SPATIAL PATTERNS OF TUBERCULOSIS INCIDENCE IN BUFFALO CITY MUNICIPALITY, EASTERN CAPE PROVINCE, SOUTH AFRICA: THE DISEASE MAP APPROACH

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Abstract

The purpose of this research was to investigate the spatial and temporal distribution of tuberculosis (TB) between 2008 to 2015, and to also identify clusters of higher prevalence and incidence of TB in Buffalo City Municipality, Eastern Cape Province of South Africa, in order to generate a disease atlas. Spatial patterns and distribution of disease incidence were investigated using the Arc GIS 9.2 and descriptive statistics by a graphical ranking method imposed on the map. Also clustering techniques was used to identify the exact locations for high and low incidences of TB. The cluster mappings were also produced as building blocks in the profiling of the TB cases. GIS queries were also carried out to further emphasize the clustering patterns of the disease for the period of 2008-2015.From our investigations and findings, four clusters of high incidence of TB was identified in East London, Mdantsane, Duncan village and King William's Town for all the years under study. This high prevalence of TB cases in those locations also showed a high association with HIV/AIDS prevalence. The GIS showed an eastward outlook in the prevalence of TB in the municipality. The combined cluster map and GIS queries also showed an eastward high prevalence of TB.TB prevalence in the municipality showed a systematic pattern in the distribution of the disease cases in the region and is found to concentrate in areas of high HIV/AIDS rates and also areas mostly populated by Blacks. Multifaceted and hidden relationships may exist between TB incidence and a wide range of environmental and inherent factors, which call for future research.

Keywords: Geographical Information System, Statistics, Tuberculosis, Spatial Epidemiology

Introduction

Tuberculosis (TB) is an infectious disease, generally chronic, and caused by a group of bacteria: Mycobacterium tuberculosis, M. africanum, M. bovis, M. microti and M. canettii. The main transmission is from person to person by micro drops generated by coughing or sneezing of a person with active TB (Baker et al., 2011). It is still one of the oldest human diseases that still affect large population groups. Tuberculosis is closely linked to both overcrowding and malnutrition, making it one of the principal diseases of poverty (Lawn et al., 2011). More people in the developing world contract tuberculosis because of a poor immune system, largely due to high rates of HIV infection and the corresponding development of AIDS (Lawn et al. 2011).

South Africa ranks as the third highest in the world-burden of Tuberculosis and for three consecutive years (2007, 2008 and 2009), tuberculosis ranked as the number one among the ten leading underlying natural causes of death (WHO 2010). Tuberculosis in the Eastern Cape Province mainly affects the economically active age group. Within the age group of 25-34 years the percentage distribution of reported TB cases was 15.9%, 0.7% and 23.1% for the years 2003, 2004 and 2005 respectively. A report on South African National Burden of Disease study 2000 Eastern Cape Province by MRC showed that tuberculosis was the second leading cause of death among women and the third leading cause of death among men aged 15-44 years. Eastern Cape Province ranks as the second highest burden of TB by province after Kwa Zulu Natal (NDoH 2010 data).In people with normal immune systems, the lifetime risk of progressing from latent TB infection to active TB disease is 10%. HIV, by weakening the immune system, increases a person's risk of progressing from latent TB infection to active TB disease by 10% per year. The province has an extremely high burden of TB, co-infection with TB and HIV (TB/HIV) and MDR-TB. In 2008, there were more than 60 000 new TB cases in the province. Of these, there were 1,251 confirmed cases of MDR-TB and 385 confirmed cases of XDR-TB. In 2010, the total of new TB and re-treatment cases identified in the province stood at 62,226 (ECAC 2012).

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The study of geographic patterns of disease is part of

replacement for the blend of lifestyle, environmental, and possibly genetic factors that may trigger variations in rates of disease across populations. The goal is both to describe such variations and to identify possible causes that could explain them. Disease risk varies geographically as a result of many factors, including differences in environmental exposures, and cultural and behavioural differences between the inhabitants of different areas. One of the most important reasons for these differences is poverty, with a recent Audit Scotland report (Audit Scotland (2012)) finding that people in deprived areas have higher rates of coronary heart disease, mental health problems, obesity, alcohol and drug misuse, diabetes and some types of cancer (Anderson 2015).

