ORIGINAL ARTICLE

Urbanization and Tuberculosis in Peninsular, Malaysia (2011-2015)

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ABSTRACT

Introduction: Tuberculosis (TB) is a major global concern as it continues to kill million people annually despite the availability of effective treatment. One of the social factors affecting the spread of tuberculosis is urbanization. Tuberculosis remains as the leading cause of death from communicable diseases in Malaysia for more than a decade. Geographic information system (GIS) has been used to understand the epidemiology of infectious diseases, to identify hot spots/ clusters of areas/ populations at high risk. The aim of this study was to determine the correlation between urbanization and TB in the Peninsular of Malaysia during 2011-2015 and develop TB incidence risk map using GIS. **Methods:** A cross-sectional study was conducted using TB cases data on tuberculosis incidence, tuberculosis deaths, urban population, population and population density from the Ministry of Health, Malaysia for the period 2011 to 2015. This data was analysed using SPSS version 23.0 and Arc GIS. **Results:** The number of TB cases and urbanization varied in the Peninsular. There was a statistically significant strong positive correlation between the number of TB cases and urban population ($r=.884$, $p<.001$). The highest mean of TB cases was recorded in Selangor (3922) while the lowest mean was in Perlis (146). Selangor state was noted to have the highest number of urban population and TB cases. **Conclusion:** The areas with higher urban population are at a higher risk of TB compared to those with low urban population.

Keywords: GIS, Tuberculosis, Urban population, Urbanization

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INTRODUCTION

Tuberculosis (TB) is a chronic airborne infectious disease which is caused by Mycobacterium tuberculosis and commonly affects the lungs though is capable of affecting other organs (1). It has been ranked as the leading cause of adult mortality from a single infectious disease worldwide by the World Health Organization (WHO) in 2018 (2). Globally there is one new TB case every 4 seconds and more than 2 TB deaths every minute (3). TB remains a serious global public health issue as it accounts for a substantial number of deaths annually despite the availability of effective anti-tuberculosis chemotherapy (4). One fourth of the world's population is currently infected by tuberculosis (2). The risk factors known to increase the probability of acquiring TB infection include smoking, diabetes, human immunodeficiency virus (HIV) co-infection, malnutrition, on immunosuppressive drugs, overcrowding, poor ventilation, poverty, and homelessness (2,5,6).

South-East Asia (44%), Africa (24%) and Western Pacific (18%) Regions of WHO were noted to have the highest incidence of TB in 2018 (2). Malaysia is currently categorized as an Intermediate TB burden country by WHO with incidence rate of 92/100,000 population but is surrounded by countries (Thailand, Indonesia, Vietnam, Cambodia and Philippines) which are declared as high TB burden countries (7). Tuberculosis has become a disease without borders in Malaysia because of the regular influx of foreigners (8). Malaysia has not been able to meet the WHO target in treatment and cure of TB as the cure rate (78.62%) and mortality rate (6.65) in 2018 is not close to 85% and 3 respectively (9). Tuberculosis has become the leading cause of death among infectious diseases in the past ten years in Malaysia with mortality rates of 5.56 per 100,000 population (10).

In Malaysia, a 25% increase in the number of TB cases was reported in 2015 since 2010 when 24,220 TB cases were reported in 2015 as compared to 19,337 cases in 2010 (11,12). The number of TB deaths increased by 5.8% from 1,603 deaths in 2014 to 1,696 deaths in 2015 in Malaysia (10). The density of urban populations has been known to favour transmission of Tuberculosis (9,13,14). Urbanization is defined as increase in the number of populations of the cities/ towns/ urban areas in comparison with rural areas (1, 14). In 2015, almost half (54%) of the world's population was living in the urban cities and this is projected to increase to almost 70% by 2050 (15). In 2018, 2/3rd of the total population (76.04%) of Malaysia was living in the urban areas (16). The urban areas serve as incubators for new epidemics because of the increase in international travel and immigration to cities of late (17). This can lead to spread of the diseases in a more rapid manner and therefore adequate city planning and surveillance is recommended to decrease the burden of infectious diseases (13,17).

