tibet, Ningxia, and Xinjiang) and northern China (Beijing and Tianjin) than in other regions of China. Similarly, Xu et al. (2017) demonstrated that Beijing and Tianjin, two developed cities, ranked the top two among China's cities for bacillary dysentery risk.

To the best of our knowledge, few studies have analyzed the spatiotemporal heterogeneity of the incidence of bacillary dysentery from a long-term perspective and quantified the effects of meteorological and socioeconomic factors on the incidence of this disease in northern and southern China. Therefore, this study aimed: 1) to explore the province-level spatiotemporal heterogeneity of the incidence of bacillary dysentery from a long-term perspective in China, 2) to quantify the determinant powers of meteorological and socioeconomic factors in identifying the regional determinate factors in northern and southern China, and 3) to identify the hot and cold spots and the associated mechanisms therein.

2. Methods

2.1. Study area

Some areas that are located in the eastern and northern part of China and extend to the sea have great climatic variation across the coast to the inland areas because of the effects of the geological environment (Fig. 1). Moreover, the natural conditions, geographical features, agricultural production, and living customs are clearly different between the north and south regions of the Huai River-Qinling Mountains. Based on these differences, in this study, China was divided into two regions: northern (Beijing, Tianjin, Hebei, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Ningxia, Shandong, Henan, Shanxi, Shaanxi, Gansu, Qinghai, and Xinjiang) and southern (Jiangsu, Anhui, Hubei, Chongqing, Sichuan, Tibet, Yunnan, Guizhou, Hunan, Jiangxi, Guangxi, Guangdong, Fujian, Zhejiang, Shanghai, and Hainan). This study aimed to estimate the subnational magnitude of influence of meteorological and socioeconomic factors, using the Bayesian space-time hierarchy model and GeoDetector model.

2.2. Data sources

Monthly data of bacillary dysentery cases for the period January 2013 to December 2017 were obtained from the Data Center of China Public Health Science. Monthly data of meteorological variables, namely average temperature, relative humidity, precipitation, air pressure, wind speed, and hours of sunlight, for the same period were collected from the China Meteorological Data Sharing Service System (Fig. 2). Yearly data of province-level socioeconomic variables, namely per capita gross domestic product (GDP), illiteracy rate, population density, number of health beds, number of health technicians, and total waste water discharged, were acquired from the governmental economic Statistical Yearbooks of China (Fig. 2).

2.3. Statistical analysis

In this study, the Bayesian space-time hierarchy model (BSTHM) was used to investigate the spatiotemporal heterogeneity of the influence of bacillary dysentery in China and to quantify the associations between the meteorological factors and the influence of bacillary dysentery from a long-term perspective in northern and southern China. GeoDetector was then used to quantify the determinant powers of the socioeconomic factors that affect bacillary dysentery in northern and southern China and the spatiotemporal stratified heterogeneity of the incidence of bacillary dysentery.

