Preplanned Studies

Exploring the Association Between Infectious Diarrheal Diseases and Sea Surface Temperatures — Coastal Areas of China, 2009–2018

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Summary

What is already known about this topic?

Coastal areas of China have a higher reported incidence of other infectious diarrheal diseases (OIDD; excluding cholera, dysentery, typhoid, and paratyphoid) than inland areas of China.

What is added by this report?

The incidence of OIDD in high latitude coastal provincial-level administrative divisions (PLADs) near Bohai Sea was positively correlated with sea surface temperatures (SSTs), while in coastal PLADs near the South China Sea was negatively correlated.

What are the implications for public health practice?

The marine environmental risk factors acquired by remote sensing provide a new way for diseases surveillance and early warning. SSTs can be employed as predictor of OIDD in some coastal areas in China.

Infectious diarrhea is an important public health problem worldwide (*1*). As a type of common and important infectious disease, it poses a serious threat to human health and was ranked as the leading cause of death among people of all ages, especially young children in developing countries (*2*). Other infectious diarrheal diseases (OIDD) refer to a group of intestinal infectious diseases with diarrhea that exclude cholera, bacterial and amoebic dysentery, typhoid, and paratyphoid. Spatial analysis and Pearson's correlation was employed to explore the association between the monthly OIDD incidence of the each coastal provincial-level administrative divisions (PLADs) and the average monthly sea surface temperature (SST) of its nearby offshore based on ten years data of China from 2009 to 2018. The results showed that the incidence of OIDD in coastal PLADs was higher than that of inland PLADs in China; coastal PLADs of high latitude areas near Bohai Sea had significant positive correlations with the SSTs, but those of low latitude areas near South China Sea were negatively correlated with the SSTs. SSTs can be a potential predictor of OIDD in some coastal areas in China.

Meteorological conditions have been confirmed to impact pathogen exposures, in particular those associated with waterborne transmission. Several epidemiological studies used time series analysis to show that temperature or precipitation factors had a strong triggering effect on diarrhea (*3*). Extreme rainfall caused floods may contaminate drinking water by flushing diarrhea-causing pathogens from pastures and dwellings into drinking water supplies (*4*). High ambient temperatures can further promote diarrhea transmission by enhancing pathogen replication rates or by changing water usage behaviors and hygiene and sanitation practices (*5*). The ocean is the largest reservoir of viruses and bacteria globally. The marine environmental parameters including sea surface temperature, sea surface height anomaly and sea chlorophyll concentration are potential predictors of many infectious diseases such as cholera to coastal regions (*6*). SSTs in the central equatorial Pacific Ocean have been proved to be linked to diarrhea outbreaks to the many Asian and South American countries including Bangladesh, Peru, and Japan (*5*). While the association between meteorological factors and diarrhea incidence has been well documented in China, limited attention has been directed at whether the marine environmental factors especially the SST have an influence on the incidence of OIDD in coastal areas of China.

Ten years monthly-recorded OIDD data of China from 2009 to 2018 were extracted from the Data-center of China Public Health Science. This database included all data since the initiation of network reporting system, which were the number of cases, incidence by PLAD. Only the diarrhea cases confirmed clinically or by laboratory tests, including microscopic examination and biochemical identification, were included in the database. SSTs data of the same period were acquired from NASA'S Jet Propulsion Laboratory (http://podaac.jpl.nasa.gov). The data were produced

using the satellite images from the National Oceanographic and Atmospheric Administration Advanced Very High Resolution Radiometer (AVHRR). The SSTs data used in the study were monthly AVHRR Oceans Pathfinder SST data with a spatial resolution of 4 km.

Descriptive statistics methods were used to describe the study variables in coastal PLADs of China. ArcGIS software (version 10.2, ESRI, Redlands, USA) was employed for the spatialization of the OIDD incidence data. Meanwhile, Pearson's correlation analysis was conducted to assess the associations between SSTs and OIDD incidence and a two-tailed test of significance was used. Offshore China was divided into four seas including Bohai Sea, Yellow Sea, East China Sea, and South China Sea. The 31 PLADs of the mainland of China were divided into 11 coastal PLADs and 20 non-coastal PLADs. The coastal PLADs near the Bohai Sea include Liaoning, Hebei, Tianjin, and Shandong; near the Yellow Sea include Liaoning, Shandong, and Jiangsu; near the East China Sea include Shanghai, Jiangsu, and Zhejiang; near the South China Sea include Fujian, Guangdong, Hainan, and Guangxi.

