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Analysis of Air Quality Impacts on Human Health Using the Geoinformatics Application: Chiang Rai Province

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Abstract

This research aims to study air pollution dispersion in Chiang Rai Province, Thailand. The relationship between air pollutants, meteorology and population health were considered. The levels of air pollutants were used to establish a spatial and temporal analysis by Inverse Distance Weighted (IDW) interpolation from Geographic Information Systems (GIS), involved with occurrences of disease cases in the study area. The average monthly air pollution data were collected from Thailand's Pollution Control Department and data on respiratory disease were collected from Chiang Rai Provincial Public Health Office during 2011 to 2014. The results indicated that monthly average PM10 concentrations started to rise from December to April. PM10 concentrations peaked during the hot season of every year, when open burning is practiced. During this period, PM10 levels exceeded Thailand's national ambient air quality standards of 120 $\mu g\ m^{-3}$. Accumulative influenza and pneumonia cases in Chiang Rai Province were very high in Chiang Rai city centre. The spatial temperature distribution map showed higher incidence of cases of influenza and pneumonia throughout the lower temperature area of Chiang Rai city centre. Influenza was affected by PM10, rainfall, relative humidity, and temperature, according to the following correlation ratios: 0.8217, 0.8842, 0.9375 and 0.8775, respectively. The incidence of pneumonia was affected by rainfall, relative humidity and temperature following the correlation ratios 0.7746, 0.7621 and 0.9684, respectively. Whereas PM10 was low associated with pneumonia as a significant ratio was 0.6079. Pneumonia incidence decreased when rainfall and temperature decreased, and increased when relative humidity increased.

Keywords: Air pollution; GIS; Health; Spatial analysis; Chiang Rai Province

Introduction

In recent years, the increasing population and changing climatic conditions around the globe have given room to the outbreak of different diseases [1]; at the same time the ability to forecast weather (in terms of both accuracy and lead times) has greatly improved in recent years, especially with the use of remote sensing [2]. Currently, geographic information systems (GIS) tools are used in conjunction with global event management, coordination and communications, and early warning and forecasting to monitor the spread of diseases across communities and across geopolitical borders. GIS can assist in analyzing known or potential risk factors for the effective control of influenza, including poultry densities, flight routes of migratory birds for avian influenza, water bodies, tropical forests, elevation and land use [3]. In addition, data about ambient air quality are generated to know the character of the air environment by utilizing technological advancements to know the quality of the air [4]. GIS tools have numerous applications in human health and could be integrated into health care management though spatial decision support systems [5] to generate thematic maps that depict the intensity of a disease or vector [6].

Chiang Rai faces a smoke haze situation in February and March annually; it is the period of time when levels particulate matter of diameter equal or smaller than 10 μm (PM10) exceed Thai national ambient air quality standards of 120 μg m^{-3} for 24 h [7]. There is an association between short-term exposure to coarse PM and increased rates of hospital admissions for emphysema, asthma, and pneumonia, which become much more pronounced during the cool period [8]. Rain precipitation was the main factor that reduced concentrations of air pollutants, as both particulate and gas phases. In the wet season, a high amount of precipitation cleanses the contaminated atmosphere and the sky becomes clear. In the dry season, there is high atmospheric pressure and a low amount of rain, leading to air pollutant accumulation [9]. The weight of air pollution sources depends on environmental and geographical factors, with winds, geographical characteristics of the area, the ratio between produced and scattered pollutants, seasons, urban concentration, industrial density, and air pollution density comprising the most important factors [10].

Material and methods

1) Data used in the research

Air quality data encompassing rainfall, relative humidity, temperature, and PM10 were obtained from the Pollution Control Department of Thailand for the years 2011-2014 from 12 air monitoring stations in Chiang Rai, Chiang Mai, Phayao, Lamphun, Mae Hong Son, Phrae, Nan and Lampang provinces. The numbers of influenza and pneumonia cases were obtained from Chiang Rai Provincial Public Health Office (506 Form) from January 1st, 2011 to December 31st, 2014.

2) Study area

Chiang Rai, the northernmost province of Thailand, is about 785 kilometers north of Bangkok. Chiang Rai covers an area of approximately 11,678 square km^2 with an average elevation of 600 m above sea level. Chiang Rai has three distinct seasons; the hot (summer) season extends from March through May, the rainy season from May through October, and the cool (winter) season from November through February. Over the course of the year, the temperature typically varies from 13 °C to 34 °C and is rarely below 10 °C or above 38 °C. Chiang Rai experiences extreme seasonal variation in monthly rainfall and perceived humidity. Smoke haze problems in Chiang Rai have caused adverse socio-economic and health impacts since 10 years ago. PM10 is considered the most significant air pollutant that leads to the serious smoke haze problem. The Health Information System Development Office reported that the highest number of respiratory patients was 18,412 cases in Chiang Rai during one week of March in 2012. Likewise PM10 levels are associated with a rise in pneumonia and COPD admissions.

