Spatial Analysis of Food and Waterborne Diseases in Sabah, Malaysia
(Analisis Reruang bagi Penyakit Bawaan Makanan dan Air di Sabah, Malaysia)

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ABSTRACT

Food and waterborne disease (FWBD) epidemic can produce devastating public health outcomes. From 1990 to 2006, the annual notifications for FWBDs in Malaysia ranged from 2,000 to about 10,000 cases. The purpose of this study was to describe the spatial epidemiology of FWBDs in four districts of Sabah from the year 2011 to 2014. This study was a retrospective review of four years (i.e. 2011 to 2014) worth of data from Kota Kinabalu, Penampang, Putatan, and Papar districts. All reported cases of cholera, dysentery, food poisoning, typhoid, and viral hepatitis A from these areas and district health offices were included. Coordinates for the locations of the cases were based on home addresses. Among a total of 1997 cases of FWBDs, food poisoning was the highest reported disease with 1787 (89.4%) cases. Kota Kinabalu had the most reported cases of FWBDs with 1368 (68.5%). In the year 2012, FWBD incidence was the highest at 16.44 per 10,000 populations. Kernel density estimation demonstrated hot spots of food poisoning and cholera in the western areas near the coast, while typhoid and viral hepatitis A cases had minimal hot spots and appeared to be dispersed. Average nearest neighbour analysis showed clusters of food poisoning and cholera cases. Further analysis with the nearest neighbour hierarchical spatial clustering presented 32 clusters of food poisoning and 7 clusters of cholera. Food poisoning and cholera usually occur in clusters. From these findings, it can be concluded that these areas, food poisoning, and cholera have significant spatial clustering and patterns. Meanwhile, other FWBDs did not occur in clusters for this study. This indicates the possibility of under-reporting or real dispersion of cases brought about by an efficient mechanism of spread from a common source.

Keywords: Cluster; foodborne; GIS; spatial analysis; waterborne

ABSTRAK

Epidemik penyakit bawaan makanan dan air (FWBD) boleh mengakibatkan masalah kesihatan awam. Dari tahun 1990 hingga 2006, dilaporkan bahawa bilangan kes tahunannya berada dalam lingkungan 2,000 hingga 10,000 kes. Tujuan kajian ini adalah untuk menghuraikan epidemilogi ruang bagi penyakit bawaan makanan dan air di empat buah daerah di Sabah dari tahun 2011 hingga 2014. Sorotan retrospektif ini melibatkan data selama 4 tahun (2011 hingga 2014) yang dikutip daripada Kota Kinabalu, Penampang, Putatan dan Papar, Sabah. Semua kes kolera, disentri, keracunan makanan, tifoid dan hepatitis A virus yang dilaporkan oleh pejabat kesihatan kawasan dan daerah dikaji. Koordinat bagi lokasi kes adalah berdasarkan alamat rumah. Daripada sejumlah 1,997 kes FWBD, keracunan makanan dilaporkan sebagai kes yang paling tinggi dengan 1,787 (89.4%) kes. Kota Kinabalu merekodkan bilangan kes yang paling tinggi, iaitu 1,368 (68.5%). Bilangan kes FWBD adalah paling tinggi pada tahun 2012 dengan catatan 16.44 per 10,000 populasi. Anggaran kepadatan Kernel menunjukkan bahawa kawasan yang mencatatkan kes keracunan makanan dan kolera tertinggi adalah di bahagian barat berhampiran pantai. Kes-kes tifoid dan hepatitis A virus tidak banyak dilaporkan di kebanyakan kawasan dan kelihatan berselerak. Analisis jiran terdekat purata menunjukkan kelompok bagi kes-kes keracunan makanan dan kolera sahaja. Analisis lanjut melalui pengkelompokan ruang hierarki jiran terdekat menunjukkan 32 kelompok bagi kes keracunan makanan dan 7 kelompok bagi kes kolera. Keracunan makanan dan kolera biasanya berlaku secara berkelompok. Keputusan daripada kajian ini menunjukkan kes keracunan makanan dan kolera mempunyai ciri-ciri kelompok dan corak reruang yang signifikan. Sementara itu, penyakit bawaan makanan dan air lain bagi kajian ini tidak berlaku secara berkelompok. Ini mungkin disebabkan terdapat kes yang tidak dilaporkan atau kes berselerak sahih berlaku dan merebak dengan cepat berasal daripada punca yang sama.