Urbanization in Malaysia has created high density housing areas which are susceptible to TB contagions because of their poor ventilation. The opening of shopping complexes, public transport terminals and public recreational places act as places of high public concentration which is conducive for TB transmission (18). It has attracted foreigners from high burden TB countries for study/ work or leisure purpose and thereby putting the local population at risk of contracting TB (18). It is estimated that by 2050, seven out every ten people will be residing in the city (15). It was noted that TB incidence was much higher in the cities in comparison to the rural areas globally. New York city was noted to have four times higher TB incidence than the national TB incidence (19). Geographic Information System (GIS), applications in the health informatics and epidemiology include community health profiling, disease mapping, disease surveillance, health risk analysis, health access and planning (20). Currently GIS has been deployed to assess the spatial distribution and clustering of TB in many countries (21-25). Since there is scarcity of literature on use of GIS to understand the distribution of TB and urbanization in the Peninsular of Malaysia, this study was conducted to develop TB incidence risk map and also the correlation between urbanization and TB cases in the Peninsular.

MATERIALS AND METHODS

This is a cross-sectional study. Data about the number of TB incidence cases, TB deaths and population details (total population, urban population) about the states in the Peninsular, Malaysia from the year 2011 till 2015 was obtained from Ministry of Health, Malaysia (Health Indicators and Health Facts for 2016, 2015, 2014, 2013, 2012) (11,12,26-31). This is an open access information from their official website hence no approval was sought for before using their data. The information about the urban population and population density was obtained from the website of Department of Statistics, Malaysia (32). This again was unrestricted information. The data cleaning revealed missing data for the year 2010 and also change in the reporting of TB incidence for Labuan in the year 2010 (it was grouped along with Sabah) and 2011 (had separate report for Labuan and Sabah), hence the data for the year 2010 was dropped from the analysis. Since the number of TB cases and deaths was reported together for Kuala Lumpur and Putrajaya, they were clubbed together in one group and their population added manually before entering for the analysis. The input layer of data was created in the Arc-GIS for the each of the variables, the data was then processed by creating attributes for each variable, ranking the scales of each attribute, developing map for each year (2011-2015) based on each attribute. The TB incidence risk map was developed by merging the attributes of TB incidence and urban population for the time period (2011-2015). The flow chart of the development of the risk map is as shown in the fig.1.

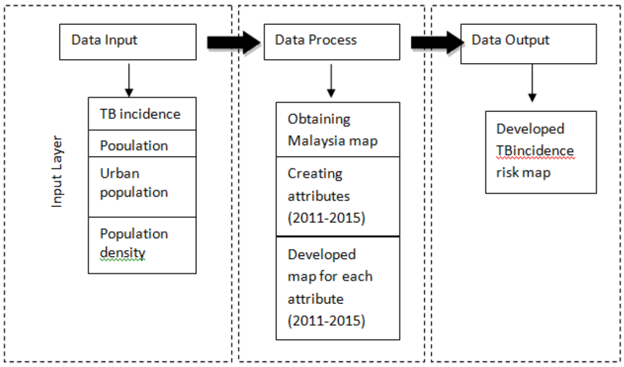

Fig. 1 : Flowchart of development of Risk Maps in GIS

DATA ANALYSIS

The data obtained was analysed using Statistical Package for Social Sciences version 23 (SPSS Inc, Chicago, IL, USA) and Arc GIS (10.4). Univariate and bivariate analysis of the variables was done. In univariate analysis, the continuous variables were described in their means and standard deviation. The normal distribution of the studied variables was checked and most of the variables were not normally distributed. Therefore, non-parametric Spearmen's correlation coefficient 'r' was interpreted instead of the Pearson's correlation coefficient. Correlation coefficient values of the variables studied are depicted in the table I. ArcGIS software was used to develop the TB cases distribution maps and also TB incidence risk maps for the Peninsular of Malaysia for 2011-2015.