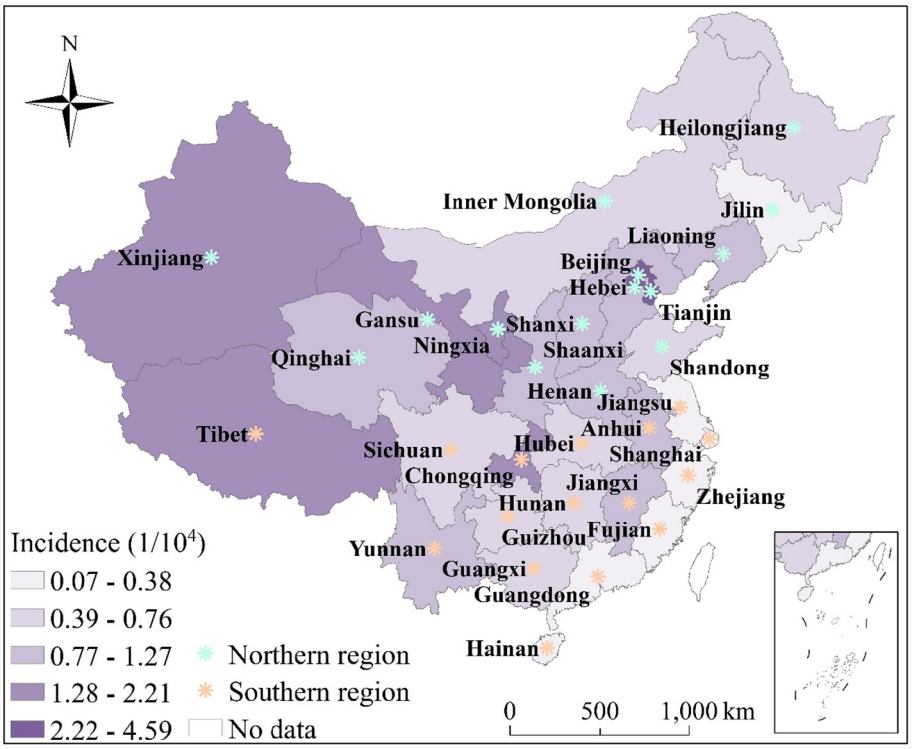

Fig. 1. Monthly incidence of bacillary dysentery during 2013–2017 in China.

2.3.1. Bayesian space-time hierarchy model

BSTHM was used to reveal the spatiotemporal heterogeneity of the incidence of bacillary dysentery and quantify the associations between the meteorological factors and the incidence of bacillary dysentery. Specifically, a BSTHM with Poisson distribution was used to model the number of cases y_{it} and the risk population n_i, as follows:

$$y_{it} \sim Poisson(n_{it}u_{it})$$

$$log(u_{it}) = \alpha + s_i + (b_0t^* + v_t) + b_{1i}t^* + \varepsilon_{it} \quad (1)$$

where u_{it} is the spatiotemporal risk of bacillary dysentery in province i ($i = 1, \ldots, 31$) and month t ($t = 1, \ldots, 60$), and α is the overall logarithm of bacillary dysentery risk in China. The index s_i is the spatial disease risks in province i, which is affected by some relatively stable factors in the study period, such as the local geographic environment, economic conditions, and medical resources. The temporal term $(b_0t^* + v_t)$ expresses the overall time trend with $v_t \sim N(0, \sigma_v^2)$ and t^* represents the

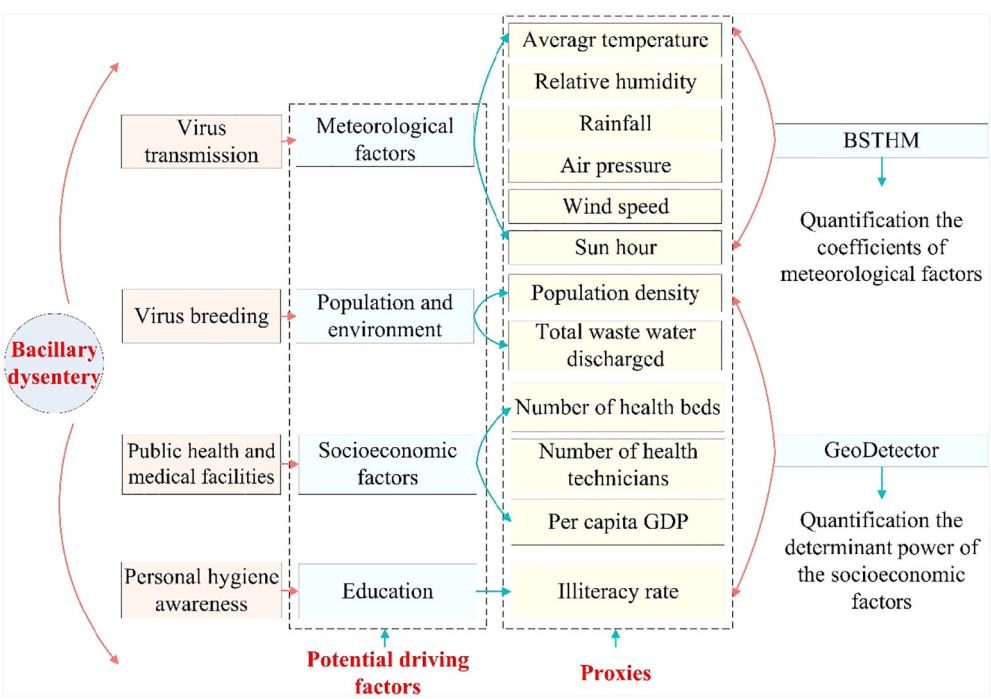

Fig. 2. Potential driving factors of bacillary dysentery risk and the methodology used in this study.

