# Spatial epidemiological techniques in cholera mapping and analysis towards a local scale predictive modelling

# Spatial epidemiological techniques in cholera mapping and analysis towards a local scale predictive modelling

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**Abstract.** Cholera spatial epidemiology is the study of the spread and control of the disease spatial pattern and epidemics. Previous studies have shown that multi-factorial causation such as human behaviour, ecology and other infectious risk factors influence the disease outbreaks. Thus, understanding spatial pattern and possible interrelationship factors of the outbreaks are crucial to be explored an in-depth study. This study focuses on the integration of geographical information system (GIS) and epidemiological techniques in exploratory analyzing the cholera spatial pattern and distribution in the selected district of Sabah. Spatial Statistic and Pattern tools in ArcGIS and Microsoft Excel software were utilized to map and analyze the reported cholera cases and other data used. Meanwhile, cohort study in epidemiological technique was applied to investigate multiple outcomes of the disease exposure. The general spatial pattern of cholera was highly clustered showed the disease spread easily at a place or person to others especially 1500 meters from the infected person and locations. Although the cholera outbreaks in the districts are not critical, it could be endemic at the crowded areas, unhygienic environment, and close to contaminated water. It was also strongly believed that the coastal water of the study areas has possible relationship with the cholera transmission and phytoplankton bloom since the areas recorded higher cases. GIS demonstrates a vital spatial epidemiological technique in determining the distribution pattern and elucidating the hypotheses generating of the disease. The next research would be applying some advanced geo-analysis methods and other disease risk factors for producing a significant a local scale predictive risk model of the disease in Malaysia.

## 1. Introduction

There are many guidelines introduced the WHO and other organizations to control cholera outbreaks worldwide, but their suitability depend on local situations or environments of a region. Maybe the current methods fail to prevent cases of cholera, and need medium and long-term activities [1], and multidisciplinary approaches [2,3]. Cholera is emerging disease that is may be influenced by multi-factorial causation especially spatial environmental factors such as climate, environment, natural disaster, and social status of a community. GIS and epidemiological approaches are helpful tools to control the disease spatially and temporally. GIS is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data [4]. The general functions of GIS in health studies are disease mapping and modeling, spatio-temporal changes analysis and risk assessment, public health care and hospital management. This study explores spatial analysis toolset in ArcGIS and Excel software for cholera mapping and pattern analysis in the district of Tawau, Sabah.

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## 2. Cholera spatial pattern and ecology

Cholera epidemiology is the scientific study of the spread, and control of diseases. Cholera spreads worldwide in seven main pandemics started from 1817 until today. It becomes a major cause of morbidity or mortality throughout the world either in developing countries or industrialized countries mostly in tropical areas such as African, Asia, and Southern America [5]. Cholera situation in Malaysia is sporadic that is may be influenced by multi-factorial causation especially local environmental factors [6,7]. General cholera causation is faecal contaminated water supply and food sources, unhygienic sanitation and environment.

Environmental factors such as global warming, climate change, rainfall can affect the microorganism growth, and human health [2,6,8,9,10,11,12,13,14,15]. *Vibrio cholerae* (*Vc*) can easily transmit or break out through human and animal [15-19], low human lifestyle or socioeconomic [14,16,20,21] especially in rural unhygienic community lacking clean water supplies, improper sanitation facilities [22], and pollution [10]. These previous studies have showed that the main spatial characteristics of cholera high risk areas in the world are at unhygienic and crowded environment especially those with poor lifestyle and low socioeconomic, improper sanitation and contaminated daily water and food supply.

## 3. Cholera control plan using spatial epidemiological techniques

Although cholera is treatable and not a critical disease in Malaysia, there is needed long-term activities [1], and multidisciplinary approaches [2,3] as long as the alternative techniques introduced should be conducted professionally [9]. GIS can analyze the spatial disease distribution and its influential environments towards creating an innovative cholera control plan in the country. Spatial epidemiology is an essential approach in understanding of spatial disease risk transmission and pattern particularly disease mapping and descriptive analysis [23]. Cholera dot map drawn by John Snow in London, and Global Health Map Gallery provided by WHO have showed the successfully implementation of GIS and mapping technology in cholera control and prevention. Spatial Statistics and Pattern Tool in ArcGIS utilized to examine and analyze the disease pattern (see methodology).

Cholera disease map can display a descriptive spread of the spatial disease and generate hypotheses about disease causation, but they cannot establish the precise cause of triggered multi-factorial diseases that need specific information about disease etiology, and local knowledge for interpretation of demographic and temporal aspects [24]. Cohort study (Figure 1) and statistical analysis (Figure 2) can be integrated with GIS techniques to analyze the spatial pattern of the disease effectively. Cohort study in epidemiological technique is suitable to investigate multiple outcomes [25] of a disease. Disease and exposure in the past (prospective cohort), present, and future (retrospective cohort) can be measured. Plot and Pearson's correlation coefficient, r are statistical method used to determine the descriptive association and strength of relationship between two variables [26]. The range of correlation strength value is explained from +1 to -1 which means the strongest and weakest correlation. Meanwhile the value of 0 shows minimal or no correlation.