3) Methodology

Correlations between rainfall, temperature, relative humidity and PM10 of each season were analyzed. The relation graphs between PM10, influenza, pneumonia, and meteorology parameters were considered, while the spatial distribution map of rainfall, relative humidity, temperature, PM10, influenza, and pneumonia was analyzed as shown in the flow chart of Figure 2.

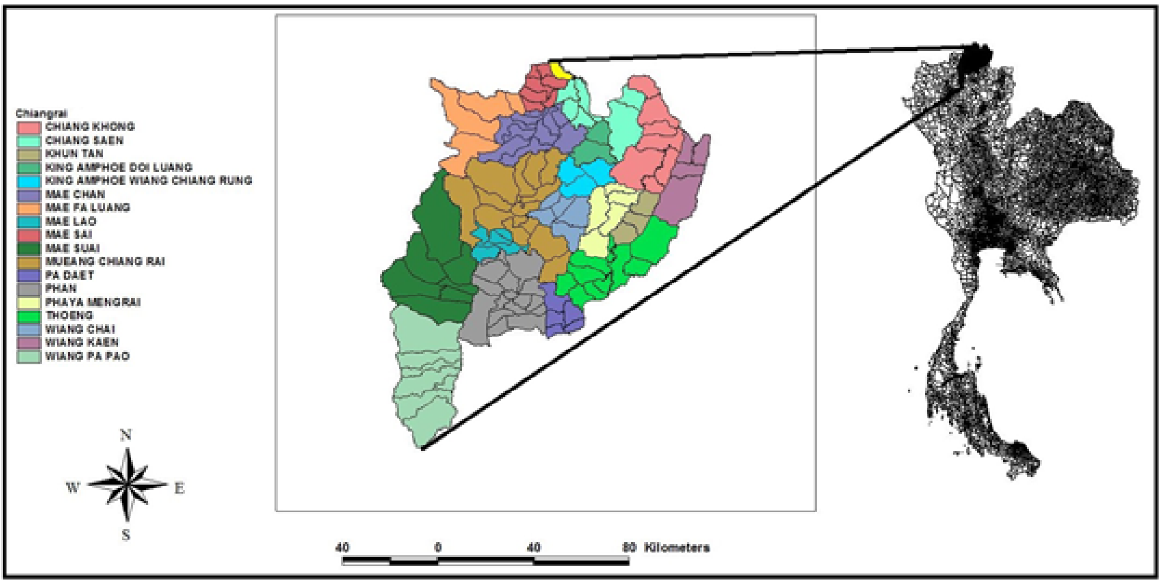

Figure 1 Location of Chiang Rai Province.