mid-observation period. The term b_{1i} captures the departure extent from b_0 for province i; for example, if $b_{1i} \geq 0$, then the local temporal variation intensity is higher than the overall temporal variation trend (Li et al., 2014). The term $\varepsilon_{1i} \sim N(0, \sigma_\varepsilon^2)$ is the Gaussian random noise variable (Gelman, 2006).

The study area was further classified into hot, cold, and other spots according to a specific 2-stage criteria (Richardson et al., 2004). In the first stage, a county was defined as a hot spot for posterior probability p (exp $(s_i) > 1$ | data) was greater than 0.90 and as a cold spot if p (*exp* $(s_i) > 1$ | data) was less than 0.10. The remaining counties were defined as neither hot nor cold spots. In the second stage, based on the posterior probability of local slope *exp* (b_{1i}), the areas corresponding to each risk category in the first stage were further classified into one of three trend patterns. A faster decreasing trend compared to the overall trend was assumed to be present if p $(b_{1i} > 0 \mid h_i$, data) ≥ 0.90, if it was less than 0.10, then a slower decreasing trend was assumed to be present, a local trend approximating the overall trend if $0.1 < p$ $(b_{1i} > 0 \mid h_i$, data) < 0.9. Thus, there were a total of nine categories (three risk categories × three trend categories). All analyses were performed using WinBUGS 14 (Lunn et al., 2000).

2.3.2. GeoDetector q statistics

The GeoDetector model uses the q-statistic to quantify the determinant powers of the influencing factors from spatiotemporal perspectives and the stratified heterogeneity of a dependent variable (temporal and spatial heterogeneity of the influence of bacillary dysentery) (Wang et al., 2010; Wang et al., 2016; Wang and Xu, 2017). It is expressed as follows:

$$q = 1 - \frac{1}{N\sigma^2}\sum_{h=1}^{L} N_h \sigma_h^2 \tag{2}$$

where q is the determinant powers of socioeconomic factors. Its value ranges from 0 to 1, denoting the determinant power of a risk factor or a target variable's heterogeneity. h ($h = 1, 2, \ldots, L$) represents the spatial stratification of the single factor X. N and N_h are the numbers of units in the entire area and stratum h, respectively. σ^2 and σ_h^2 are the variances of the bacillary dysentery in the entire area and stratum h, respectively.

3. Results

3.1. Spatiotemporal heterogeneity

Over the 60 months between January 2013 and December 2017, a total of 710,202 cases of bacillary dysentery were reported in 31 provinces in China. The highest number of cases was reported in summer (June to August), with a monthly incidence of 1.87 per 10,000 people, while the lowest number of cases was reported in winter (December to February), with a monthly incidence of 0.57 per 10,000 people.

Geographically, the spatial relative risks (RRs) calculated from BSTHM differed substantially, with a q statistic value of 0.50, indicating apparent spatial stratified heterogeneity. Fig. 3 shows the spatial RRs of bacillary dysentery at the province level from 2013 to 2017. The spatial RRs of provinces in northwestern China and in the Beijing-Tianjin-Hebei region were higher, indicating that these regions have relatively higher risks of bacillary dysentery. Conversely, provinces in southeastern China mainly presented relatively lower disease risks.

Additionally, the overall temporal variation presented a decreasing trend (Fig. 4), and there was significant seasonality, in which the highest disease risk occurred in summer (June to August) and the lowest disease risk occurred in winter (December to February). These findings indicated that the risk of bacillary dysentery has apparent temporal stratified heterogeneity, as showed by a q statistic value of 0.48.