Kata kunci: Analisis ruang; bawaan air; bawaan makanan; GIS; kelompok

Introduction

The global number of food and water-borne diseases (FWBD) reported is largely unknown (Newell et al. 2010). The FWBD epidemic can produce devastating health outcomes in both developing and developed countries. In Malaysia, the annual notifications of FWBDs ranged from 2000 to about 10,000 cases from 1990 to 2006 (Ministry of Health 2006).

Environmental factors such as climate, seasonality, temperature, and rainy seasons have shown relationships and can thus manifest temporal variants (Carrel et al. 2009) Malaysia, in general and Sabah specifically is affected by climate change, which is evident in situations that have occurred such as floods, landslides, and tropical storms, which are attributed to the cyclical monsoon seasons. Weather extremes such as storms, floods, and droughts cause the emergence of climate-sensitive diseases from the contamination of water and environment (Alhoot et al. 2016). In Malaysia and in particularly Sabah, the major factor contributing to food and waterborne diseases is insanitary food handling procedures which accounted for more than 50% of the poisoning episodes (Soon et al. 2011).

Spatial analysis has the potential for monitoring and managing FWBD surveillance. Its examples include interactive mapping, analysing dynamic changes for transmission risk factors, and creating a framework for the disease management system. The current static or pin map of disease distribution can be improved by using dynamic disease mapping, which helps in making decisions, illuminating the causes, and generating hypotheses of the cause of disease. It is achievable via ecological or epidemiological risk assessment. For example, data of spatio-temporal changes and geographical statistical correlation or interpretation can be used together (Abdul Rauf & Abdul Malek 2012).

This study is conducted in the four districts of Sabah, which are Kota Kinabalu, Penampang, Putatan, and Papar. Sabah is one of the states in Malaysia located in the northernmost part of Borneo, recording a total population of 3,120,040 and an annual population growth rate of 1.7%. Its major ethnic groups are Kadazan/Dusun (17.9%), Bajau (14.0%), Chinese (9.1%), Malay (5.7%), Murut (3.3%), other Bumiputera (20.5%), and non-citizens (27.8%) (DOSM 2020). The purpose of this study was to describe the spatial epidemiology of FWBDs in these four districts of Sabah from the year 2011 to 2014.

Materials and Methods

This was a retrospective review and spatial analysis spanning over four years (i.e. 2011-2014) of data for FWBDs, which included cholera, dysentery, food poisoning, typhoid, and viral hepatitis A. The analysis included reported cases in the online disease notification system. All the reported cases from the Area and District Health Offices were taken as samples, whereas the coordinate system used was Rectified Skew Orthomorphic (RSO) Timbalai 1948 Borneo (metres). Approval and registration for this research were obtained from the Sabah State Health Department, Universiti Kebangsaan Malaysia (FF-2014-319), and the National Medical Research Register (NMRR-14-331-19140), Malaysia.

Next, programs such as Statistical Package for the Social Sciences (SPSS) v20, ArcGIS v10, and CrimeStat IV were used for data analysis and mapping. In particular, five environmental features were analysed via a proximity analysis spanning 500 metres, which were the nearest market, sewage plant, municipal landfills, water treatment plant, river, and coastline.

Spatial analysis is a type of geographical analysis which seeks to explain patterns of human behaviour and its spatial expression in terms of mathematics and geometry, that is, locational analysis (Esri 2013). Points and polyline were plotted and analysed accordingly based on the resulting FWBD diagnosis. Meanwhile, kernel function was used to create a smooth map of values from spatial data, which appeared like a spatially-based histogram. It depicted the level at each location along the map reflecting the point pattern intensity for the surrounding area (Anselin et al. 2000). Next, the nearest neighbourhood method was used to calculate the distance to the nearest neighbour. The ratio is called the Nearest Neighbourhood Index. If the ratio is less than 1, the observed distribution is clustered; if the ratio is larger than 1, it is dispersed (Esri 2013). In the nearest neighbour hierarchical spatial clustering, clusters are identified and put together based on two criteria, namely the threshold distance and the minimum number of points that are close enough (Safian et al. 2008).

Results and Discussion

A total of 1997 cases of FWBDs were reported from the four districts of Sabah from the year 2011 to 2014. The highest age group was between 10 and 14 years old with 441 (10.4%) cases, while the female group had a slightly higher number of cases with 1094 (54.8%). The ethnic group of Peribumi Sabah was the representation and presented with 1421 (71.2%) cases. Meanwhile, in terms of diagnosis, food poisoning was the highest reported disease from all four districts with 1787 (89.4%) cases, whereas dysentery was the least reported with only 2 (0.1%) cases (Table 1). In an acute diarrhoea study done locally, it was found that young adults had the highest incidence of acute diarrhoea, which could be attributed to their lifestyle and eating habits as they were likely to be single and more active. The same study also showed that Peribumi Sabah having the highest incidence of acute diarrhoea (Gurpreet et al. 2011). However, under five years of age, Bangladesh had the highest incidence of typhoid (Dewan et al. 2013). Part of the epidemiology

of foodborne illness is tied to behavioural factors, socio-cultural practices, food choices and availability, consumer and societal attitudes towards food, and food preparation practices (Tam 2008).