Disease mapping is usually carried out to investigate the geographical distribution of disease burden. Area specific estimates of risk may inform public health resource allocation by estimating the disease burden in specific areas, and the informal comparison of risk maps with exposure maps may provide clues to etiology or generate hypotheses (Wakefield 2007). The applications of disease mapping in epidemiology and public health have enjoyed a great deal of acceptance. Disease mapping refers to the estimation and demonstration of summary measures of health outcomes that are spatially observed (Rezaeian et al., 2007). Mapping of disease incidence and prevalence is a common concept in public health and epidemiology. Regularly the main interest in disease mapping is to smoothen and predict some response variables over a geographical area of interest. However, there are two central characteristics of disease mapping, namely geographical distribution and the disease. The area-specific estimates of the diseases can be used by policy makers to prioritize and make decisions on public health resources allocation and interventions.

The concept of disease mapping can also be used to describe geographical variation of diseases, identify clustering of diseases and generate atlas of diseases. A good number of statistical reviews on disease mapping have been done (Wakefield 2007; Clayton and Bernardinelli, 1992; Smans and Esteve, 1997; Wakefield et al., 2000; Manda et al., 2011). Disease mapping has a long history in epidemiology (Walter, 2000) as part of the classic triad of person/ place/time. A number of statistical reviews are available (see for example, Smans and Esteve, 1992; Clayton and Bernardinelli, 1992; Mollie, 1996; Wakefield and others, 2000).

Research to evaluate the spatial distribution of TB and to identify high-risk areas is also limited especially in developing countries (Bishai et al. 1998; Verver et al. 2004; Vieira et al. 2008).Since it is known that control efforts are best designed when areas of high prevalence are known, it is also important to know areas where rates are abnormally high given the underlying risk factors. The use of spatial analysis techniques for mapping the geographic distribution of TB cases have been considered by many authors (Alvarez-Hernandez et. al.,

2010; Touray et al. 2010). By exploring the nature of TB incidence data, it was found that TB is not randomly distributed among geographical locations, with the cases tending to gather at particular locations (Maciel et al. 2010). Therefore, the identification of these areas with different levels of TB prevalence takes into account that the public health system deals with the features and underlying risk factors of each location specifically and prioritizes those that show higher incidences of the disease. Special tools in spatial statistics have advanced our understanding of the geographic distribution of disease and improved the focus of public health actions (Anselin, 1995; Bailey, 2001).

Some recent publications have emphasized the role of Geographical Information Systems technology in Public Health research, its use being limited by the quality of address information, particularly those available in routine information systems. Yu and Christakos studied the spatio-temporal mapping of the bubonic plaque in India using stochastic concepts and GIS techniques (Yu et al. 2006). In the case of TB, various researchers have used GIS to study this infectious disease. Moonan et al. (2004) used GIS to identify the geographic locations of TB transmission and incidence in the United States of America during 1993 to 2000. Tiwari et al. (2006) used GIS and spatial scan statistics to detect the geo-spatial hotspots of TB in Almora district of India and found significant high rate spatial and space-time clusters in three areas of the district. Nunes also used spatial scan statistic and GIS to study the TB incidence in Portugal (Nunes, 2007). Bastida et al. (2012) used scan statistics and GIS to identify the spatial and temporal distribution of TB in the state of Mexico with age-gender and margination as covariables, and found out that TB is spatially clustered.At present, geographic information systems (GIS) are among the most useful tools in epidemiology, as they can be used to detect geographical areas and population groups with a higher risk of disease or premature mortality and which therefore require higher preventive care or health information and monitoring of diseases in time and space (Martinez et al., 2001; Kulldorf et al,. 1995).The use of Geographical Information system (GIS) with spatial statistics, including spatial cluster filtering and cluster analysis have been applied to many cases to analyse and more clearly, display the spatial patterns of disease (Odoi et al., 2004; Hsu et al.2004; Dechello et al. 2006). Many authors agree that GIS is a useful tool for awareness against TB.

Materials and Methods

Study area

Buffalo City is a metropolitan municipality situated on the east coast of Eastern Cape Province, South Africa (figure 1). It includes the towns of East London, Bhisho and King William's Town, as well as the large townships of Mdantsane and Zwelitsha. Buffalo City is the key urban centre of the eastern part of the Eastern Cape and consists of a corridor of urban areas, stretching from the port city of East London to the east, through Mdantsane to Dimbaza in the west. East London is the primary node, while King Williams Town area is the secondary node. This region also contains a wide band of rural areas on either side of the urban corridor (ECSECC 2014).

