# Geocorrelation of Contributing Factors to Asthma in New South Wales

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**Abstract**

*This paper aims to identify contributing factors and geographical correlations to asthma patients in New South Wales, Australia. Socio-demographic data such as poverty/income levels and asthma triggers e.g. air pollution are examined. Not only the percentile asthma patients within a given geographical areas but also spatial relationships among contributing factors are studied. The main constraint of previous studies is that detailed geographic information of asthma patients is unavailable due to the confidentiality issues. Spatial functions and database queries are utilized in this study in order to overcome such a detrimental disadvantage and restore the geographic information up to the postcode level based on a population-weighted interpolation. From previous study results in other countries, influencing factors to asthma prevalence in NSW are hypothesized to be poverty/income levels and air pollution. However, this study indicates that no statistically meaningful correlation between poverty/income levels and asthma occurrences in NSW is found. Eleven suburbs in non-metropolitan areas exhibit a relatively high rate (greater than 1%) of asthma occurrences. This finding is also different from the previous study result that asthma patients are likely found in inner cities. Significant air pollution in close proximity to an area with a high rate of asthma patients is identified by a buffer analysis. Particulate matter of less than 2.5 micrometers is identified as a strongly contributing factor to the largest number of asthma patients. The relationships between air pollution and asthma intensity from this study are useful information to alert asthma sufferers to be aware of the levels of air pollution, weather conditions, and locations where high levels of pollutants are anticipated.*

## 1. Introduction

The incidence of asthma, a common chronic disease of the airways, significantly increased worldwide over the past few decades (Koren, 1995). According to National Health Survey (NHS) in Australia in 2001, about 12% of Australians suffer asthma. In the same year, 175 males and 247 females died from asthma (Australian Bureau of Statistics, 2006). A "western" lifestyle and urbanization in developing countries around the world are expected to prevail over the next few decades, which will further increase the number of global asthma patients. By 2025, the proportion of the chronic asthma population is estimated to grow up to 14.7% in Australia and up to 15.1% in New Zealand (Masoli et al., 2004 and Rees, 2006). Allergies and irritants are well-known triggers of asthma attacks. Allergies are generally attributed to allergens such as dust mites, cockroaches, pollens, and particulate matter from trees and grass (Malveaux, 1995). Irritants include triggers such as tobacco smoke (National Heart Lung and Blood Institute, 2006). By overlaying spatial and aspatial data of asthma patients, Geographical Information System (GIS) can assist health experts to identify and address health problems. GIS has been used to monitor the outbreak of an epidemic (Rob, 2003) and explore the state of a nation's health (Goodchild, 1993). GIS has been also used in various health-care studies in order to identify correlations between air pollution and health problems (Huen et al., 2006 and Kuiper et al., 2003). Asthma research also has been conducted to monitor and evaluate spatio-temporal data (Peled et al., 2006, English et al., 1999, Choi et al., 2006 and Zeitz et al., 2006). The main objective of this study is to examine not only the patient data but also socio-demographic data of asthma patients (e.g. poverty/income levels) so that GIS can be fully utilized to obtain pertinent information such as the intensity of the asthma patients, the correlation between poverty/income levels and asthma occurrences, the granularity of pollutants as asthma triggers, etc. From previous study results in other countries e.g. US, influencing factors to asthma prevalence in NSW is hypothesized to be poverty/income levels and air pollution. Any health data is confidential by its nature and therefore detailed geographical information of asthma patients is typically either unavailable or destroyed. This is the major source of errors in existing GIS-based asthma studies. The datasets used in this study is collected in the 2000-2001 time frame. The attributes of the datasets are classified into four main categories: air pollution, health status, population and financial status. The methodology adopted in this study differs from previous studies in that the geographical information of asthma patients is estimated up to the postcode level in a unique way to take the socio-demographic data into account, whilst other datasets are transformed to obtain geographical uniformity in order to ensure consistency throughout the data analysis.