Kota Kinabalu District, which is the most populated among the four districts, had the highest number of reported cases with 1368 (68.5%) cases of FWBDs from the year 2011 to 2014. In contrast, Putatan had the least reported cases with 166 (8.3%). In terms of the year, FWBDs were highest reported in the year 2012 with 622 (31.1%) cases, while 2011 showed the lowest amount of reported cases with 380 (19.0%) cases. The highest FWBD incidence was in 2012 with 16.44 per 10,000 population.

Table 2 shows the association between the outbreak and sporadic cases of food and waterborne cases in the four districts of Sabah from 2011 to 2014. A significant difference was seen in the outbreak and sporadic cases by district (χ2= 233.355, p<0.01), ethnicity (χ2= 16.204, p<0.05), and age (χ2= 249.628, p<0.01). In the findings, food poisoning had the most reported number of cases and clusters. Gastrointestinal infections such as salmonellosis or cryptosporidiosis may show significant spatio-temporal clusters of food poisoning and be transmitted by disease carriers (Pardhan-Ali et al. 2012). Food poisoning may also depict a widespread occurrence in numerous households, especially if the causative food or products are sold at supermarkets and retail outlets (Asao et al. 2003) with 420 cases frequently ingested dairy products manufactured by a factory in Osaka City.

In Figures 1 to 4, the Kernel Density Estimation (KDE) analysis shows the high-density areas of food poisoning and cholera cases from the year 2011 to 2014 on the western side of the four districts. Typhoid and viral hepatitis A cases illustrated minimal hotspot areas and the smoothed areas were spaced out, which could be due to the dispersing of cases in space. Dysentery was not mapped with KDE as there were only two cases. Geographic Information System (GIS) has been effectively used in various fields including healthcare. Its implementation in healthcare is an important step towards the growth of smart and focused interventions, bringing forth better health outcomes with a diminution in the cost of healthcare services (Hart et al. 2005).

Table 3 depicts the average nearest neighbour analysis of the FWBD cases from 2011 to 2014. The reported cases of typhoid, viral hepatitis A, and even dysentery did not show any clusters, whereas the null result appeared as there were too few records for analysis as it generally required at least two features. Even though this study had only a total of 17 confirmed cases of viral hepatitis A reported and no clusters were identified, the cases were significantly dispersed spatially. In an outbreak investigation of hepatitis A in children in an urban slum of Tamil Nadu, the cases were distributed with no particular clustering, which indicated that the outbreak might be due to a generalised source such as

water contamination and not as a result of a point-source spread. The lack of spatial clustering helped to formulate the hypothesis that the outbreak could have been due to the contamination of water supply to the entire area (Sowmyanarayanan et al. 2008).

In this study, too few dysentery cases were reported and thus no clusters were detected. However, in China, the fluctuations of Shigella clusters found had caused food poisoning and dysentery (Tang et al. 2014). The incidence of dysentery in an urban area can be attributed to poor hygiene. Furthermore, such cases are influenced by meteorological factors such as a rise in temperature and relative humidity, which will increase the incidence of cases; these findings should be considered in relevant prevention and control programmes (Li et al. 2015).

In 2011, only Kota Kinabalu and Papar illustrated food poisoning clusters. Between the year 2012 and 2014, Kota Kinabalu, Penampang, and Putatan had a clustering of food poisoning cases. This study found hotspot clusters that occurred in institutions such as schools, whereby school lunch programmes might potentially have bacterial growth in their food due to early preparation and handling. The use of GIS in epidemiological investigation and analysis of food production may assist in locating the sources or vehicles of infection. Contamination could be further linked to food production that took place in a direct spatial and temporal association. Further spread of infection caused by the primary source can be probably avoided by immediate measures (Kistemann et al. 2000).