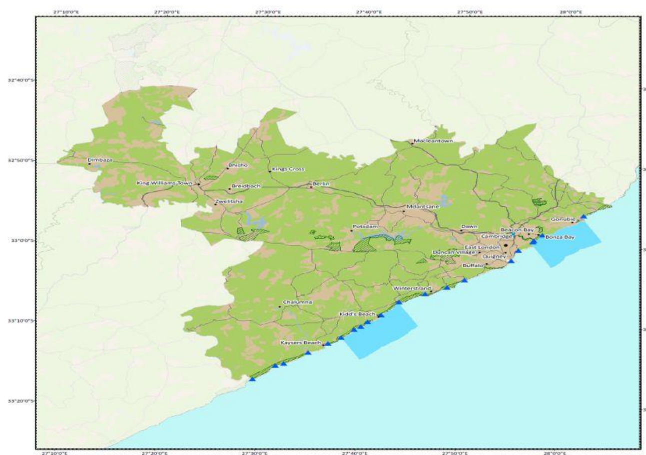


Figure 1: Map of Buffalo City Municipality, Eastern Cape, South Africa.

The municipality city is situated at 32.59°S and 27.52°E in the Province (Figure 1). The municipality was established as a local municipality in 2000 after South Africa's reorganisation of municipal areas, and is named after the Buffalo River, at whose mouth lays the only river port in South Africa. On 18 May 2011 it was separated from the Amathole District Municipality and converted into a metropolitan municipality.

Population data from census 2011 by Statistics South Africa showed it has an estimated population of 755,200. The municipality also has a racial mix-up and details as follows: Black African 85.1%; Coloured 6.0%; Indian/Asian 0.8%; White 7.7%.

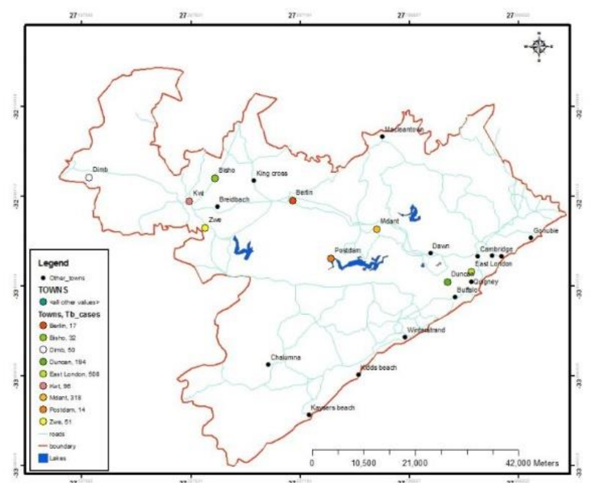


Figure 2: Location and geographical distribution of TB cases from 2008-2015 in Buffalo Municipality, SA. (Source: Author's Lab Work, 2017)

Analyses: Statistical, Spatial and Geographical Analysis.

TB frequencies and temporal distribution: Identifying and determining TB frequencies were done with statistical graphical methods to identify areas of high incidence by time plots and also by their histograms imposed on the map for each location.

Geographical analysis: For the geographic and graphic representation of the disease prevalence, Arc GIS 9.2 was used to identify and query areas of TB clusters. The distribution of the disease clusters for each region was used to generate a disease map to display the spatial patterns and clustering of TB in the municipality.

Ethical Consideration: This study was carried out under the authorization and permission of the Ethical committee of the University of Fort hare and Eastern Cape Department of Health respectively, with ethical clearance certificate reference number QIN041SOBA01. ResultsThere were 1,275 living human TB cases that were traceable by their addresses from 2008 to 2015, distributed in nine (9) locations in the municipality: East London (EL), King William's Town (KWT), Mdantsane (MDANT), Zwelitsha (ZWE), Duncan Village, Bisho (BSH), Dimbaza (DIM), Berlin and Postdam. The locations with more than 100 TB cases are EL with 508 (39.8%); MDANT 318 (24.9%) and Duncan 194 (15.2%).Three types of analyses were performed from using the collected information: Descriptive statistical analyses, spatial analysis and GIS queries.