The total cases and monthly OIDD incidence of each PLAD in the mainland of China was shown in Table 1. The average incidence of OIDD in coastal PLADs was significantly higher than that in inland PLADs. A total of 9,527,747 OIDD cases were reported in China from 2009 to 2018, including 5,124,303 cases in the 11 coastal PLADs that accounted for 54% of the total cases. The average monthly incidence in China was 5.817/100,000. While the monthly incidence in coastal PLADs was higher than the average, which reached 7.230/100,000. Tianjin Municipality had the highest incidence of monthly OIDD, which was 19.846/100,000. Because the consultation rate of OIDD in China was estimated to be between 50% to 80%, some cases were missed, and the true incidence was higher than the reported incidence.

The dynamic curve of monthly OIDD incidence in coastal PLADs and China from 2009 to 2018 was shown in Figure 1. The data exhibit a clear seasonality with the outbreaks concentrated in summer and winter. The monthly OIDD incidences between 2009 and 2018 in coastal PLADs were always higher than that in inland PLADs all the year around. The time series monthly SSTs extracted from the four offshore areas vary greatly from each other. The average monthly SST in Bohai Sea was 13.2 ℃ and varied from 1℃ to 27 ℃; the characteristics of SST in Yellow Sea were similar to that of the Bohai Sea; the average value of SSTs in Yellow Sea was 15.3 ℃ and it varied from 5 ℃ to 28 ℃, both of which had seasonality. While average monthly SST in the South China Sea was 27.9℃ and varied only from 25 ℃ to 30 ℃. In the East China Sea, the average monthly SST was 22.2 ℃ and varied only from 16 ℃ to 30 ℃.

Pearson's correlation coefficient was employed to analyze the association between the monthly OIDD

TABLE 1. The total cases and monthly OIDD incidence of each PLAD in the mainland of China from 2009 to 2018.

Areas	PLADs	Total OIDD cases	OIDD incidence (1/100,000)
Coastal PLADs	Tianjin	370,781	19.846
	Zhejiang	1,059,099	15.602
	Guangdong	1,334,039	9.953
	Guangxi	529,972	9.041
	Hebei	535,975	5.940
	Fujian	255,043	5.434
	Shandong	603,132	5.023
	Liaoning	186,186	3.551
	Hainan	39,326	3.270
	Shanghai	52,878	1.822
	Jiangsu	157,872	1.638
Inland PLADs	Beijing	437,431	16.793
	Ningxia	87,545	10.701
	Anhui	738,954	9.845
	Chongqing	317,852	8.613
	Jiangxi	310,117	5.591
	Xinjiang	154,375	5.262
	Shaanxi	241,495	5.247
	Qinghai	35,155	4.896
	Hubei	334,722	4.726
	Henan	504,081	4.394
	Gansu	118,912	3.774
	Shanxi	161,360	3.632
	Hunan	270,434	3.285
	Sichuan	323,674	3.249
	Yunnan	173,563	3.013
	Guizhou	90,778	2.113
	Inner Mongolia	35,157	1.159
	Heilongjiang	50,075	1.101
	Jilin	17,022	0.522
	Xizang (Tibet)	742	0.200

Abbreviations: OIDD=other infectious diarrheal diseases; PLADs=provincial-level administrative divisions.

incidence of each coastal PLAD and the average monthly SST of its adjacent offshore sea. Marine environmental factors may have a delayed effect on the OIDD outbreaks, so one-month lag effects for SST were created in the study. The correlation analysis was used for both the current and one-month lag OIDD with the SST. As shown in Table 2, the PLADs of Liaoning, Hebei, Tianjin, Shandong, and Shanghai had significant correlations with the SSTs. The monthly OIDD incidences in Fujian and Guangdong were significantly negative correlated with the SSTs. However, Jiangsu, Zhejiang, Hainan, and Guangxi had little or no significant correlation with SSTs.

DISCUSSION

Our findings confirm the average OIDD incidence in coastal PLADs was higher than in inland areas of China and demonstrated an association between coastal SSTs and local OIDD incidence. Specifically, we found that coastal PLADs of high latitude areas near Bohai Sea had significant positive correlations with the SSTs, but those of low latitude areas near South China Sea were negatively correlated with the SSTs. No matter in coastal PLADs or inland areas, reported cases mostly occurred in summer and winter, and the incidence dynamic curve showed bimodal fluctuation.