Cholera showed several clustering of cases, such as in 2011 and 2014 in Kota Kinabalu. In the years of 2011 and 2013, Penampang and Papar districts were shown to have the nearest neighbour index of less than 1 for cholera, but the p-value was not significant and meant that the pattern did not appear to be significant. Further analysis with the Ripley K function exhibited the most significant distance clustering for food poisoning and cholera, which were up to 1.8 km and 3.3 km, respectively. Ripley K function has slightly different results compared to the average nearest neighbour analysis as it considers second-order clusters and not just the measurement distance of the nearest neighbours. Typhoid cases in the year 2012 showed clustering at a very short distance, which was not observed in the average nearest neighbour analysis.

There were four food poisoning and cholera points, respectively, and one typhoid point at a 500-metre radius around the marketplace. Meanwhile, there were only two food poisoning points and one cholera and typhoid point, respectively, near a sewage plant. There were no cases in a 500-metre radius around the municipal landfill, while only one food poisoning point was found near a water treatment plant. Then, a proximity analysis was also done for rivers and coastlines, which displayed the most prominent findings. There were 37 points of food

poisoning, 43 cholera points, 6 typhoid points, 2 viral hepatitis A points, and 1 dysentery point within 500 metres near a river and coastline (Table 4). Pathogen contamination is a major cause of stream impairments, making it a major health risk (Pandey et al. 2014). Persistent and heavy rainfall may affect the health in areas near rivers when flooding occurs, as it increases the risks of infectious diarrhoea in the affected areas (Ding et al. 2013). A close affiliation was found between the health condition and viral contamination of wastewater product effluents, and consequently, the surface water contamination (Prevost et al. 2015).

Nearest neighbour hierarchical clustering analysis was used with a pair of points by a chance of 0.50, 10 minimum points per cluster, and 1 standard deviation. There were no clusters identified for typhoid, viral hepatitis A, and dysentery, while the typhoid cases did not show spatial clustering. This finding conflicts with other study findings. For example, a typhoid study in Kelantan showed that typhoid usually occurred in clusters and each case usually occurred near other cases as the causative agent would be present in the surrounding area (Safian et al. 2008). Clusters of typhoid are also influenced by the environment, such as a change in the temperature, rainfall, and river level (Dewan et al. 2013).

Food poisoning had a total of 32 clusters; of those, 29 were first-order and 3 were second-order clusters (Figure 5). The findings in this study exhibited significant clustering of cases in food poisoning in which some clusters were also found in villages and squatter areas. Similar spatial studies were done before to demonstrate

these areas to have a clustering of FWBD cases, which were associated with the shortage of safe drinking water and poor sanitation (Kazembe et al. 2009). Besides, adequate facilities and infrastructures, which include safe water access and sanitation, are needed to avoid pathogens that are causing diarrhoea (Zuckerman et al. 2007).

Cholera had seven clusters; of those, six were first-order and one was a second-order cluster (Figure 6). Cholera could be observed in areas with higher population density and might be due to the increased density of refuse dumps and breakdown of sanitation, which led to a higher risk of cholera in a particular area (Kanungo et al. 2012). Meanwhile, isolated clusters of high cholera incidence may be attributed to poor hygiene practice in the community. Next, endemic cholera may occur when its reservoirs are readily available in coastal areas and the sea (Ali et al. 2006). Temporal seasons, which cause optimal taking in of nutrient and sunlight, are the best conditions for plankton growth (Abdul Rauf et al. 2011). Cholera distribution is influenced by the temperature, precipitation, elevation, distance to the coastline, and oceanic environmental factors, such as sea surface temperature, sea surface height, and ocean chlorophyll concentration. With this information, a forecast using GIS can offer great prospects as a forewarning method for cholera (Xu et al. 2015).

This study is not without its limitations; when using surveillance data, there is the possibility of under-reporting of FWBD cases. Furthermore, this study did not include climate factors in the analysis.

TABLE 1. Patient characteristics of FWBDs from 2011 to 2014 in Kota Kinabalu, Penampang, Putatan, and Papar, Sabah

Characteristics	n (%) N = 1997
Age	
Under 1 year old	8 (0.4)
1 to 4 years old	60 (3.0)
5 to 9 years old	208 (10.4)
10 to 14 years old	441 (22.1)
15 to 19 years old	431 (21.6)
20 to 24 years old	330 (16.5)
25 to 29 years old	146 (7.3)
30 to 34 years old	91 (4.6)
35 to 39 years old	74 (3.7)
40 to 44 years old	65 (3.3)
45 to 49 years old	58 (2.9)
50 to 54 years old	28 (1.4)
55 to 59 years old	23 (1.2)
60 to 64 years old	15 (0.8)
65 years and above	19 (1.0)