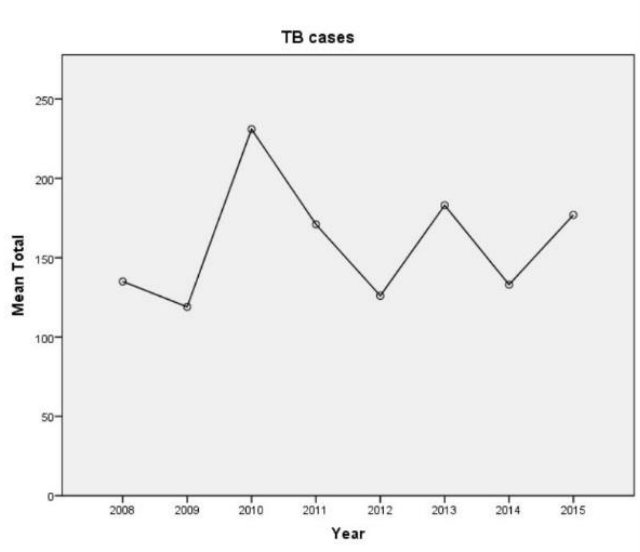
Descriptive Statistics Analysis. A distribution table of means and skewness was obtained to show the descriptiveness of the data in Figure 3. Also, from the TB data, the distribution of the 1,275 cases is shown in the time plot in Figure 3 with a high peak of 231 in 2010 and lowest recorded number of 119 cases in 2009. Also, the frequency of TB cases by locations is also displayed in Figure 4 with East London, Duncan and Mdantsane showing high incidence of TB. King Williams Town and Zwelitsha also showed a slightly high incidence of TB over the years under study.

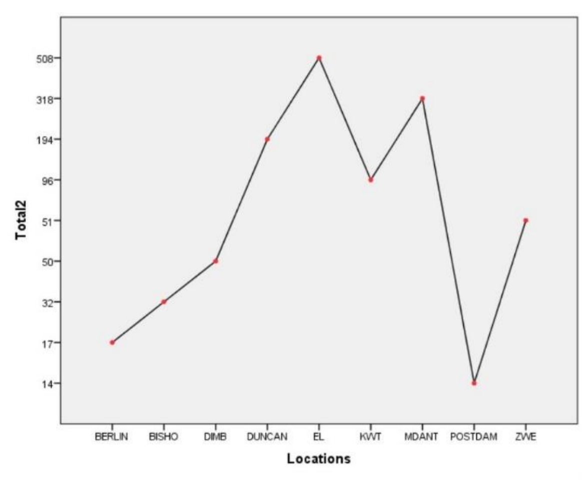
Statistics

		2008	2009	2010	2011	2012	2013	2014	2015
N	Valid	9	9	9	9	9	9	9	9
	Missing	0	0	0	0	0	0	0	0
Mean		15.0000	13.2222	25.6667	19.0000	14.0000	20.3333	14.7778	19.6667
Skewness		1.086	1.152	1.539	1.854	1.616	1.828	1.762	1.678
Std. Error of Skewness		.717	.717	.717	.717	.717	.717	.717	.717

Fig. 3: Table of distribution for means and skewness of TB cases for 2008 to 2015. (Source: Author's Lab Work, 2017)

Fig. 3: Time plot distribution of TB cases in Buffalo.Fig. 4: Total frequency line plot of TB cases by locations/towns in the municipality. (Source: Author's Lab Work, 2017)





Spatial (GIS) Analysis. TB prevalence and spatial distribution for the years 2008 to 2015 was shown by GIS analysis. Histograms representing the total localization of the cases were imposed on the respective locations on the map by GIS. Three major locations show a high incidence rate: East London, Mdantsane and Duncan village, but with Duncan village showing a flatter histogram. This implies a more clustering of the cases for all the years under study and showed also that transmission of the disease is more rapid with little resistance and prevention. Regions with higher incidence also showed an eastern pattern of spatial distribution: East London, Mdantsane and Duncan village (Fig.5).

Individual cluster maps were produced for all the years to display annual clustering patterns of TB cases in the municipality. Three clusters of TB cases were also identified in East London, Mdantsane and Duncan village, with \East London and Duncan showing an almost interwoven clustering for all the years (Fig.6).

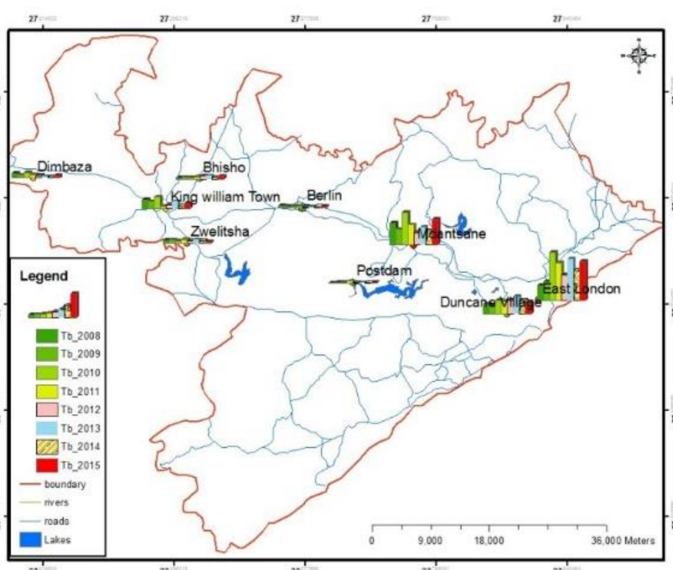


Fig. 5: Map of Buffalo City showing spatial distribution frequencies of TB cases from 2008-2015.