As mapping the disease showed only the highlights of spatial variations of TB incidence but did not actually evaluate the distribution pattern of the TB (clustered, dispersed or random), spatial autocorrelation was carried out. The method selected for spatial autocorrelation was Moran's Statistics, as this method retains the interval values of the data in its calculation and thus retaining all the information (33). The null hypothesis (H_0) was that there is no spatial autocorrelation between TB incidence and the states of Peninsular, Malaysia. The alternative hypothesis (H_1) was that there is spatial autocorrelation between TB incidence and the states of Peninsular, Malaysia (clustered, dispersed or not random). The test statistic of the Moran's statistics is:

$$z = \frac{I - E_I}{\sigma_I}$$

Where σ_I is the standard deviation, I is the Moran's coefficient of spatial autocorrelation and E is the expected value of I, given as: $E_I = -\frac{1}{n-1}$

Where n is the total number of areas in the study region. The test of significance of the spatial autocorrelation was carried out under randomization sampling because we are considering the situation in the study area only. The Moran's coefficient I was calculated using the formula:

$$I = \frac{n \sum^{J}_{i=1} (x_i - x)(x_j - x)}{J \sum^{n}_{i=1} (x_i - x)^2}$$

Where n is the total number of areas, J is the total number of joins, x_i and x_j are the values of the values of the attribute variables for two contiguous areas and x is the mean of all the x values. The calculations conducted are as follows:

$$I = \frac{12(-25493947.69)}{19(273868009.8)} = -0.06$$

$$E = \frac{-1}{11} = -0.09$$

Since the standard deviation needed the value of kurtosis in the formula, it was calculated using the formulas below:

$$\sigma = \frac{\sqrt{\sum^{n}_{i=1} (x_i - x)^2}}{n-1} \quad \text{and} \quad k = \frac{\sqrt{\sum^{n}_{i=1} (x_i - x)^4}}{n\sigma^4}$$

The value of σ and k calculated was 4989.70 and 4.01 respectively. These values were substituted in the formula of deriving σ_I is as shown below:

$$\sigma_I = \frac{\sqrt{(n[J(n^2+3-3n) + 3J^2 - n\sum^{n}_{i=1} L^2] - k[J(n^2-n) + 6J^2 - 2n\sum^{n}_{i=1} L^2]}}{J^2 (n-1)(n-2)(n-3)}$$

Where, J is the total number of joins and L is the number or areas to which an area is joined, k is the kurtosis of the variable x.

The σ_I was calculated and the value was 0.19. The test statistic, z of Moran's statistic was subsequently calculated and was 0.16.

The critical values were -1.96 and +1.96 as the significance level was 0.05. Since the test statistic, z falls outside the critical region the null hypothesis cannot be rejected. There is no spatial autocorrelation between TB incidence and the states of Peninsular, Malaysia. The Hotspot analysis was not carried out further as the spatial autocorrelation showed no clustering distribution in the previous test. The necessary calculations used for determination of I, E_I, σ_I, k and σ are provided in the appendix A .

Table I : Correlation coefficient values of the variables

Variables	Spearman's correlation 'r'	'p' value
TB and Population	.942	.000**
TB and Urban Population	.884	.000**
TB and Population Density	.236	.069
TB Deaths and Population	.860	.000**
TB Deaths and Urban Population	.717	.000**
TB Deaths and Population Density	.007	.956**

**correlation is significant at the .01 level (2-tailed).

RESULTS

In the Peninsular all the 11 states (Perlis, Kedah, P. Penang, Perak, Selangor, N. Sembilan, Melaka, Johor, Pahang, Terengganu, Kelantan and 2 federal territories (Kuala Lumpur and Putrajaya) were evaluated in this study. There was gradual increase of TB cases in the Peninsular from 14,710 in 2010 to 17,065 in 2015. The minimum number of TB cases and TB deaths recorded in the Peninsular of Malaysia for the duration 2011-2015 were 99 and 4 respectively while the maximum TB cases and TB deaths recorded were 4,747 and 272 respectively. The Selangor state was noted to have the highest number of TB cases (>3,000) and Deaths (>182) in the Peninsular for the whole duration of 2011-2015. The state with the least number of TB cases (<200) and TB deaths (<20) in the Peninsular was Perlis for the whole duration of 2011-2015. The states with highest urban population percentage in the Peninsular during 2011-2015 was Kuala Lumpur and Putrajaya (100%) closely followed by Selangor (>90%) and P. Penang (>90%). The states with minimum urban population percentage for the duration of 2011-2015 in the Peninsular was Kelantan (<50%). The Population density was highest in Kuala Lumpur and Putrajaya (>6000/km2) and lowest in Kelantan (<45/ km2) for the duration 2011-2015 in the Peninsular.