## 2. Methodology

The asthma patient data is obtained from the Australian Institute of Health and Welfare (AIHW) and is classified as New South Wales (NSW) hospital separation data. The data records with a population of less than 1,000 people are omitted from the analysis in order to trim data outliers off. The ideal scenario for this type of analysis is to have access to data that accurately locates the location of the asthma occurrences, however, the point data was unavailable at the time of this study due to the patient privacy and therefore the complexity of the analysis process is increased. The classification shown in Figure 1 is a geographical distribution of asthma patients leaving hospital in each postcode area during the time frame of July 2000 until June 2001. The smallest class represents a range of 0-5 patients. The largest class ranges from 264 to 413 patients. Air pollution has been known as the major influence on asthma patients. Ambient environmental exposures to ozone, sulfur dioxide, nitrogen oxides, aerosols, and particulate matter (predominantly fine particles) are asthma triggers (Koren, 1995 and Rob, 2003). Study by the Woolcock Institute of Medical Research suggests that sulfur dioxide at a low level (e.g. 0.25-0.5 ppm) can trigger an attack to asthma patients. Contrastingly, a higher level (up to 5 ppm) of sulfur dioxide does not affect normal people (Marks, 2005). Repeated exposure to air pollutants from car emissions may aggravate asthmatic symptoms (English et al., 1999). Air pollution is likely to have a greater impact on children patients who have no access to routine medical care (Bates, 1995). Quarterly monitoring of air quality in NSW measured from July 2000 to June 2001 is obtained from the Department of the Environment and Conservation through the Environmental Protection Authority (EPA) (New South Wales Government, 2001).

The quarterly data is then merged and averaged to obtain an annual figure. As monitoring of each substance requires a different process, not all substances can be monitored at each site. This situation complicates the interpolation process. The data contains air pollution indexes: ozone ($O_3$), nitrogen dioxide ($NO_2$), nitrogen oxide (NOx), nitric oxide (NO), sulphur dioxide ($SO_2$), carbon monoxide (CO), lead (Pb), cadmium (Cd), and particulate matter (PM). In this study, the assessment of PM is narrowed down to two categories: $PM_{10}$ that represents particulate matter between 2.5 μm and 10 μm, and Tapered Element Oscillating Microbalance (TEOM-$PM_{2.5}$) of less than 2.5 μm. This methodology is based on the previous research on the substances that are mostly influential to asthma patients (Rob, 2003). The population data at the postcode level has been obtained from the Australian Bureau of Statistics in 2001. The data is then combined with the patient data in order to obtain percentile rates of asthma patients in each area, which is the basis of all spatial analyses in this study. It is known that there exists an association between asthma occurrences and people with a low socio-economic status. The prevalence of asthma has decreased when the family income has increased (Centers for Disease Control and Prevention, 2001). Higher asthma prevalence is also recognized in inner city areas (Rob, 2003). In Australia, the poverty line for June 2001 is $561.88 per week for a family income unit comprising a couple plus two children where only the head of the family is in workforce (Johnson, 2001). To further investigate socio-economic aspects of the study, financial data is collected through the Australian Bureau of Statistics. This data is obtained per postcode region and is the median weekly income range from $200-$299 up to $1,500 -$1,999 (see Figure 2).

## 3. Geocorrelation

By plotting the percentile asthma occurrences in each postcode area as illustrated in Figure 3, one can see that the mean value is 0.26 % and the median is 0.21 %. There exist highly dense areas (above 1 %) as listed in Table 1. Unexpectedly those areas are located outside the metropolitan cities. Figure 4a shows that the Pearson product-moment correlation coefficient between the population and the asthma occurrences is 0.859. Therefore the ratio can be used to predict the number of asthma patients if the population increases. However, as shown in Figure 4b, there exists no indication that poverty or a low income is a contributing factor to the asthma prevalence.