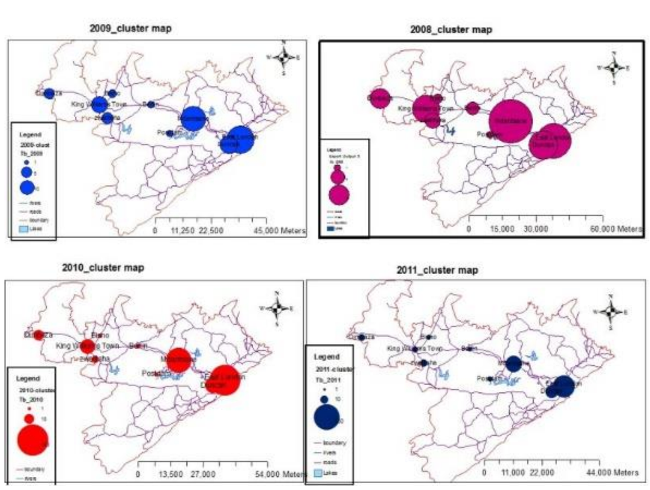


Fig. 6 (a): TB cluster maps from 2008-2011.
Source: Author's Lab Work, 2017

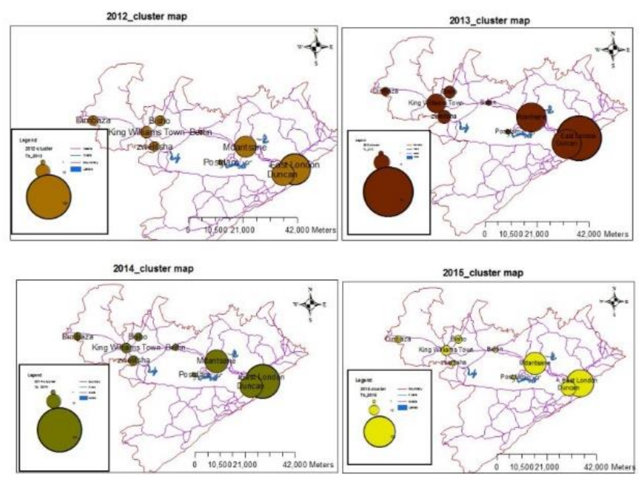


Fig. 6(b): TB cluster maps from 2012- 2015.
Source: Author's Lab Work, 2017

GIS Queries. The attractiveness of GIS is in its ability to query the database, for the purpose of identifying the trend and consistency of areas with high incidence of TB cases. The following queries were performed on the annual TB cases data with Figures 8(a) and (b) showing areas with TB cases of 30 and above during the study years as primary clusters: East London, Mdantsane and Duncan village.

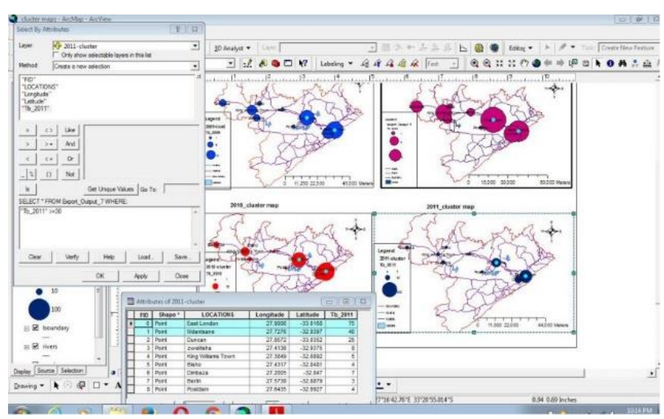


Fig. 8 (a): Query 1. Showing areas with TB cases of 30 and above. Source: Author's Lab Work, 2017

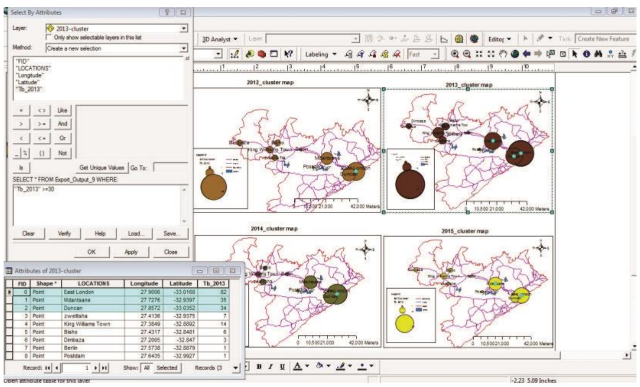


Fig. 8 (b): Query 1. Showing areas with TB cases of 30 and above. Source: Author's Lab Work, 2017