We classified the 31 provinces into 3 categories, namely, hot spots, cold spots, and neither hot nor cold spots. Among the 31 provinces in China, 7 (22.58%) and 5 (16.13%) provinces were identified as hot and cold spots, respectively. The other 19 (61.29%) provinces were classified as neither hot nor cold spots. As shown in Fig. 5, the hot spot areas were mainly distributed in northwestern China (Xinjiang, Gansu, and Ningxia) and northern China (Beijing, Tianjin, and Hebei), while the

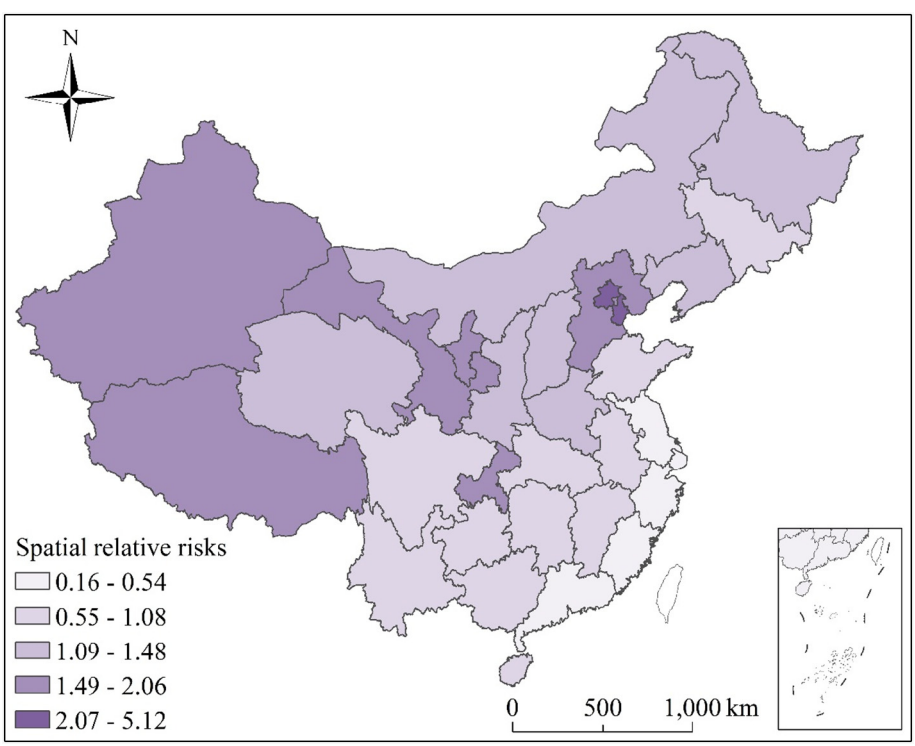

Fig. 3. Spatial relative risks of bacillary dysentery in each province of China.

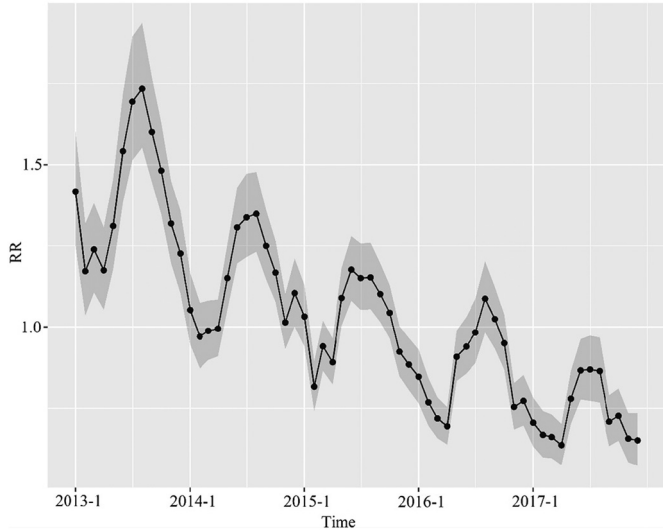

Fig. 4. Monthly temporal relative risks of bacillary dysentery from 2013 to 2017.

cold spots were mainly distributed in the southeastern provinces (Jiangsu, Zhejiang, Fujian, and Guangdong).