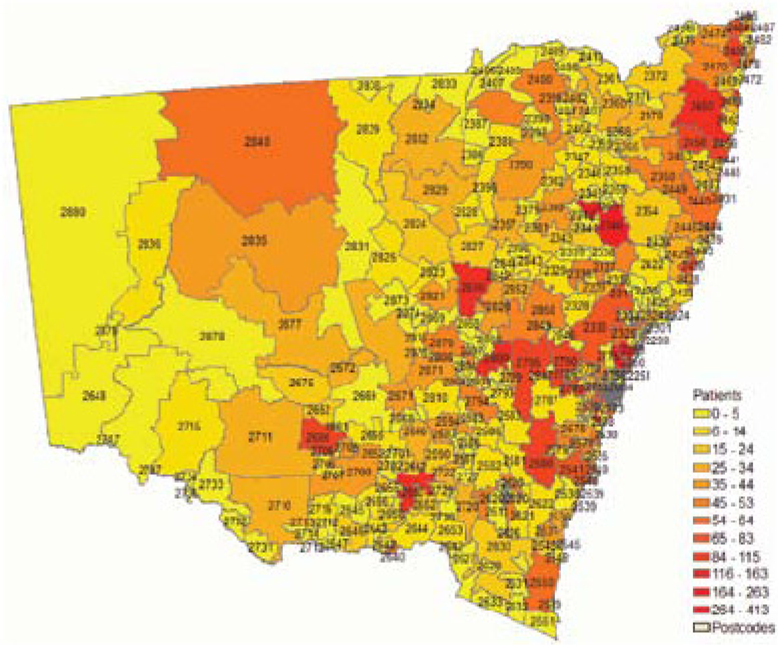


**Figure 1: Geographical distribution of asthma patients per postcode in NSW**

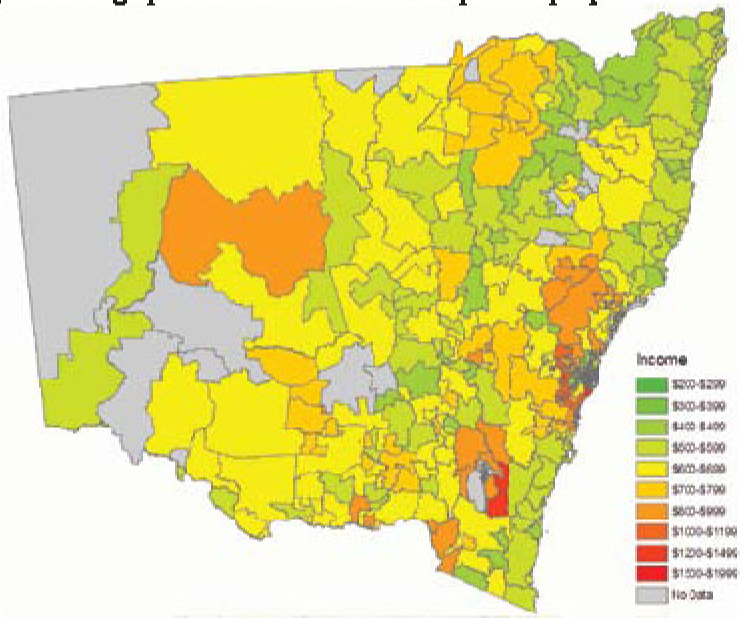


**Figure 2: Median weekly income range**

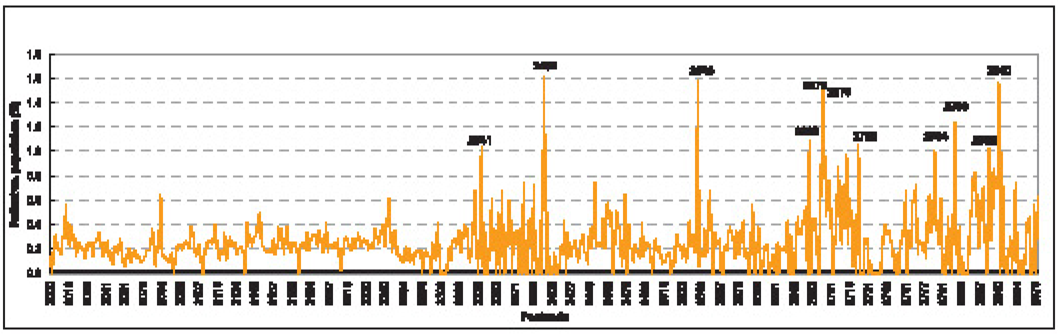

**Figure 3: Percentile asthma occurrences per postcode**

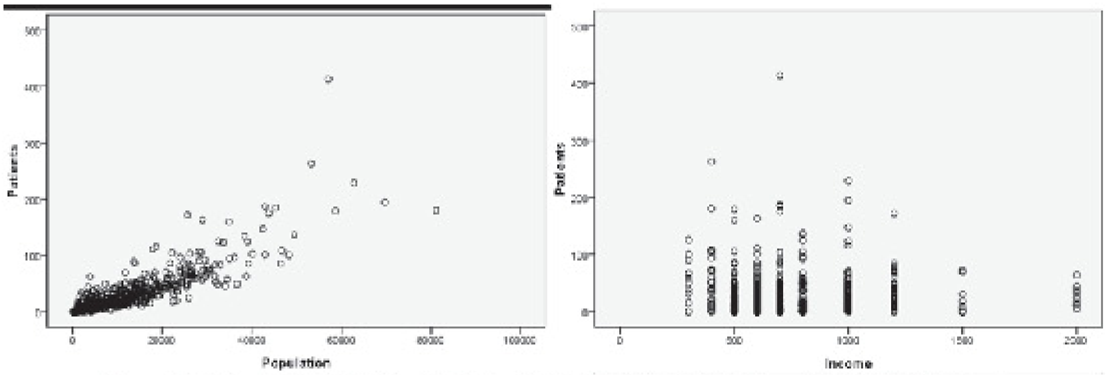


**Figure 4: Correlation between the number of patients and a) population or b) income**

**Table 1: Areas with high asthma occurrences**

| Postcode | Number of Patients | Population | Rate (%) |
|---|---|---|---|
| 2402 | 34 | 2104 | 1.62 |
| 2545 | 17 | 1075 | 1.58 |
| 2840 | 62 | 3973 | 1.56 |
| 2672 | 27 | 1768 | 1.53 |
| 2799 | 44 | 3540 | 1.24 |
| 2660 | 15 | 1376 | 1.09 |
| 2722 | 32 | 3010 | 1.06 |
| 2341 | 15 | 1446 | 1.04 |
| 2832 | 32 | 3148 | 1.02 |
| 2675 | 19 | 1885 | 1.01 |
| 2784 | 11 | 1090 | 1.01 |

**Table 2: NEPM Ambient Air Quality Standards**

| Pollutant | Averaging period | Standard or goal (Maximum concentration) |
|---|---|---|
| Carbon monoxide (CO) | 8 hours | 9.0 ppm |
| Nitrogen dioxide ($NO_2$) | 1 hour<br>1 year | 0.12 ppm<br>0.03 ppm |
| Photochemical oxidants measured as ozone ($O_3$) | 1 hour<br>4 hours | 0.10 ppm<br>0.08 ppm |
| Sulphur dioxide ($SO_2$) | 1 hour<br>1 year | 0.20 ppm<br>0.08 ppm |