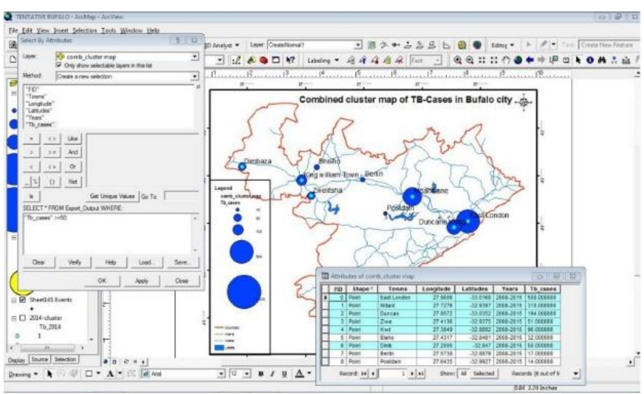


Fig. 8(c): Query 2. Shows areas highlighted as towns with TB cases of 50 and above from 2008 to 2015. Source: Author's Lab Work, 2017

A secondary cluster was defined as areas with TB cases of 50 and above and it was discovered that all the locations under study fall in this category. The implication of this is that all the locations in the municipality were susceptible and prone to TB spread and would beat a high risk of the disease if not controlled. For the three primary clusters with 30 cases and above, it implies that it has regular incidence of the disease yearly for those three locations: East London, Mdantsane and Duncan village.

Discussion

In the field of spatial epidemiology, one of the most important analyses is the detection and identification in space and time of a disease incidence and cluster. In this study, we have used some descriptive statistics and GIS techniques to investigate the distribution and incidence of TB cases in Buffalo City municipality in the Eastern Cape Province of South Africa. This study is compatible with previous ecological analyses on spatial epidemiology, that TB incidence and distribution is systematic and not random for most geographical locations (Bestida et al. 2012; Roza et al. 2012; Rindra et al. 2010).

The use of GIS and spatial statistics has been employed to investigate and determine spatial distribution patterns of some communicable and non-communicable diseases (18-22). ArcGIS software has been used globally to detect various disease clusters like TB. GIS plus molecular methods have been used to trace TB clusters and to identify the Mycobacteruim responsible for the outbreak (10).

From our results using ArcGIS and descriptive statistics, three primary clusters with high prevalence were identified, and it showed that TB is not randomly distributed in Buffalo City municipality but systematic in a spatial pattern. These three TB clusters are closely located to and around East London, the largest town in the municipality. The highest incidence rates of TB are usually found in urban areas (24) when compared with rural areas. Our outcomes hereby agreed with those reported by Moonan et al. (10). They found a strong relationship between the strains of TB clusters and the distance to the center of urban regions. Our three TB cluster locations were also observed to have a very high co-infection with HIV/AIDS during the years 2008, 2012 and 2014 from our data information collected, though outside the scope of this study. East London: 56.6%, 58.2% and 68.3% respectively; Mdantsane: 36.4%, 33.3% and 42.9 respectively and Duncan: 65.0%, 61.5% and 42.3% respectively. This also proves that TB and HIV/AIDS have a linear and positive association (Lawn et al. 2011).

Of the three identified clusters, another location, King Williams Town, is also in agreement with those identified as high incidence from the GIS queries, but the other towns in the municipality are situated in areas not close to the spatial clusters.

The results of this study are and will be of great and immense importance in TB epidemiological surveys and assessment in the municipality, and especially to the Department of Health in the Sub-district. The identification and presence of clusters is valuable to healthcare systems since strategies and interventions can be revised accordingly in those areas containing the disease clusters.

Conclusions

Tuberculosis is spatially and systematically clustered in Buffalo City Municipality, Eastern Cape, South Africa. Three major primary clusters were identified using three types of analyses: Descriptive statistics, spatial statistics and GIS queries. The clusters were mainly found in East London, Mdantsane and Duncan village. King Williams Town was also found to have a significant high rate of TB incidence.