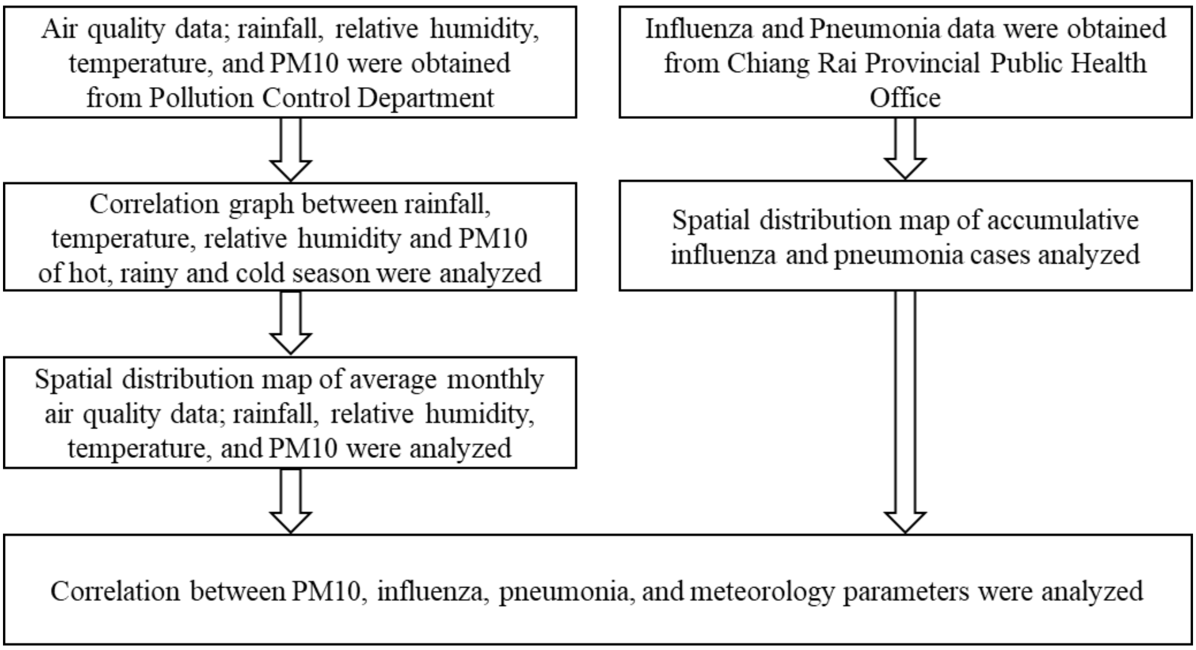

Figure 2 Methodology flowchart.

Results

The monthly averages for PM10 concentrations for the years 2011-2014 had similar patterns and trends as indicated in Figure 3. The monthly average of PM10 concentration started to rise during the period from December to April as this was the cool season with less rain. Then PM10 levels decreased from May to September when the heavy rain came, and remained low in the cool season which had some rain. PM10 concentrations peaked during the hot season (February to April) every year at the same time as the open burning season after harvesting. It is also the time when PM10 concentrations usually exceed the Thai national ambient air quality standards of 120 μg m^{-3}. When considering relative humidity and temperature, those values were constant throughout the whole year and had less impact on the PM10 level.

The researcher decided to use the highest value of PM10 from the year 2014 in order to compare the distribution pattern between PM10 and each of the meteorology parameters: rainfall, relative humidity, and temperature during the smoke haze episodes (January to April) of the years 2011-2014 as shown in Figure 4.

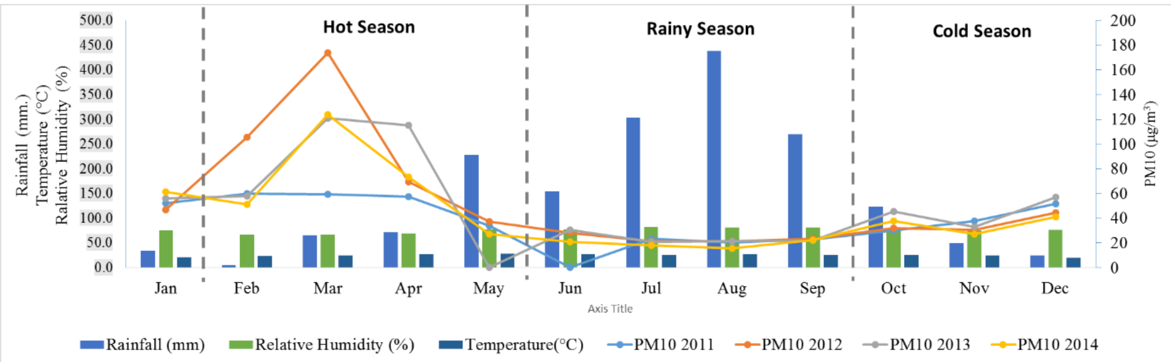

Figure 3 Quantity of PM10 with average rainfall, temperature and relative humidity on a monthly basis during the years 2011 to 2014.