Among the seven hot spots, Beijing, Tianjin, Hebei, Ningxia, and Gansu, showed a faster decreasing trend than the overall decreasing trend. Consequently, the risk in these regions will likely be lower than the overall risk, and they will become cold spots in the future. By contrast, Xinjiang and Hainan showed a slower decreasing trend than the overall decreasing trend; thus, these provinces will likely continue to have a high risk and remain hot spots in the future. The public health department should therefore focus on these provinces (Fig. 5).

Among the five cold spots, Zhejiang exhibited a faster decreasing trend than the overall decreasing trend, while Shanghai and Fujian showed slower decreasing trends. The risks in these provinces will be lower than the overall risk in the future. Finally, the trends in the other cold spots, Jiangsu and Guangdong, were consistent with the overall trend. Thus, the current risk level in these provinces will remain constant in the future (Fig. 5).

Among counties that were neither hot nor cold spots, Heilongjiang, Liaoning, Henan, Chongqing, Qinghai, and Tibet showed faster local decreasing trends, while Jilin, Shandong, Hunan, Guizhou, and Yunnan showed slower decreasing trends, indicating that these provinces will likely become cold spots in the future. Finally, the trends in Inner Mongolia, Shanxi, Shaanxi, Sichuan, Anhui, Hubei, Jiangxi, and Guangxi, were consistent with the overall trend (Fig. 5).

3.2. Risk factor analysis

Bacillary dysentery risk showed apparent spatial heterogeneity and seasonal changes (Figs. 2 and 4), indicating that both meteorological and socioeconomic factors played a dominant role in the spatial heterogeneity and temporal evolution of the disease. The factors with the highest determinant powers in northern China were average temperature and per capita GDP, while the factors in southern China with the highest determinant powers were average temperature and number of health technicians.

Particularly, in northern China, average temperature presented the most dramatic relationship and was positively associated with the influence of bacillary dysentery. A 1 °C increase in average temperature was related to an increase of 1.01% (95% *CI*: 0.30–1.90) in the risk of bacillary dysentery (RR: 1.01; 95% *CI*: 1.00–1.02) (Table 1).

The other potential meteorological risk factors also had a non-negligible effect. For example, a 1-h increase in the total hours of sunlight was related to a 0.14% (95% *CI*: 0.07–0.21) increase in bacillary dysentery risk, with a corresponding RR of 1.01 (95% *CI*: 1.00–1.02) (Table 1).

A positive association was found between precipitation and bacillary dysentery risk. A 1-mm increase was related to a 0.05% (95% *CI*: 0.01–0.09) increase in bacillary dysentery risk, with a corresponding

