Socio-Environmental Factors and Tuberculosis: an Exploratory Spatial Analysis in Peninsular Malaysia

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Abstract

Spatial pattern of tuberculosis (TB) describes the environmental variation of the disease. Controlling the disease is not only depends on bio-medical method, but there is also a need to explicitly understand socio-environmental contexts which include the elements of people, space and time. A spatial exploration of local TB dynamic in Malaysia’s perspectives is necessary since earlier studies were limited in addressing these contexts. This paper discusses a general spatial pattern of TB distribution pattern in Peninsular Malaysia for a ten-year period from 2004 to 2014 and its general possible correlation with socio-environmental factors in 2010. Geographical information system (GIS) and correlation analysis are fundamental techniques used to explore the local pattern of TB distribution and the relationship. Data on annual TB cases and state map were collected from the Ministry of Health and the Department of Rural and Country Planning Malaysia respectively. The overall spatial pattern of TB cases has shown increasing trends and concentrating in five states, including Selangor, Johor, WPKL, Kelantan and Kedah, even though there is no specific pattern in the area. This study suggests that the majority of the cases have occurred in the urban states, having high-medium incomes and populous areas.

Keywords: GIS, Correlation; Peninsular Malaysia; Social Environment; Spatial Pattern; Tuberculosis

1. Introduction

This TB occurs in every part of the world and can kill three million people in the world for both of developed or developing countries. [8] reported the majority of the TB cases come from the 22 high burden countries, especially from African and Asian regions. Malaysia recorded medium burden cases of TB incidence with 81 per 10,000, 24,711 cases, and 1,603 deaths in 2004, but the number of new TB cases increased from 15,000 in 2005 to 19,251 in 2011 (MOH, 2012). These local situations and dynamics bring up key research question: which states have the highest cases of TB? and why are the states experienced such risk situations?

Previous studies have shown the environmental risk factors in high burden countries of TB can be divided into two main indicators, including ecological environment, human or social environment. The ecological environment is another term of the environment, relating the biotic and abiotic surrounding of an organism or population. For example, TB high-risk prevalence areas are co-impacted by spatial proximity or geographical factors [1][2][12] especially in urban area [1][12][3][38], poor housing quality, crowded and small living condition [14]. Low SES also contributes to the global TB occurrences [2][12] such as unemployment, low educational level and poverty. Human factors both individual and population have been also identified as a major of global TB epidemics, especially in crowded or higher population, migrant population, high risk group or people with co-infection or infectious disease such as HIV, drugs abuse, AIDS and so on.

Therefore, molecular and analytical epidemiology used to control the disease in terms of local demographic characteristics, genetic, behaviours, environmental exposures, and other potential risk factors. However, there is a need of a geographically based tool for a better understanding of the TB epidemiology (Murray and Alland, 2002; Narayanan, 2004). Studying spatial pattern of TB in Malaysia is imperative to understand well the spatial distribution of the disease since there are limited studies on these particular local perspectives A spatial analysis framework developed by [37] is general guidelines used to control disease in medical and geographical perspective by identifying a spatial pattern and of disease cluster, as well as to predict disease risk factors and areas. This analysis can stimulate an idea to create a hypothetical framework for the dynamics TB distribution pattern and risk factors complexities in the context of Malaysia

2. Review on Socio-Spatial Relations in the Tuberculosis Environment

2.1. Geographical Pattern of Tuberculosis Distribution

Tuberculosis (TB) is caused by tuberculosis bacilli called as mycobacterium tuberculosis that is spread from person to person through the air, and then it can transmit through a community across the geographical boundaries. TB Epidemiology is a study of the disease distribution and determinants of risk factor in a specified population, and to the control of health problems that related with time, place, and person characteristics. Narayanan, (2004) has suggested apart of human-based tool, there is a need of
the geographically based tool for a better understanding and controlling of tuberculosis cases. TB remains a major global health problem that can attack any people or regions both in developed or developing countries. [7] described global TB incidence and estimates that approximately one-third of the global community is infected with M. tuberculosis. TB is the second most common cause of death due to an infectious disease after human immunodeficiency virus/HIV/AIDS. In 2013, the majority of the TB cases come from African and Asian regions especially in South Africa and India [8], where the largest number of new TB cases occurred in the South-East Asia and Western Pacific Regions, accounting for 56% of new cases globally.