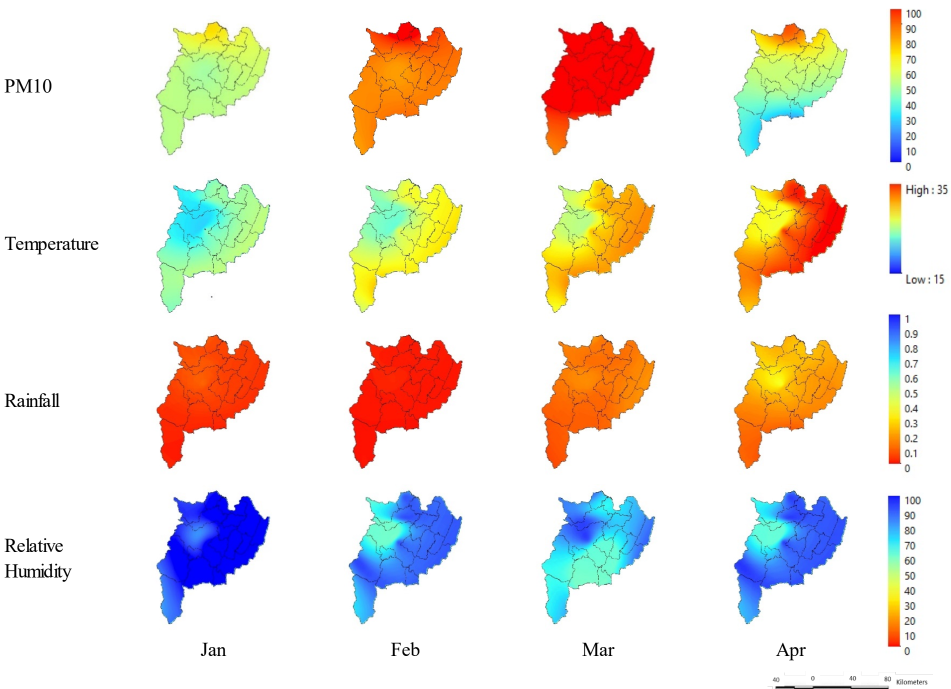

Figure 4 Distribution of PM10 and different meteorology parameters.

The distribution map of PM10, rainfall, and relative humidity showed a similar pattern. PM10 is very high at the time of low rainfall and humidity since the particulate matter is captured in the atmosphere. Accompanied by the open burning season plus the low quantity of rainfall in January to March, conditions allow particulate matter to accumulate in the air and cause an increase in the PM10 level. The high relative humidity in January when the air is saturated by vapor permits the capture of more particulate matter. PM10 decreases in April due to the fact that rainfall and relative humidity are then slightly increased.

Cumulative influenza and pneumonia case distributions in Chiang Rai province were very high in Muang District (central Chiang Rai) as shown in Figure 5. This relates to the distribution map of temperature in Figure 4 as the map indicates that a large quantity of the influenza and pneumonia evidence was spread out in the low temperature area of Muang District.

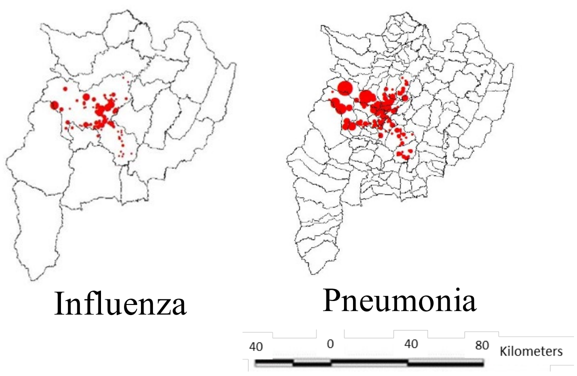

Figure 5 Respiratory cases (Influenza and Pneumonia) in Chiang Rai

In Figure 6, evidence of influenza was affected by PM10, rainfall, relative humidity, and temperature, with the following correlation ratios: 0.8217, 0.8842, 0.9375 and 0.8775, respectively. The solid form of PM10 had very small particles (10 µm in diameter) which could be suspended in ambient air for long periods, becoming the possible cause of transmission of the influenza virus to the respiratory tracts of patients. Relative humidity and temperature were significantly related to influenza epidemics because these factors affect the survival of airborne viruses in aerosols, especially in the cool season. Also, the epidemic of influenza was greatest in the rainy season because of low temperatures and high humidity that could support the spread of influenza.

Pneumonia evidence was affected by rainfall, relative humidity, and temperature in the following correlation ratios: 0.7746, 0.7621 and 0.9684, respectively. PM10 showed low association with pneumonia at a significant ratio of 0.6079 which may indicate less influence upon the spread of pneumonia. Pneumonia decreased when rainfall and temperature decreased, and increased when relative humidity increased.