Gender	
Male	903 (45.2)
Female	1094 (54.8)
Ethnic	
Malay	182 (9.1)
Chinese	154 (7.7)
Indian	10 (0.5)
Peribumi Sabah	1421 (71.2)
Peribumi Sarawak	31 (1.6)
Others	51 (2.6)
Non Malaysian	148 (7.4)
Diagnosis	
Food poisoning	1787 (89.4)
Cholera	162 (8.1)
Typhoid	29 (1.5)
Viral Hepatitis A	17 (0.9)
Dysentery	2 (0.1)

TABLE 2. Chi-square test between outbreak and sporadic cases of food and waterborne cases in the four districts of Sabah from 2011 to 2014

Variables	Outbreak N= 1701 n (%)	Sporadic N= 296 n (%)	χ2	p-value
Gender			0.820	0.365
Male	762(84.4)	141(15.6)		
Female	939(85.8)	155(14.2)		
District			233.355	<0.01*
Kota Kinabalu	1276(93.3)	92(6.7)		
Penampang	225(67.0)	111(33.0)		
Putatan	105(63.3)	61(36.7)		
Papar	95(74.8)	32(25.2)		
Ethnicity			16.204	<0.05*
Malay	154(84.6)	28(15.4)		
Chinese	129(83.8)	25(16.2)		
Indian	9(90.0)	1(10.0)		
Peribumi Sabah	1227(86.3)	194(13.7)		
Peribumi Sarawak	29(93.5)	2(6.5)		
Other Malaysian	37(72.0)	14(28.0)		
Non-Malaysian	116(78.4)	32(21.6)		

Age			249.628	<0.01*
Under 1 year old	2(25.0)	6(75.0)		
1 to 4	33(55.0)	27(45.0)		
5 to 9	182(87.5)	26(12.5)		
10 to 14	416(94.3)	25(5.7)		
15 to 19	406(94.2)	25(5.8)		
20 to 24	287(87.0)	43(13.0)		
25 to 29	111(76.0)	35(24.0)		
30 to 34	64(70.3)	27(29.7)		
35 to 39	57(77.0)	17(23.0)		
40 to 44	55(84.6)	10(15.4)		
45 to 49	44(75.9)	14(24.1)		
50 to 54	20(71.4)	8(28.6)		
55 to 59	10(43.5)	13(56.5)		
60 to 65	8(53.3)	7(46.7)		
65 years and above	6(31.6)	13(68.4)		

*significant p-value of <0.05

TABLE 3. Average nearest neighbour analysis for FWBD cases from 2011 to 2014

		2011 (NNI)	2012 (NNI)	2013 (NNI)	2014 (NNI)
Kota Kinabalu	Food Poisoning	0.000 [a]	0.010* [a]	0.117* [a]	0.000* [a]
	Cholera	0.609* [a]	2.028* [b]	1.662* [b]	0.682* [a]
	Typhoid	184.387* [b]	131.547* [b]	Null	212.650* [b]
	Viral Hepatitis A	Null	4.583* [b]	3.989* [b]	109.820* [b]
Penampang	Food Poisoning	2.414* [b]	0.539* [a]	0.417* [a]	0.470* [a]
	Cholera	0.834 [a]	2.007* [b]	2.324* [b]	1.927* [b]
	Typhoid	Null	Null	Null	Null
	Viral Hepatitis A	Null	Null	Null	Null
Putatan	Food Poisoning	Null	0.439* [a]	0.904* [a]	0.546* [a]
	Cholera	Null	1.041 [b]	83.249* [b]	2.899* [b]
	Typhoid	Null	2.100* [b]	Null	87.149* [b]
	Viral Hepatitis A	Null	Null	Null	Null
Papar	Food Poisoning	0.375* [a]	1.695* [b]	1.490* [b]	1.371* [b]
	Cholera	Null	1.937* [b]	0.918 [a]	Null
	Typhoid	2.095* [b]	2.381* [b]	Null	Null
	Viral Hepatitis A	239.849* [b]	89.547* [b]	Null	Null

Nearest Neighbour Index (NNI): if the ratio is less than 1, it is clustered; if the ratio is larger than 1, it is dispersed.
*p-value <0.01, [a]clustered, [b]dispersed

TABLE 4. Proximity analysis in the range of 500 metres near environmental features