The statistical test of correlation shows that the TB incidence has strong positive correlation with population (r=.942, p<0.001) and urban population (r= .884, p <0 .001) which are statistically significant but weak positive correlation with population density (r= .236, p= .069) which is not statistically significant. TB deaths have strong positive correlation with population (r=.860, p<0.001) and urban population (r=.717, p<0.001) which are statistically significant whereas the correlation between TB deaths and population density has a weak positive correlation (r= .007, p= 0.956) which is not statistically significant. The results conclude that with the increase in the population and urban population there will be an increase in TB incidence and deaths in the Peninsular, Malaysia. The maps showed very low TB incidence in the state of Perlis and very high in the state of Selangor during the 5-year study period (2011-2015). The maps were developed using TB incidence for the various time periods (2011-2015).

The attributes of TB incidence and urban population were aggregated after the statistical analysis and the risk map of TB incidence in the Peninsular, Malaysia was developed. The map is shown in the fig 2 , fig 3 fig 4, fig 5 and fig 6 respectively. The fig 2 shows very high TB incidence and high urban population in the state of Selangor with very low TB incidence and very low urban population in the state of Perlis for the year 2011. The fig 3 shows very high TB incidence and high urban population in the state of Selangor with very low TB incidence and very low urban population in the state of Perlis for the year 2012.The fig 4 shows very high TB incidence and high urban population in the state of Selangor with very low TB incidence and very low urban population in the state of Perlis for the year 2013. The fig 5 shows very high TB incidence and high urban population in the state of Selangor with very low TB incidence and very low urban population in the state of Perlis for the year 2014. The fig 6 shows very high TB incidence and high urban population in the state of Selangor with very low TB incidence and very low urban population in the state of Perlis for the year 2015. However, the spatial autocorrelation test revealed that there was no spatial autocorrelation between TB incidence and the states of Peninsular, Malaysia with the absolute value of Moran's *I* close to 0.

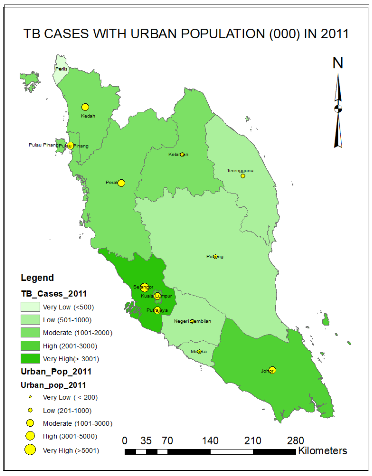

Fig. 2 : TB incidence risk map for Peninsular, Malaysia, 2011
Legend
TB cases
Very low (500)
Low (500-1000)
Moderate (1000-2000)
High (2000-3000)
Very high (>3000)
Urban population per 100000
Very low (<200)
Low (201-1000)
Moderate (1001-3000)
High (3001-5000)
Very high (>5001)

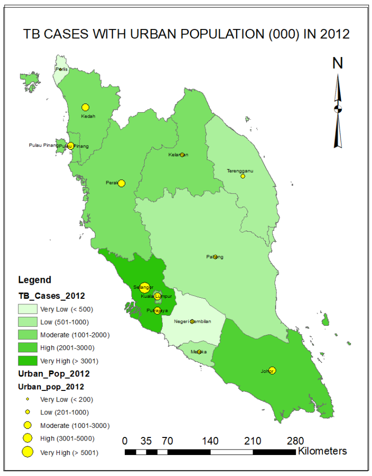

Fig. 3 : TB incidence risk map for Peninsular, Malaysia, 2012
Legend
TB cases
Very low (500)
Low (500-1000)
Moderate (1000-2000)
High (2000-3000)
Very high (>3000)
Urban population per 100000
Very low (<200)
Low (201-1000)
Moderate (1001-3000)
High (3001-5000)
Very high (>5001)