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References

Adrian Zaragoza Bastida, Marivel Hernández Tellez, Lilia P. Bustamante Montes, Imelda Medina Torres, Jaime Nicolás Jaramillo Paniagua, Germán David Mendoza Martínez, & Ninfa Ramírez Durán.(2012). Spatial and Temporal Distribution of Tuberculosis in the State of Mexico, Mexico. The Scientific world Journal Volume 2012, Article ID 570278.

Alvarez- Hanandez, G., lara-Valencia, F., Reyes-Castro, P.A. & Rascon-Pacheco, R.A. (2010).An analysis of spatial and socio-economic determinants of tuberculosis in Hermosillo, mexico, 200-2006. Int J Tuberc Lung Dis. 14:708-713.

Anselin, L. (1995).Local Indicators of Spatial Association-LISA Georg Anal. 27:91-115.

Bailey, T.C. (2001). Spatial Statistical Methods in Health. Cadernos De Saude Publica 17, 1083-1098.

Baker, M.G., Venugopal, K. & Howden, C.P. (2011).Household Crowding and Tuberculosis, World Health Organization Regional Office for Europe, Copenhagen, Denmark.

Bishai, W.R., Graham, N.M., Harrington, S. et al. (1998). Molecular and geographical patterns of tuberculosis transmission after 15 years of directly observed therapy. JAMA. 280:1679-1684.

Burden of TB by Province In South Africa.(2010). National department of Health (NDoH) 2010 Data.

Carla Nunes. (2007). Tuberculosis incidence in Portugal: spatio-temporal clustering. International Journal of Health Geographics. 6:30 doi:10.1186/1476-072X-6-30.

Clayton, D. & Bernardinelli, L. (1992). Bayesian methods for mapping disease risk: Geographical and environmental epidemiology, methods for small-area studies. Oxford University Press, Oxford.

Craig Anderson (2014). Identifying Clusters in Bayesian Disease Mapping (PhD thesis) December 2014.

Daiane Leite da Roza , Maria do Carmo Gullaci, Guimarães Caccia-Bava & Edson Zangiacomi Martinez. (2012) Spatio-temporal patterns of tuberculosis incidence in Ribeirão Preto, State of São Paulo, southeast Brazil, and their relationship with social vulnerability: a Bayesian analysis. Revista da Sociedade Brasileira de Medicina Tropical 45(5):607-615.

Debbie Bradshaw, Nadine Nannan, RiaLaubscher, Pam Groenewald, JanéJoubert, Beatrice Nojilana, Rosana Norman, Desiréé Pieterse & Michelle Schneider. (2000). Mortality Estimates for Eastern Cape Province..Medical Research Council (MRC), South Africa.Burden of Disease Research Unit. 2000.

Eastern Cape AIDS Council (ECAC) 2012. Eastern Cape Provincial Strategic Plan for HIV, TB and STIs (2012-2016).Elias, J., Harmsen, D., Claus, H., Hellenbrand, W., Frosch, M. &

Vogel, U. (2006). Spatiotemporal analysis of invasive meningococcal disease, Germany. Emerging Infectious Diseases, vol. 12, no. 11, pp. 1689 1695.

Graham Barr, Diez-Roux, A.V., Knirsch, C.A. & Pablos-Méndez, A. (2001) .Neighborhood poverty and the resurgence of tuberculosis tuberculosis in New York City, 1984 1992.American Journal of Public Health, vol. 91, no. 9, pp. 1487 1493, 2001.

Hwa-Lung Yu& George Christakos. (2006).Spatiotemporal modeling and mapping of the bubonic plague epidemic in India. International Journal of Health Geographics.5:12.

Kulldorff, M. & Nagarwalla, N. (1995). Spatial disease clusters: detection and inference. Statistics in Medicine, vol. 14, no. 8, pp. 799 810.

Lawn, S.D. &Zumla, A.I. (2011).Tuberculosis. The Lancet, vol. 378, no. 9785, pp. 57 72.

Maciel, E.L.N., Pan, W., Dietze, R., Peres, R.L.,Vinhas, S.A., Ribeiro, F.K., Palaci, M., R. R. Rodrigues, R.R., Zandonade, E.& J. E. Golub, J.E. (2010).Spatial patterns of pulmonary tuberculosis incidence and their relationship to socio-economic status in Vitoria, Brazil. Int. J. Tuberc. Lung Dis. 14(11): 1395 1402.

Manda, S.M., Feltbower, R.G. & Gilthorpe, M.S. (2011).Review and empirical comparison of joint mapping of multiple diseases. Southern African Journal of Epidemiology and Infection, 27(4):169:182.