Diagnosis	Market	Sewage plant	Municipal landfill	Water treatment plant	River and coastline
Food poisoning	4	2	0	1	37
Cholera	4	1	0	0	43
Typhoid	1	1	0	0	6
Viral Hepatitis A	0	0	0	0	2
Dysentery	0	0	0	0	1
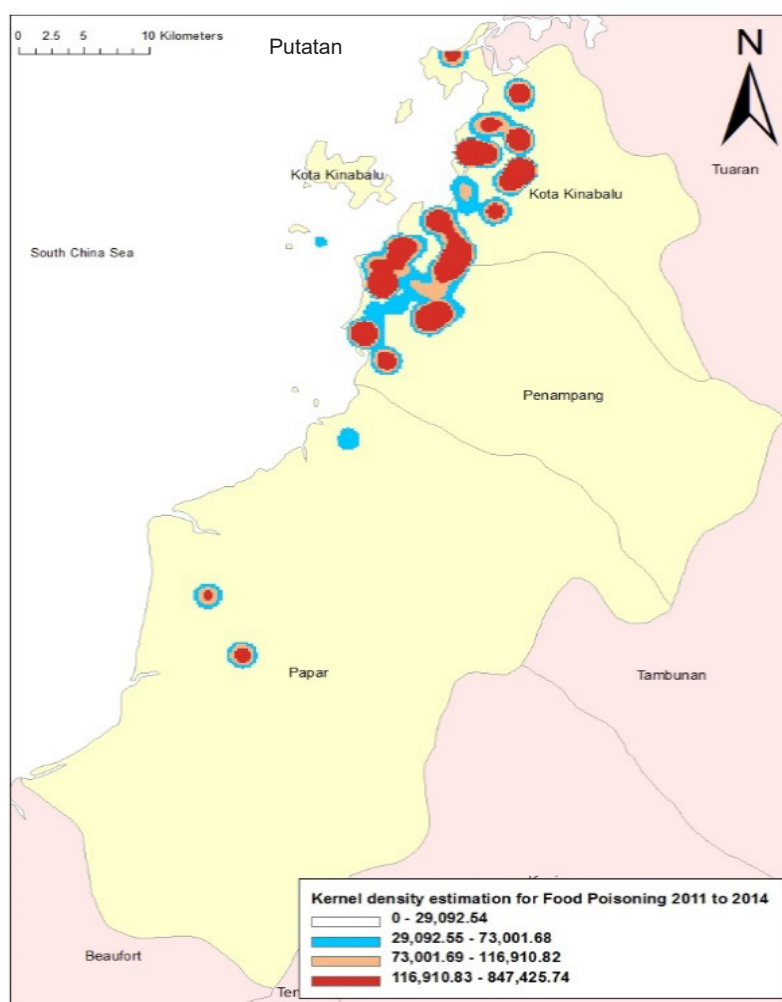
FIGURE 1. Kernel density estimation of reported food poisoning in the
four districts of Sabah from 2011 to 2014
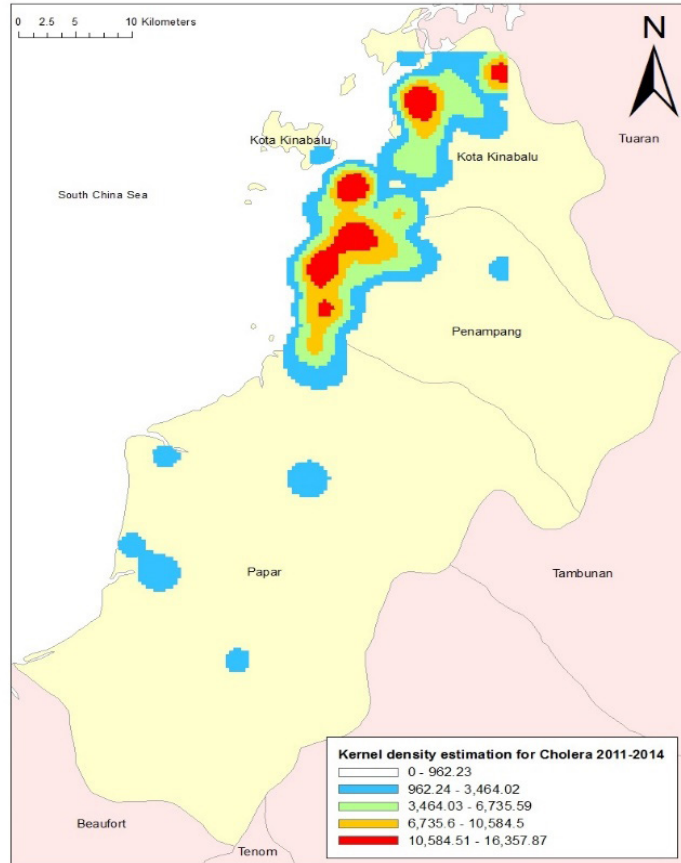