In Malaysia, the TB among high risk groups continue to be an important disease [18]. The number of new TB cases in the country increased from 15,000 in 2005 to 19,251 in 2011 especially in three states of Sabah, Selangor and Sarawak. While pulmonary TB is the commonest form of TB in Malaysia, extrapulmonary TB (EPTB) still posed a threat. The majority of patients are in the 21 - 60 years age group (69.5%) and there is a male predominance (65%). Overall, most of the global TB cases occur in Asian and African regions, especially in developing countries. In Malaysia, the clustering is dynamically cases since every state has owned risk factors and potentials to be attacked by the TB cases.

2.2. Tuberculosis in Socio-Spatial Dimensions

Empirical global studies have shown the common environmental (endogenous or extrinsic) risk factor affects TB risk vulnerability are the biophysical or ecological environment, socioeconomic status, human population and demographic characteristic. TB spatial clustering and variation, the high-risk areas are impacted by areal proximity or geographical factor [1][2][12] especially in urban area [1][2][3], and socio-economic status [2][3].

Moreover, human factor both population or individual have been also identified as a major of global TB epidemics including crowded or higher population [4][38], migrant population, high risk group and people with co-infection or another infectious disease such as HIV, drugs abuse, AIDS and so on. Since each country has unique local environments, then the effect of risk factors and dynamics of TB occurrences might be different in particular areas. As a result, some experts have pointed out some recommendations on these particular problems, as well as to enhance the current result.

The well-established risk factors need to combine among themselves or other potential intrinsic risk factors for major impact on the state of public health in the current century [10] and better reflect the true risk factors of TB burden and guide national TB programmes to execute more effective TB control interventions. Moreover, there a need to be studied in depth in future research for complex relationships such as between SES and environment [1][13][15][33][11][12][16][10][17].

In the context of Malaysia, The [12] identified the risk of TB transmission came from a high risk group. This human or demographic factor may be the main factor affecting local TB occurrences such as pulmonary TB (PTB), patients are in the 21 - 60 years age group and male predominant [12]. Table 1 summarises the common risk factors according to global situations, focusing on social economic status, human population and demographic. It can be concluded that in order to determine potential key risk factors of TB in certain local areas, studying spatial pattern and precise causal associations between TB cases and related risk conditions is crucial to investigate the real scenario of local TB cases.

| Table 1: Common Risk Factors in Global Tuberculosis |
|----------------|---------------------------------|----------------|
| Risk Factor | Specific criteria/determinants | Author(s), region(s) |
| 1. Socio Economic Status, SES (Job, salary and occupation-related to poor and social vulnerability) | 1.1 The level of education of people with primary level or with illiterate level, type of TB and place of residence from Asian and African Regions. Habitat/settlement censuses, and living conditions | 1.1 [19], West Azerbaijan Province, Iran. 1.2, [19][20][22][21] 1.3. [1][12][13][10][13][33][15][16] 1.4. [2]. Antananarivo, Madagascar. 1.5 [11], Brazil. 1.6.[23][24] Cameroon and Southern Africa. |

2. Population and Demographic Characteristics (crowd/density environment, migration and low SES)

2.1 Geographical characteristics of the area at the risk are high density/populated areas in the urban and rural areas, poor sanitation, poorly built housing, and lack of both adequate sewage systems and water supply facilitate pathogen spread. These situations are related with in neighbourhoods of low SES and HIV/TB mortality among children aged 1-5 years 2.2 TB related with socio-economic status specially poverty, urbanicity and population density in comparison with rural areas, but the higher level of CS/location, risk factor/biological and comparative studies need to be considered. 2.3 [27][29][30][31] American Latin. 2.4 [33], USA.
3. Methodology

The analytical framework of GIS and spatial epidemiology adapted from [37] is the research methodology used in this study. It includes two main stages, namely, data collection, data processing and data analysis. The first stage describes the study area and datasets used in the study while the second stage covers the process and analysis of the data input of cases and selected variables using classification and Correlation and Spatial Analyst tool in ArcGIS. The data analysis describes spatial pattern of TB cases in the Peninsular Malaysia from 2005 to 2014.

3.1. Study Area and Data Collection

Peninsular Malaysia or West Malaysia, in Malaysia, is selected as the study area. Malaysia is located in Southeast Asia, with Kuala Lumpur as its capital city (Fig. 1). The Peninsular Malaysia has an area of 8.10 million ha, consisting of twelve administrative states from the smallest area (Perlis), to the largest area (Pahang). The TB cases of state of Wilayah Persekutuan Putrajaya (WPP) are combined into Wilayah Persekutuan Kuala Lumpur (WPKL) because of geopolitical changes. The area as a whole is composed of 80% present lowland and 20% highland.