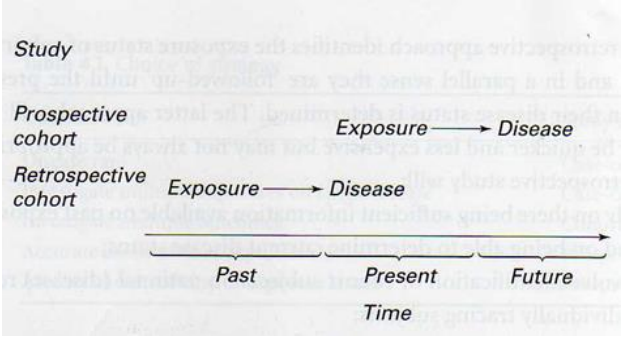


**Figure 1.** Cohort study for measuring disease and exposure [23].

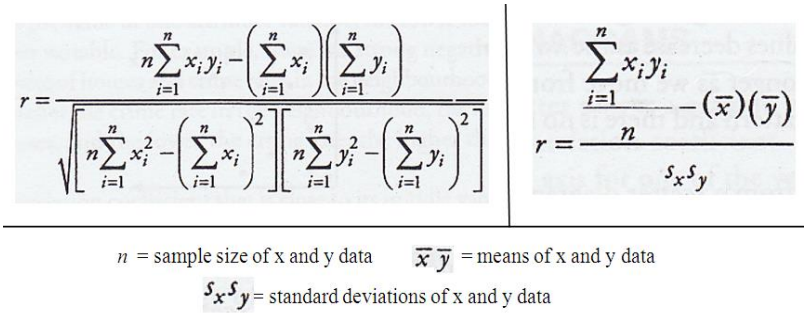


**Figure 2.** Calculation of Pearson's Correlation Coefficient, *r* [29].

## 4. Methodology of cholera mapping and analysis

Three main steps were conducted to examine and analyze the cholera pattern and outbreaks in the study area; i) data collection ii) data processing and, iii) result and analysis

### *4.1. Data collection*

Epidemiological or ecological approach [27,28] was used in this stage to get initial views of the study area, and pre-evaluate the results of the study. The specific tasks applied in this approach were site visit or field observation with the aid of handheld GPS, camera, topographical map, besides conducting open-ended questionnaires, and interview session with selected respondents. Reliable secondary sources were obtained by collecting published reports, projects, archives, and documents such as topographical map of the district, epidemiological data of reported cholera cases, as well as other ancillary data sets.

### *4.2 Data processing*

Some statistic tools in ArcGIS and Microsoft Excel software were applied to map and analyze the reported cholera incidents and its environments. ArcGIS software offers spatial statistics tool for analyzing patterns, mapping and measuring geographical distributions of cholera. These statistical approaches are different from traditional statistics in terms of geographical relationships. Average Nearest Neighbor (ANN), proximity analysis (buffering), and standard deviational ellipse (SDE) were integrated to analyze and identify the general cholera geographic patterns in the district of Tawau. Points and area-based map of cholera were also generated to show the geographical distribution of the disease as data locations.

The ANN involved calculating the mean nearest distances between all the point cases and their nearest neighbours. The ANN distance of the disease random pattern was larger than a cluster pattern but shorter than a scattered pattern. Buffering was used to determine the certain radius of cholera potential risk or dangerous zone. The SDE was utilized for creating new elliptical features, which showed the orientation of potential high risk area of the outbreaks.

### *4.3 Result and analysis*

Cholera distributive pattern in the district was highly clustered in the south-east region especially at the Seri Tanjung *mukim* (Figure 3). Interestingly, the affected areas in the *mukim* are located close to coastal water and river particularly 1500 meter from cholera sources (Figure 4), concentration of higher population and human daily activities (e.g. aquaculture, socio- economic activities (Figure 5). These results were expected as obtained in the previous studies indicated the disease is related with transmission of water or food source [9,29], high population and low socio-economic status [6,20,22,30].