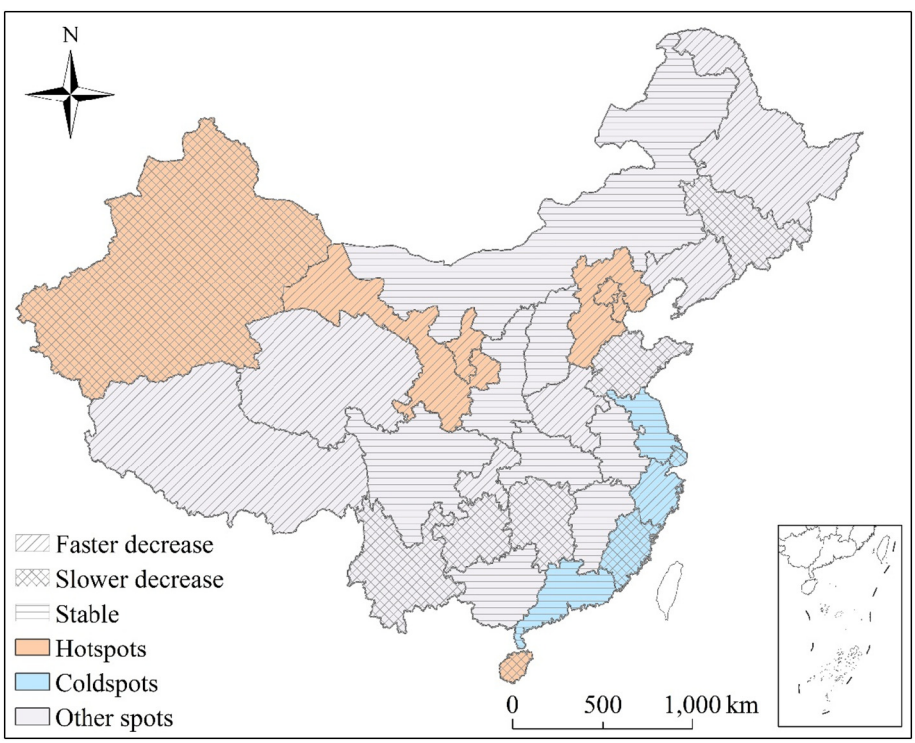

Fig. 5. Distribution of hot and cold spots of bacillary dysentery in China.

Table 1
Quantified posterior mean values and relative risks (RRs) of all meteorological factors in the northern regions of China.

Meteorological factors	Posterior mean (95% CI) (100%)	RR (95% CI)
Average temperature (°C)	1.01 (0.30, 1.90)	1.01 (1.00, 1.02)
Relative humidity (%)	−0.17 (−0.51, 0.18)	0.998 (0.99, 1.00)
Air pressure (hPa)	0.03 (−0.07, 0.14)	1.00 (0.99, 1.001)
Precipitation (mm)	0.05 (0.01, 0.09)	1.00 (0.99, 1.001)
Sun hour (h)	0.14 (0.07, 0.21)	1.001 (1.00, 1.002)
Wind speed (m/s)	−0.41 (−1.47, 0.69)	0.99 (0.98, 1.01)

Table 3
Quantified posterior mean values and relative risks (RRs) of all meteorological factors in the southern regions of China.

Meteorological factors	Posterior mean (95% CI) (100%)	RR (95% CI)
Average temperature (°C)	4.26 (3.87, 4.64)	1.04 (1.03, 1.05)
Relative humidity (%)	0.24 (−0.02, 0.50)	1.00 (0.99, 1.01)
Air pressure (hPa)	−0.28 (−0.32, −0.23)	0.997 (0.99, 1.00)
Precipitation (mm)	0.01 (−0.01, 0.03)	1.001 (1.00, 1.01)
Sun hour (h)	0.02 (−0.02, 0.07)	1.00 (0.99, 1.01)
Wind speed (m/s)	−1.65 (−2.74, −0.60)	0.98 (0.97, 0.99)

RR of 1.00 (95% *CI*: 0.99–1.001). Additionally, the estimated coefficients for relative humidity, air pressure, and wind speed were not significant (Table 1).

The results of the socioeconomic effect in GeoDetector indicated that socioeconomic factors also play an important role in the transmission of bacillary dysentery. For example, in northern China, the determinant power of per capita GDP was the strongest, with a q value of 0.81. The determinant powers of population density and the number of medical beds were 0.78 and 0.75, respectively, the determinant powers of total waste water discharged and illiteracy rate were 0.49, and 0.34, respectively; and the determinant power of the number of health technicians was 0.33 (Table 2).

In southern China, average temperature had the most significant effect on the incidence of bacillary dysentery. A positive association was found between average temperature and bacillary dysentery risk: a 1 °C increase was related to a 4.26% (95% *CI*: 3.87–4.64) increase in bacillary dysentery risk, with a corresponding RR of 1.04 (95% *CI*: 1.03–1.05) (Table 3).

A negative association was found between wind speed and bacillary dysentery. A 1-m/s increase was related to a 1.65% (95% *CI*: −2.74 to −0.60) decrease in bacillary dysentery risk, with a corresponding RR of 0.98 (95% *CI*: 0.97 0.99) (Table 3).

Air pressure also presented a negative association with the risk of bacillary dysentery. A 1-hPa increase was related to a 0.28% (95% *CI*: −0.32 to −0.23) decrease in bacillary dysentery risk, with a corresponding RR of 0.997 (95% *CI*: 0.99 to 1.00). Additionally, the estimated coefficients for relative humidity, precipitation, and hours of sunlight were not significant (Table 3).