FIGURE 2. Kernel density estimation of reported cholera in the four
districts of Sabah from 2011 to 2014
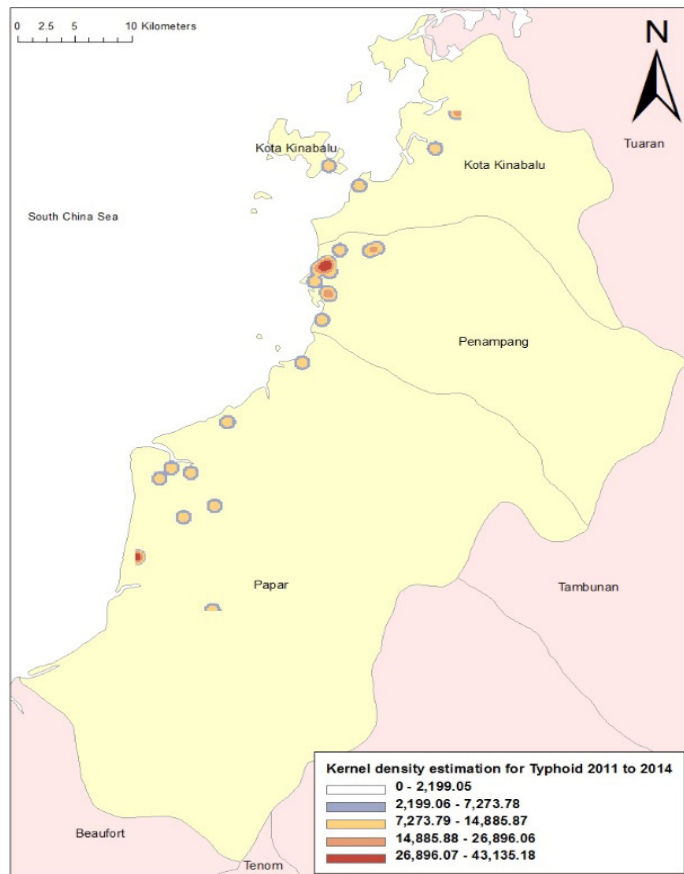
FIGURE 3. Kernel density estimation of reported typhoid in the four
districts of Sabah from 2011 to 2014
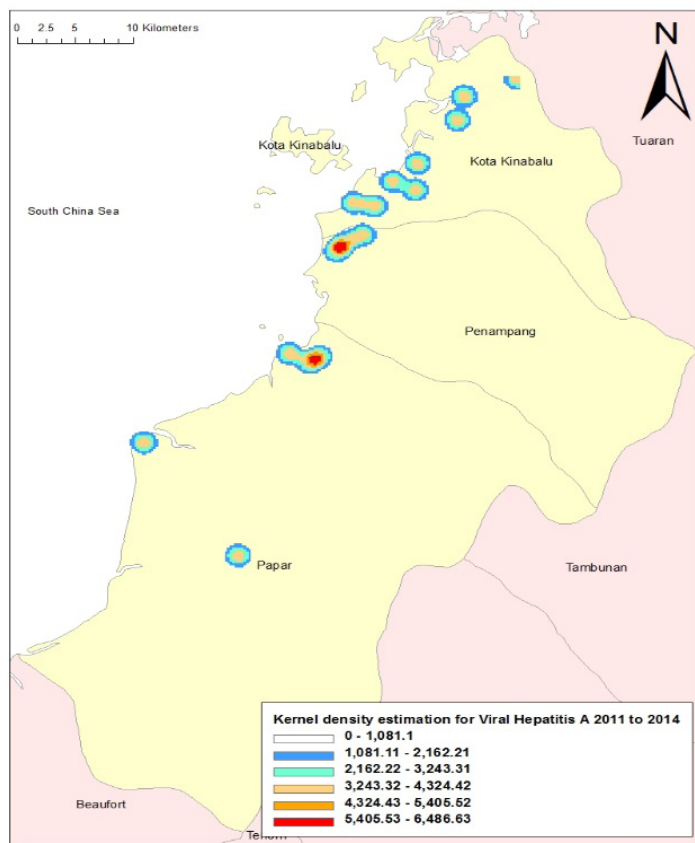
FIGURE 4. Kernel density estimation of reported viral hepatitis A in the
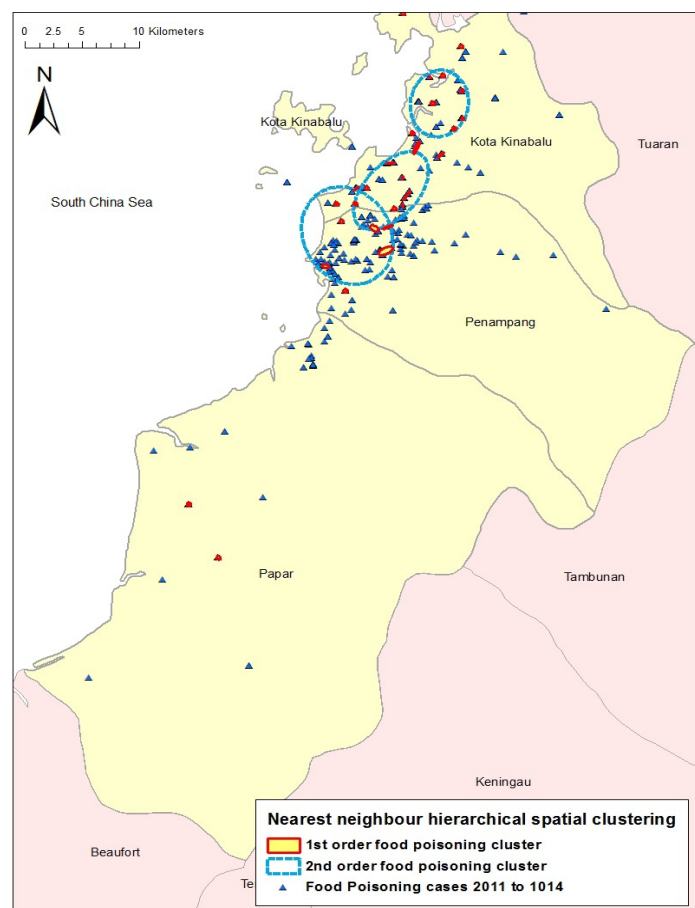four districts of Sabah from 2011 to 2014