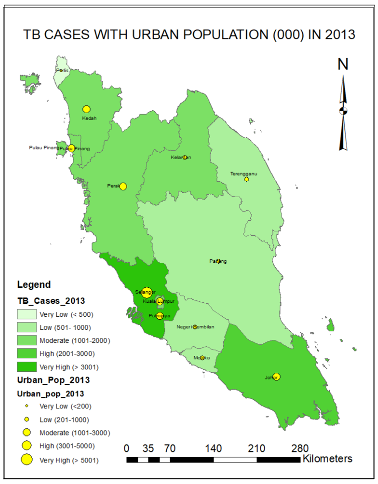

Fig. 4 : TB incidence risk map for Peninsular, Malaysia, 2013
Legend
TB cases
Very low (500)
Low (500-1000)
Moderate (1000-2000)
High (2000-3000)
Very high (>3000)
Urban population per 100000
Very low (<200)
Low (201-1000)
Moderate (1001-3000)
High (3001-5000)
Very high (>5001)

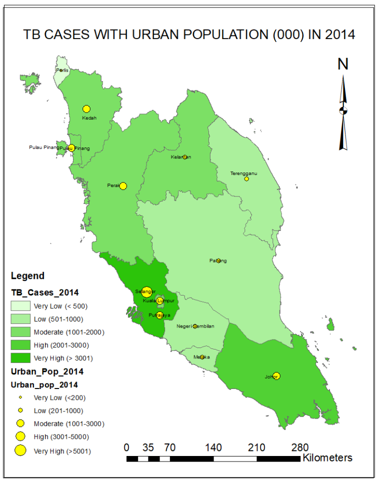

Fig. 5 : TB incidence risk map for Peninsular, Malaysia, 2014
Legend
TB cases
Very low (500)
Low (500-1000)
Moderate (1000-2000)
High (2000-3000)
Very high (>3000)
Urban population per 100000
Very low (<200)
Low (201-1000)
Moderate (1001-3000)
High (3001-5000)
Very high (>5001)

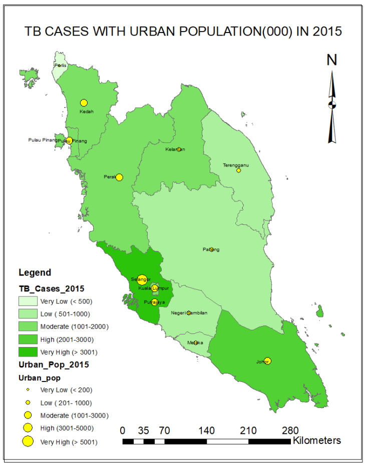

Fig. 6 : TB incidence risk map for Peninsular, Malaysia, 2015
Legend
TB cases
Very low (500)
Low (500-1000)
Moderate (1000-2000)
High (2000-3000)
Very high (>3000)
Urban population per 100000
Very low (<200)
Low (201-1000)
Moderate (1001-3000)
High (3001-5000)
Very high (>5001)

DISCUSSION

The distribution of the number of TB cases varied in different states in the Peninsular. The states with high population and urban population were noted to have higher number of TB cases and TB deaths while the states with the low population and urban population were noted to have low number of TB cases and TB deaths. This can be explained by the fact that the TB transmission pattern is influenced by geographic and social factors (6,22). Selangor and Johor remained the states with high population and urban population and high number of TB cases while Perlis had lowest population, urban population and lowest TB cases throughout the 5 year period.

Even though most of the states showed an increase in their urban population but only Selangor state was noted to have a very high increase in the TB incidence. This could be related to the fact that Selangor state is the home to the two Federal Territories namely Kuala Lumpur (capital city of Malaysia) and also Putrajaya (administrative hub of Malaysia). This could explain the high influx of immigration of foreigners and also locals from other states into Selangor for bussiness, work, education, health and leisure related activities. Thus making Selangor state a favourable place for TB transmission. However, apart from urbanization, other socio-economic factors affecting TB incidence in the Selangor state must be studied to confirm this postulation. This is consistent with the findings of a study conducted in the United states where the large cities had TB incidence rates two times higher than the rest of the counrty(5). Spatial analysis of TB incidence in Burundi also revealed that the eastern provinces had low TB incidence rate in comparison to its middle and western provinces (34). The findings of our study resonate the spatial variations in the TB incidence in the states of Peninsular, Malaysia over the 5 year duration period.