The results of the socioeconomic factors in GeoDetector indicated that the determinant power of the number of health technicians was the strongest, with a q value of 0.49. The determinant powers of population density and total waste water discharged were 0.42 and 0.39, respectively; the determinant powers of the number of medical beds and per capita GDP were 0.35 and 0.33, respectively; and the determinant power of illiteracy rate was 0.29 (Table 2).

4. Discussion

Bacillary dysentery has remained a worldwide public health threat in recent years (Ombelet et al., 2018; Vincent et al., 2014). In this study, the spatiotemporal heterogeneity of the bacillary dysentery risk in China and the associations between meteorological factors and bacillary dysentery were examined using the BSTHM, and the effects of socioeconomic factors on bacillary dysentery were measured using GeoDetector model in northern and southern China. The results indicated that bacillary dysentery risk presents an obvious spatiotemporal heterogeneity and that the hot spots are distributed in northwestern China and in the Beijing-Tianjin-Hebei region. Moreover, in northern China, average temperature and per capita GDP were the dominant factors, whereas average temperature and the number of health technicians were the dominant factors in southern China.

The spatial distribution of bacillary dysentery risk in China was not homogeneous. The provinces with the highest risk (hot spots) for this disease were clearly distributed in northwestern China (Xinjiang, Gansu, and Ningxia) and northern China (Beijing, Tianjin, and Hebei), demonstrating that socioeconomic conditions were closely related to bacillary dysentery risk. For example, the results of this study showed that the dominant socioeconomic factor was per capita GDP and the number of health technicians in northern and southern China, respectively. Additionally, different regions (e.g., Beijing compared with Hebei) have their own characteristics. The local associations between the meteorological and socioeconomic factors with bacillary dysentery in each region were quantified (Table S1). For example, in Beijing, the dominant factors were average temperature and per capita GDP, while in Hebei, average temperature, population density, and per capita GDP were the dominant factors. This foregoing indicates that due to regional differences, the dominant factors in each region may vary, denoting that economic level and population density are important factors in the transmission of bacillary dysentery, which is consistent with the findings of previous studies (Chang et al., 2016; Xu et al., 2017; Yan et al., 2017). Although the exact mechanism cannot be explained completely, this trend may be attributed, but not limited, to the following reasons. On the one hand, the economies in the northwestern regions are somewhat poorer than those in the other provinces of China; poor health conditions, inadequate infrastructure, and lack of personal hygiene awareness explain the high risk of bacillary dysentery in these areas (Chang et al., 2016). On the other hand, the economies in the Beijing-Tianjin-Hebei and Hainan are richer than other provinces in China. This condition contributes to their high population density and attracts a large migrant population from other regions; thus, an overcrowded environment promotes the transmission of bacillary dysentery (Ferrer et al., 2008).

The risk of bacillary dysentery presented apparent temporal heterogeneity. Meteorological factors are perceived as crucial environmental attributes, and it is widely accepted that they would influence the reproduction and spread of the bacteria that cause this disease (Cheng et al., 2017; Guan et al., 2008; Lee et al., 2015). This study showed that average temperature had the strongest positive association with bacillary dysentery risk in either northern or southern China, indicating that average temperature has a significant effect on the incidence of bacillary dysentery, which is in line coincides with the findings of other studies. For example, Gao et al. (2014) found that in Changsha, the incidence of bacillary dysentery would increase by 14.8% with each 1 °C increase in average temperature. Liu et al. (2019) conducted a study in Jinan and found that with each 1 °C increase in average temperature, the incidence of bacillary dysentery would increase by 11%. Similar results

Table 2
The q values (q_1, q_2) calculated for the association between bacillary dysentery and socioeconomic factors in northern and southern China, respectively.