Annual cumulative TB cases from 2005 to 2014 and outline state map of the study area were collected from the TB/Leprosy Sector in Ministry of Health (MOH) and the Department of Town and Country Planning (JBPD), Malaysia. General attributes of the population and urban population (people), monthly income (RM) and non-forested land (km²) in 2010 data were acquired from available online sources from the Department of Statistics, Economic Planning Unit (EPU) and Forestry Department in Malaysia. These secondary non-spatial data then were spatially converted and processed into ArcMap and ArcCatalog using a quantitative classification and a correlation coefficient technique.

3.2. Data Processing, Calculation and Analysis

The selected data were processed using spatial software or ArcGIS developed by the Environmental System Research Institute (ESRI), especially ArcMap and ArtToolbox tools. The software has some important GIS functions for geocoding, thematic mapping or displaying the data using Malayan Rectified Skew Orthomorphic (MRSO) coordinate systems. Basic GIS operations such as file setup, joining excel spreadsheets with geographic ID fields, and thematically representing data on the maps were conducted in ArcMap and Spatial Analyst tool.

ArcMap is the primary application in ArcGIS and to perform a wide range of common GIS tasks. The mean value of the cumulative TB cases, and the selected variables were used as a scale for determining the risk level of TB occurrences and risk factors in this study. For example, the total TB cases in the study area are 136,864 people and its mean value is 11.405 people after they are divided by 12 (states). If the total of cases in a particular state is more than the mean value, hence the state is assumed as a high risk area (darker colour).

Pearson’s correlation coefficient, r, is also another statistical technique applied in this study to measure the descriptive pattern, association and strength of the relationship between any two variables such as environmental factors and TB cases (Fig. 2). [36] states if the relationship is weak, then knowing the value of one attribute variable does not predict the value of the second variable.

The value of this correlation is also expressed in terms of a coefficient and it has a range (maximum negative [-1] and positive [+1]). When the correlation coefficient approaches a maximum negative value, it means that there is a strong negative correlation. This means that the higher the value of one attribute variable, the lower the value will be of the other variable (e.g. the lower the monthly income rate, the higher the TB incidence). There are two ways to calculate the correlation, which are based on sample data (Eq. 3a) and mean and standard deviations (Eq. 3b).

\[ r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{n \sigma_x \sigma_y} \]
\[ r = \frac{\sum_i x_i y_i - \frac{\sum_i x_i \sum_i y_i}{n}}{\sqrt{\left[ \sum_i (x_i - \bar{x})^2 \right] \left[ \sum_i (y_i - \bar{y})^2 \right]}} \]

\[ n = \text{sample size of } x \text{ and } y \text{ data} \]
\[ \bar{x} \text{ and } \bar{y} = \text{means of } x \text{ and } y \text{ data} \]
\[ \sigma_x \text{ and } \sigma_y = \text{standard deviations of } x \text{ and } y \text{ data} \]

4. Result and Discussion

4.1. Spatial Pattern of Tuberculosis Cases
Fig. 3 and Fig. 4 show the total cumulative TB cases by states in Peninsular Malaysia for 10 years period from 2005 to 2014. The total number of the cumulative cases recorded for the 10 years were 136,864 cases, in which Selangor dominated the cases with 21.7% of the grand total of the cases, followed by Johor (13.7%), WPKL (11.3%), Perak (9.8%), and Kelantan (9.7%). While, Pulau Pinang, Kedah, Pahang and Terengganu recorded the medium risk of TB cases, started from 7.6% to 5.1%. The other states that reported the total number of TB cases less than 5,000 cases or 5% were considered as low risk states, consisting of Negeri Sembilan (3.5%), Melaka (3.2%), and Perlis (0.9%). The cases which notified more than the mean value of the total cumulative TB cases or 11,405 cases (8.3%) are categorised as an abnormal situation or a high risk state, whilst the others are identified as medium and low risk states. Therefore, the figures also reveal that more than 66.2% of the overall cases in the area were assumed as high risk states, including Kelantan, Perak, WPKL, Johor, and Selangor. The other states only expressed low and medium risk situations, especially in Pulau Pinang, Kedah, Pahang, Terengganu, Negeri Sembilan, Melaka and Perlis.

Referring to the TB time series plot by the states and years in Peninsular Malaysia from 2005 to 2014 (Fig. 5), it is clearly explained that Selangor dominated the total cases by 21.7%. The other states reported constant higher cases than the mean value (1141 cases) were Johor, WPKL, Perak and Kelantan. The rest of the states only showed the medium and low risk of TB cases, particularly in Perlis, Melaka and Negeri Sembilan.