Martinez, R., Vidaurre, M., Najera, P., Loyola, E. & Castillo, C. (2001).SIG-Epiuso de sistemas de informacióngeográficaenepidemiologíaySalud Pública. Boletín Epidemiológico, Organización Panamericana de la Salud, vol. 22, no. 3, pp. 1 8.

Mohsen Rezaeian, Graham Dunn, Selwyn St Leger & Louis Appleby. (2007). Geographical epidemiology, spatial analysis and geographical information systems: a multidisciplinary glossary J Epidemiol Community Health; 61 :98 102. doi: 10.1136/jech.2005.043117.

Molli´e, A. (1996). Bayesian mapping of disease. In: Gilks, Walter R., Richardson, Sylvia, and Spiegelhalter, David J. (editors), Markov Chain Monte Carlo in Practice. New York: Chapman & Hall. pp 359 79.

Neeraj Tiwari, CMS Adhikari, Ajoy Tewari & Vineeta Kandpal. (2006). Investigation of geo-spatial hotspots for the occurrence of tuberculosis in Almora district, India, using GIS and spatial scan statistic.International Journal of Health Geographics. 5:33 doi:10.1186/1476-072X-5-33

Odoi, A, Martin, S.W., Michel, P., Middleton, D., Holt, J. & Wilson, J. (2004). Investigation of clusters of giardiasis using GIS and spatial scan statistic. Int J Health Georg. 3: 11-10.1186/1476-072X-3-11.

Oeltmann, J.E., Varma, J.K. & Ortega, L. et al. (2008). Multidrug-resistant tuberculosis outbreak among US-bound Hmong refugees, Thailand. Emerging Infectious Diseases, vol. 14, no. 11, pp. 1715 1721.

Patrick K Moonan, Manuel Bayona, Teresa Quitugua, Joseph Oppong, Denise Dunbar, Kenneth Jost Jr, Gerry Burgess, Karan Singh & Stephen Weis. (2004). Using GIS technology to identify areas of tuberculosis transmission and incidence.International Journal of Health Geographics. 3:23.

Rindra V Randremanana, Vincent Richard, Fanjasoa Rakotomanana, Philippe Sabatier & Dominique J Bicout. (2010). Bayesian mapping of pulmonary tuberculosis in Antananarivo, Madagascar.BMC Infectious Diseases BMC series. 10:21.

Rodrigues, R.R., Zandonade, E. & Golub, J.E. (2010). Spatial patterns of pulmonary tuberculosis incidence and their relationship to socio-economic status in Vitoria, Brazil. Int J Tuberc Lung Dis. 14(11): 1395 1402.

Smans, M. & Esteve, J. (1992). Practical approaches to disease mapping. In: Elliott, P., Cuzick, J., English, D. and Stern, R. (editors), Geographical and Environmental Epidemiology: Methods for Small-Area Studies. Oxford: Oxford University Press. pp 141 50.

Smans, M. & Esteve, J. (1997). Practical approaches to disease mapping: Geographical and Environmental Epidemiology, Methods for Small area studies. Oxford University Press.

Touray, K., Adetifa, I.M., Jallow, A., Rigby, J., Jeffries, D. & Cheung, Y.B. et al. (2010).Spatial analysis of tuberculosis in an urban west African setting: is there evidence of clustering? Trop Med Int Health. 15: 664-672.

Verver, S., Warren, R,M., Munch, Z, et al. (2004). Transmission of tuberculosis in a high incidence urban community in South Africa. Int. J. Epidemiol. 33:351 357.

Vieira, R.C., Prado, T.N., Siqueira, M..G, Dietze, R. & Maciel, E.L. (2008).Spatial distribution of new tuberculosis cases in Vitória, state of Espírito Santo, between 2000 and 2005. Rev Soc Bras Med Trop; 41:82 86.

Wakefield, J. (2007). Disease mapping and spatial regression with count data. Biostatistics, 8(2):158:183.

Wakefield, J.C., Best, N.G. & Waller, L.A. (2000). Bayesian approaches to disease mapping. In: Elliott, P.,Wakefield, J.C., Best, N.G. and Briggs, D. (editors), Spatial Epidemiology: Methods and applications. Oxford: Oxford University Press. pp 104 27.

Walter, S.D. (2000). Disease mapping: a historical perspective. In: Elliott, P., Wakefield, J. C., Best, N. G. and Briggs, D. (editors), Spatial Epidemiology: Methods and Applications. Oxford University Press. pp 223 39.

Wheeler, D.C. (2007). A comparison of spatial clustering and cluster detection techniques for childhood leukemia incidence in Ohio, 1996 lth Geographic, vol. 6, article 13.

World Health Organisation Report (2010).