The findings of strong positive correlation between TB incidence and population is similar to the findings of a local study in Shah Alam, Malaysia which found that population was the main indicator of TB endemics in Shah, Alam (21). The increase in population in a particular area leads to increase in the crowded spaces which eases TB transmission and thereby increase in the TB incidence of that area (6). The urban population of the Peninsular of Malaysia increased from an average of 71.2 % in 2011 to 74.5% in 2015. This is in keeping with the global trends which has seen an increase in the number of urban population (8). Malaysia has been recognised as one of the most rapidly urbanized region globally (35). This could also be attributed to the increasing popularity of Malaysia as the destination of choice for work, holidays and educational hub and also shift of the economy and employment from agriculture to industry and services. There was an 16% increase (2,355 cases) of TB cases in the Peninsular over the 5 years (from 14,710 cases in 2011 to 17,065 cases in 2015). This could be attributed to urbanization which create high density housing areas, new places of high people concentration and influx of immigrants of foreigners from High-burden TB countries and thereby promote easy spread of infectious diseases like tuberculosis (18).

The findings of this study showed that with the increase in the urban population there was an increase in the the TB incidence (r=.884, p <0 .001) and also TB deaths (r=.717, p<0.001). A study in Ethiopia had similar findings where they found clusters of TB in the urban areas and areas with high population density and also areas close to towns and near the roads connecting to big towns (23). A Japanese study also had similar results whereby they found hots spots for TB transmission in urban areas which had large daytime population, large proportion of foreign-born people residing and proximity to nearest railway station (24). However, a study conducted in China revealed that the TB case notification was higher in the areas with higher proportion of rural population (37). This could be attributed to difference in the allocation of the medical resources in the urban and the rural areas. Another study from Bangladesh, resonated with our results where they found that the TB related deaths were higher in the urban areas compared to the rural areas (38). This was explained by the fact that in Bangladesh, the urban areas are densely populated and a large proportion of the urban population were slum dwellers.

High population density has long been associated with high TB incidence in previous studies (37-39). However, our study showed weak positive correlation between TB incidence and population density which was not statistically significant. This may be explained by the fact that since the high population density is usually in the urban areas where the access to healthcare facilities and treatment is easier and so the timely intervention may have reduced the TB incidence and TB deaths. Another study in the United States showed that there was significant correlation between ambient air pollution and TB. This air pollution is a proxy for urban areas (36).

To conclude the study, the TB incidence risk maps developed for the Peninsular, Malaysia for the duration of 2011-2015 depicted the same that TB incidence was higher in the states with higher urban population. The northern-eastern parts of the Peninsular had lower TB incidence and also low urban population as compared to the southern and western parts. This could be either due to poor accessibility to TB control services or due to actual low TB burden in these areas. This is a cross-sectional study and thus is not conclusive to establish cause and effect. The study used secondary data and therefore it lacks control over the data quality and its appropriateness. The number of risk factors studied was limited and also there was lack of addresses in the data which would have produced a more comprehensive and accurate maps. Future studies are recommended to be conducted within the state of Selangor at district and sub-district levels by including more risk factors to understand the reason behind this variation in TB incidence. Future studies are also recommended to confirm the effect of urbanization on TB incidence. It is recommended to develop GIS index model for identifying the potential high-risk areas of TB cases in Selangor.

CONCLUSION

In conclusion, the factors affecting TB incidence were population and urban population. There was no spatial autocorrelation between TB incidence and states of Peninsular, Malaysia for the period 2011-2015. Future studies with more attributes and at district/ sub-district levels in the state of Selangor is recommended to identify the hotspot areas of TB and strengthen the local prevention and control programs of TB of those areas.

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