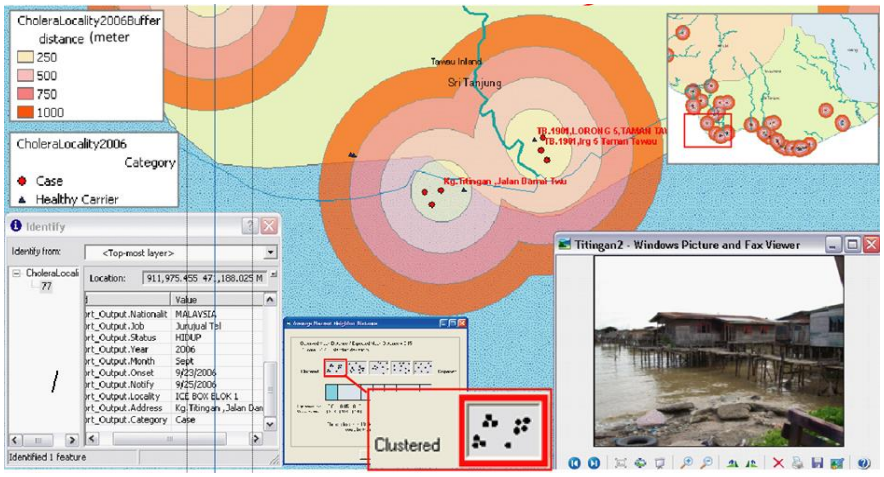


**Figure 3.** Cholera cluster distribution and analysis.

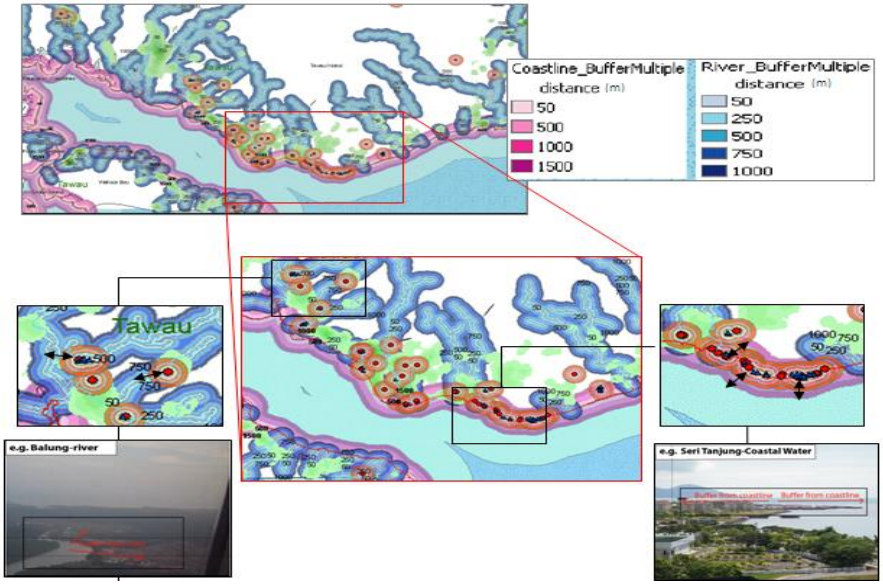


**Figure 4.** Frequency of the cholera incidents from riverline and coastline zone.

The cholera spatial variations in the district associated with water sources both coastal water or rivers which are habitat of phytoplankton and zooplankton as studied by [6,14]. It seemed true due to many cholera outbreaks in Sabah from 2001 to 2008 occurring near the coast and river. Highly clustered pattern means the confirmed cases or high endemic location in the district can easily spread (Figure 4) mainly at unhygienic environment located close to the coastal and river area of eastern Tawau, rural northern and western Tawau. The result supported by a positive normal relationship between cases and healthy carriers (Figure 5) shows that a human could be affected if they exposed to suspected cholera cases. The disease could also easily be transmitted among human with lack of clean water sources especially during the incubation period of cholera, regardless of localities either at rural areas or urban and semi-urban area.

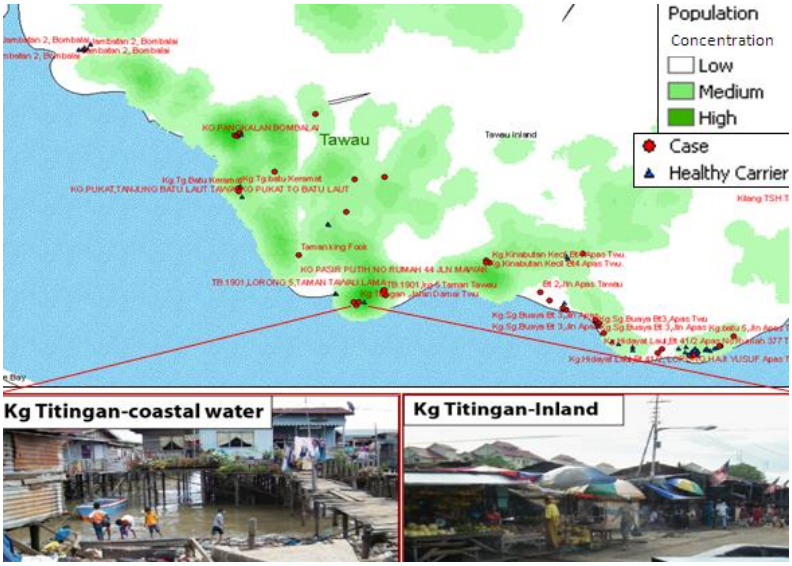


**Figure 5.** Spatial characteristics of the cholera high risk.

## 5. Conclusion

The aim of the study was to investigate the spatial pattern of cholera distribution in the selected district of Sabah from 2004 to 2008 using GIS and epidemiological techniques. The general spatial pattern of cholera in the district was highly clustered. It showed that the disease can easily be spread at a place or person to others especially 1500 m from endemic location or confirmed cases. These revealed that cholera outbreaks could be endemic at the populous areas, unhygienic environment, and close to contaminated water. Integration of GIS and spatial epidemiology techniques facilitate spatial understanding of the disease pattern and formulate the spatial etiologic perspective. A further study might be explored at other districts using some advanced geo-analysis methods and other disease risk factors towards producing a significant local scale risk predictive model in Malaysia.

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