Socioeconomic factors	q_1	q_2
Population density (person/km^2)	0.78**	0.42**
Number of medical beds (bed)	0.75**	0.35**
Total waste water discharged (10^{4}tons)	0.49**	0.39**
Per capita GDP (10^{4}CNY)	0.81**	0.33**
Illiteracy rate (100%)	0.34**	0.29**
Number of health technicians (per 10^3)	0.33**	0.49**

** Statistical significance level: 0.01.

were found in Peru, where bacillary dysentery risk increased by 8% with an increase of 1 °C in temperature (Checkley et al., 2000). In the United Kingdom, an increase in average temperature was associated with a 5% increase in bacillary dysentery risk (Tam et al., 2006). The potential mechanism involved may be that higher temperatures increase the exposure to pathogens, promote the breeding of the bacteria, and prolong the survival of bacteria in moderate environment and contaminated food or water (Checkley et al., 2000). Another mechanism could be that moderate and warm temperatures in the environment promote specific behavioral patterns in the population, such as engaging in more outdoor activities, which can increase contact among people and thereby facilitate the spread of bacillary dysentery infection.

Precipitation was found to have a positive association with the influence of bacillary dysentery in northern China. For example, the incidence of bacillary dysentery would increase by 0.05% with each 1-mm increase in precipitation, but this was not significant in southern China. These are both consistent and inconsistent with those of previous studies; for example, Ma et al. (2013) found that there was a positive correlation between the incidence of bacillary dysentery and precipitation, whereas Li et al. (2013) indicated that precipitation had a significantly negative effect on the incidence of bacillary dysentery. However, Zhang et al. (2007) reported that there was no strong association between precipitation and the incidence of bacillary dysentery. The potential mechanism involved may be that, on the one hand, the specific characteristics of different regions may result in different climate conditions, which have different effects on the epidemiology of bacillary dysentery. For example, the hot and moist environment in southern China starts earlier and lasts longer than that in northern China; thus, the bacteria in northern China are more sensitive to a hot and wet environment. On the other hand, precipitation affects water and food, which, in turn, influences the growth and reproduction of bacteria. Therefore, precipitation plays a role in promoting the transmission of this disease.

Furthermore, wind speed was found to have a negative association with the influence of bacillary dysentery in southern China, while this association was not significant in northern China. Notably, the effect of wind speed on bacillary dysentery has not been consistent in past studies. For example, Li et al. (2013) conducted a study and found that wind speed did not affect the incidence of bacillary dysentery, while Liu et al. (2019) demonstrated that, the incidence of bacillary dysentery would increase under low-wind speed conditions. The possible reasons for these phenomena could be that, first, the regional characteristics in different study areas may result in climate condition variations, which have different effects on the epidemiology of the influence of bacillary dysentery. Second, climate conditions are only some of the factors related to the risk of bacillary dysentery; human factors are also integral in the transmission of infectious diseases, such as differences in population density and medical infrastructure (Wu et al., 2016).

This study has some limitations that should be mentioned. First, spatial data at the provincial level were used, which might introduce an inevitable ecological fallacy (Jelinski and Wu, 1996), but this did not affect the long-term bacillary dysentery trends. Second, other risk factors for bacillary dysentery that were not included in the model may have introduced some uncertainties.

5. Conclusions

This study examined in detail the spatiotemporal heterogeneity of bacillary dysentery and quantified the determinant powers of meteorological and socioeconomic factors that affect the influence of bacillary dysentery from 2013 to 2017 in northern and southern China. The hot spots (high-risk areas) were distributed in northwestern China (Xinjiang, Gansu, and Ningxia) and northern China (Beijing, Tianjin, and Hebei), indicating that an overcrowded environment or poor health conditions along with an inadequate infrastructure promote the transmission of bacillary dysentery. An apparent seasonality was identified, with a higher risk mostly occurring in the summer. This indicated that a hot and wet environment can also influence the transmission of bacillary dysentery. Overall, these findings indicate that public health preparations should be promoted to prevent and control the potentially increased risk of bacillary dysentery under these weather and socioeconomic conditions while also considering the variations in different areas.

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CRediT authorship contribution statement

Xiangxue Zhang: Conceptualization, Methodology, Writing - original draft. **Xinchen Gu:** Visualization, Investigation. **Li Wang:** Investigation. **Yuke Zhou:** Data curation. **Zhentao Huang:** Data curation. **Chengdong Xu:** Data curation, Writing - review & editing. **Changxiu Cheng:** Writing - review & editing, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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