FIGURE 5. Nearest neighbour hierarchical spatial clustering analysis of food
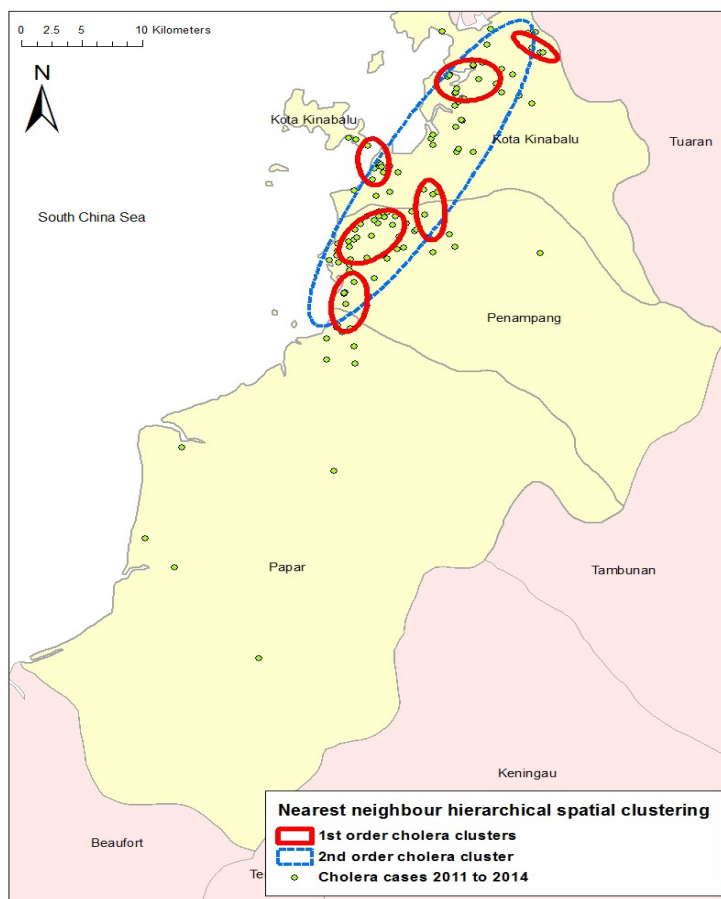poisoning cases in the four districts of Sabah from 2011 to 2014

FIGURE 6. Nearest neighbour hierarchical spatial clustering analysis of
cholera cases in the four districts of Sabah from 2011 to 2014

CONCLUSION

From these findings, one could conclude that for these particular areas, food poisoning and cholera had significant spatial clustering and patterns. However, other food water-borne diseases did not occur in clusters. This could mean that the real cases and burden were either not captured and there is under-reporting, or these were the real dispersion of cases, which was brought about by an efficient mechanism of spread from a common source.

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