An interesting trend was found in Selangor, Johor, WPKL, Pulau Pinang and Kedah where they have more significant dynamics or variations of cumulative TB distribution compared to the other states. These phenomenal dynamics might be caused by several possible factors, including the local complexities of TB transmission process, or the effectiveness of the particular state health TB control program in the disease detection and treatment.

Fig. 6 illustrates the spatial distribution pattern of TB cases in Peninsular Malaysia by states using geographical information system (GIS) technology. Similarly, the cases increased in term of a number of cases and every state had also experienced with TB occurrences. In the early three years of 2005 to 2011, the cases are likely to be significantly increased in some regions of the study area, especially in Selangor, WPKL, Johor, Perak and Kelantan. After that, in 2012 to 2014, the cases spread out to Kedah and P.Pinang then consistently occurred in these states. The state of Perlis, N.Sembilan and Melaka only notified low-medium risk for ten year-cases.
There was no specific clustering found in the study area since the pattern was slightly randomly distributed. The states with high risk situations have similarities in term of the environmental characteristics of TB ecology, particularly in the case of population changes. However, there were some differences in terms of biophysical environments and socio-economic status (SES) since TB could be occurring either in urban and/or in rural areas even though they are having high urbanisation or better socio-economic status. For example, Kelantan and Perak are in medium category in term of the socioeconomic status and urbanization, compared to Selangor and WPKL. This result is consistent with finding found from previous studies that geographical characteristics of the area at the risk are high density/ populated areas in the urban and rural areas.[10][23][24][25][26].

<table>
<thead>
<tr>
<th>Risk Level of TB (Cases)</th>
<th>States</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>Selangor, Johor, WPKL, Perak Kelantan</td>
<td>2005-2014</td>
</tr>
<tr>
<td>(All Forms) Medium</td>
<td>P. Pinang, Kedah, Pahang, Terengganu</td>
<td>2005-2014</td>
</tr>
<tr>
<td>Low</td>
<td>N. Sembilan, Melaka, Perlis</td>
<td>2005-2014</td>
</tr>
</tbody>
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Table 2: Potential risk states in Peninsular Malaysia

An explicit understanding on the TB distribution pattern is a fundamental process to explore an initial idea of the local transmission of diseases, the possible relationship with related environmental risk factors, and identifying potentially high risk areas. The integration of geographical information system (GIS) and spatial visualisation techniques have demonstrated their analytical capabilities for exploring geographic dynamics of tuberculosis (TB) cases and incidences in Peninsular Malaysia from 2005 to 2014. In general, the TB distribution in the area seems to be in dynamic pattern and risk factors are also complex since the local clustering of the disease is not detected explicitly. The spatial pattern for the ten years TB cases shows an increasing trend, particularly in Selangor, Johor, and WPKL, but no definite clustering are determined in these states. Overall, an interesting hypothesis that could be further investigated is that why the majority of the cases occurred in the urbanised states such as Selangor, WPKL, and Johor, with high-medium incomes and populous areas. The findings are not only to answer the local TB dynamics and characterisation of high risk areas in general spatial perspective, but also provide a spatial knowledge for local researchers and decision makers to find, detect, and treat better solutions to the national TB strategies and challenges. Additional data on the risk factors and other spatial regression techniques can be further explored for more significant results.

5. Conclusion

An explicit understanding on the TB distribution pattern is a fundamental process to explore an initial idea of the local transmission of diseases, the possible relationship with related environmental risk factors, and identifying potentially high risk areas. The integration of geographical information system (GIS) and spatial visualisation techniques have demonstrated their analytical capabilities for exploring geographic dynamics of tuberculosis (TB) cases and incidences in Peninsular Malaysia from 2005 to 2014. In general, the TB distribution in the area seems to be in dynamic pattern and risk factors are also complex since the local clustering of the disease is not detected explicitly. The spatial pattern for the ten years TB cases shows an increasing trend, particularly in Selangor, Johor, and WPKL, but no definite clustering are determined in these states. Overall, an interesting hypothesis that could be further investigated is that why the majority of the cases occurred in the urbanised states such as Selangor, WPKL, and Johor, with high-medium incomes and populous areas. The findings are not only to answer the local TB dynamics and characterisation of high risk areas in general spatial perspective, but also provide a spatial knowledge for local researchers and decision makers to find, detect, and treat better solutions to the national TB strategies and challenges. Additional data on the risk factors and other spatial regression techniques can be further explored for more significant results.

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6. References