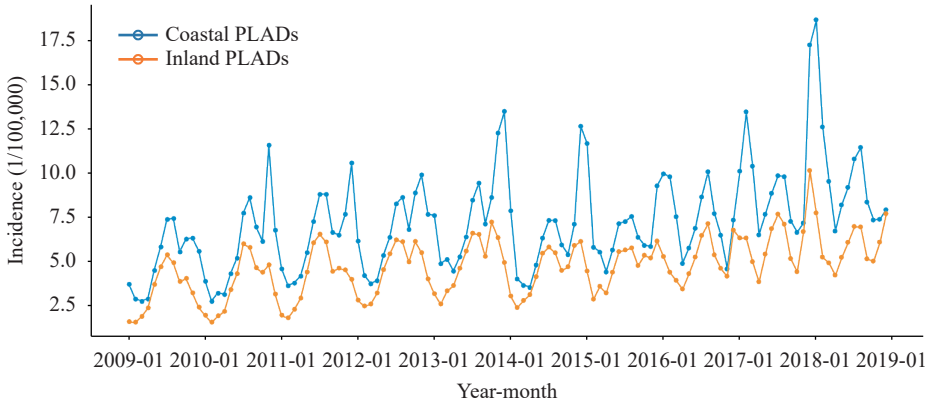

FIGURE 1. The dynamiccurve of monthly OIDD incidence in coastal and inland PLADs of mainland China from 2009 to 2018.
Abbreviations: OIDD=other infectious diarrheal diseases; PLADs=provincial-level administrative divisions.

TABLE 2. Pearson's correlation analysis between SSTs and OIDD in coastal PLADs of mainland China.

Coastal seas	Coastal PLADs	Pearson's correlation coefficient between SSTs and OIDD incidence	Pearson's correlation coefficient between SSTs and one month lag OIDD incidence
Bohai Sea	Liaoning	0.674*	0.451*
	Hebei	0.712*	0.583*
	Tianjin	0.834*	0.578*
	Shandong	0.447*	0.343*
Yellow Sea	Liaoning	0.679*	0.413*
	Shandong	0.442*	0.306*
	Jiangsu	0.024†	0.128†
East China Sea	Jiangsu	0.044†	0.154†
	Zhejiang	0.193¶	0.327*
	Shanghai	0.579*	0.322*
South China Sea	Fujian	−0.385*	−0.120†
	Guangdong	−0.457*	−0.131†
	Hainan	−0.187¶	−0.081†
	Guangxi	−0.184¶	−0.096†

Abbreviations: SSTs=Sea surface temperatures; OIDD=other infectious diarrheal diseases; PLADs=provincial-level administrative divisions.
* Significant correlation at 0.05 level.
† No significant correlation.
¶ Significant correlation at 0.01 level.

The incidence of OIDD in coastal PLADs from 2009 to 2018 was higher than that of inland PLADs. A possible reason should be related to the impact of marine environmental factors. Although the underlying mechanisms by which marine environmental factors influence infectious diarrheal diseases have not been fully clarified, these marine environments, such as SST, can impact the production or transmission of some pathogens in coastal areas. Pathogens may spread quickly through the contaminated water after flooding. In addition, the consumption and improper preservation of seafood in coastal PLADs may also be important factors affecting the OIDD incidence.

There is a spatial heterogeneity of OIDD distribution in China that the incidence of OIDD in different latitude coastal PLADs varies from each other. This further reinforced results of a former study that suggested the difference of the health effects of temperature in different regions is related to latitude. The effect of temperature on OIDD could be modified by latitude (*7*). The risk of OIDD was higher in high latitude areas at low temperatures, suggesting that high latitude areas were vulnerable areas in cold seasons (*8*). For these areas, we should improve the public's awareness of OIDD prevention and medical treatment and enhance the supply of medical resources. Many former studies have shown that high temperatures may increase the risk of infectious diarrhea by affecting pathogen activity, accelerating food decomposition, and increasing drinking water demand (*9*). However, some areas have shown that infectious diarrhea is negatively correlated with temperature.

This study was subject to some limitations. First, the SSTs were extracted from satellite retrieved products, which itself is subject to a certain level of error. Second, the mechanism of the impact of the marine environment on the incidence of diarrhea is not clear yet, and the optimal impact of the marine environment on it is unknown. Therefore, we only calculate the average value of the sea surface temperature in each offshore sea area for analysis of the association with OIDD. Finally, sea surface temperature plays an important role in the survival and reproduction of infectious diarrhea in host environments a side from humans and will affect the transmission speed of diarrhea, so there are still some other marine variables that maybe impact on the incidence of OIDD in coastal PLADs. Sea surface height can reflect the characteristics of climate change such as drought stress, water surface rise, and flooding caused by El Niño events. Seawater salinity and seawater chlorophyll concentration are important factors for the transmission and reproduction of pathogenic microorganisms in coastal PLADs. All these impact factors can be predictors for OIDD in coastal PLADs of China.

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