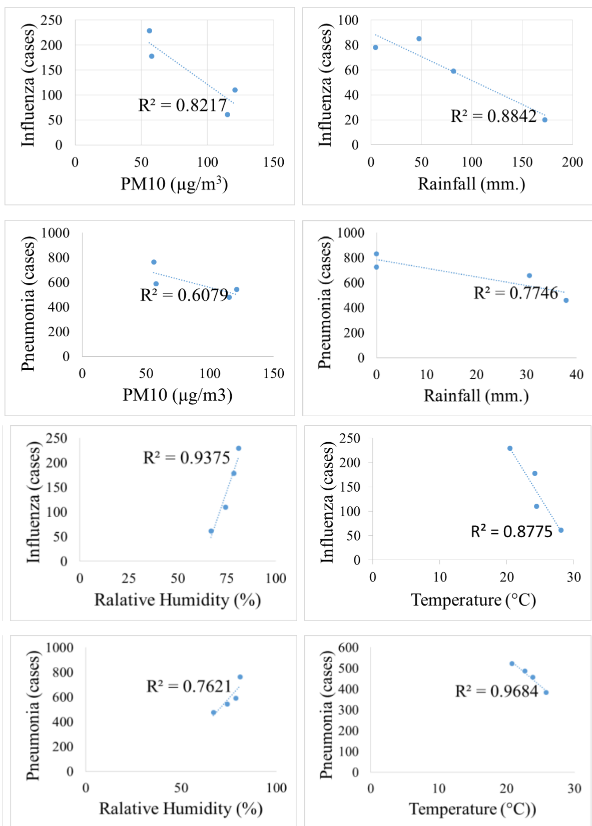

Figure 6 Relationship between influenza, pneumonia, PM10 and meteorology parameters.

Table 1 Relationship between disease and air parameters

Disease	Correlation coefficient (R^2)			
	PM10	**Rainfall**	**Relative humidity**	**Temperature**
Influenza	0.8217 (-)	0.8842 (-)	0.9375 (+)	0.8775 (-)
Pneumonia	0.6079 (-)	0.7746 (-)	0.7621 (+)	0.9684 (-)

Note: (+) mean disease increase when air parameter increased
(-) mean disease decrease when air parameter decreased

Discussion

The monthly average of PM10 levels started to rise from November to April and then remained relatively constant from May to October. Moreover, both hotspots and PM10 were found to peak in March of every year [11]. The study found that the monthly average of PM10 levels started to rise in December to April, and then PM10 decreased in May before remaining constant to September when the heavy rain came through. PM10 concentrations peaked during summer (February to April) every year at the same time as the open burning season. This was also the period of time when PM10 concentrations exceeded the Thai national ambient air quality standards of 120 μg m^{-3}.

The parameters of relative humidity and temperature were constant throughout the year and thus had less impact upon PM10 levels. The distribution maps of PM10, rainfall, and relative humidity showed similar patterns. PM10 was very high in the time of low rainfall and humidity, and decreased in April due to the fact that rainfall and relative humidity were slightly increased. The atmospheric pressure, wind velocity, and humidity were found to be significant factors compared to others influencing PM10 [12], while the distribution map showed PM10 distribution was very high when rainfall and humidity were low, but decreased when rainfall and relative humidity were slightly increased.

The evidence of influenza being affected by PM10, rainfall, relative humidity, and temperature, was shown by the following correlation ratios: 0.8217, 0.8842, 0.9375 and 0.8775, respectively. It has been observed in some research studies that mean concentrations of PM10 among samples indicate positively for influenza [13]. Furthermore, some experts believe that temperature is one of the most important factors affecting virus survival, as it can affect the state of viral proteins and the virus RNA or DNA [14]. The data showed that the levels of fine and coarse particles were correlated with increased risk of hospital admissions for RD including COPD, asthma, and pneumonia, and only on cool days [15]. These findings are in line with those of our study where PM10 was associated with evidence of pneumonia as the correlation ratio was 0.6079. In the crude relationship, the potential risk of M pneumoniae pneumonia increased as temperature increased from the lowest temperatures [16]. This result matched our study which held that the correlation ratio between pneumonia and temperature was 0.9684, which could support the increasing number of pneumonia cases. While pneumonia cases were increased with an increase in relative humidity independent of the ambient temperature [16], our study found a correlation ratio between pneumonia and relative humidity of 0.7621 which suggested the pneumonia virus could extend its accumulation and spread easily in the air.

Conclusion

The results revealed that between 2011 and 2014, the trend of PM10 in each district of Chiang Rai province is to increase from January and reach its highest levels in March as 262, 137 and 128 μg m^{-3} respectively, all of which levels were above the standard limit. Average temperatures in the mountain areas such as Mae Fah Luang and Mae Chan District are lower than in the plains area. Average rainfall is very low in January and February; however, a relationship between PM10 and the seasons showed that PM10 is very high in the hot season and very low in the rainy season. Furthermore, PM10 increases again in the early summer which is related to the quantity of rain-fall and level of relative humidity. Air quality is related to and has an influence upon human health as evidence suggests that influenza is affected by PM10 and the rainfall, relative humidity, and temperature parameters. Relative humidity and temperature were significantly related to influenza epidemics and the epidemics of influenza are greatest in the rainy season as low temperatures and high humidity support the spread of influenza. Rainfall, relative humidity, and temperature also impact upon pneumonia epidemics whereas PM10 was associated with pneumonia evidence at a medium level.

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