| Lead (Pb) | 1 year | 0.50 $\mu g/m^3$ |
| Particles < 10 µm ($PM_{10}$) | 1 day<br>1 year | 50 $\mu g/m^3$<br>30 $\mu g/m^3$ |
| Particles < 2.5 µm ($PM_{2.5}$) | 1 day<br>1 year | 25 $\mu g/m^3$<br>8 $\mu g/m^3$ |

Australia's air quality standards (listed in Table 2) are established by the National Environment Protection Measure for Ambient Air Quality (Air NEPM) on 26 June 1998 (Department of the Environment and Heritage, 2004). Figure 5a represents the ozone levels overlaid on the percentile asthma patient data. Three distinct areas are visible, each being the Sydney Basin, Hunter Valley including Newcastle, and Wollongong. The largest reading is found in the outer Sydney suburbs: Oakdale and Kurrajong Heights. The ozone level of 0.12 ppm for 1 hour is classified as having an effect on asthma sufferers (Salisbury and Ferrari 1997; Kehrl et al. 1999). As the range ends at the maximum value of 0.025 ppm, it is believed that ozone does not impact much on asthma sufferers in NSW. As for Nitrogen dioxide ($NO_2$), smaller readings are evident in the outer areas of the city and much larger values in close proximity to the coast and the industrial areas (Figure 5b). $NO_2$ is classified into two levels: low (<7.5 $\mu g/m^3$) and high (>14 $\mu g/m^3$) (Chuhan et al., 2003).

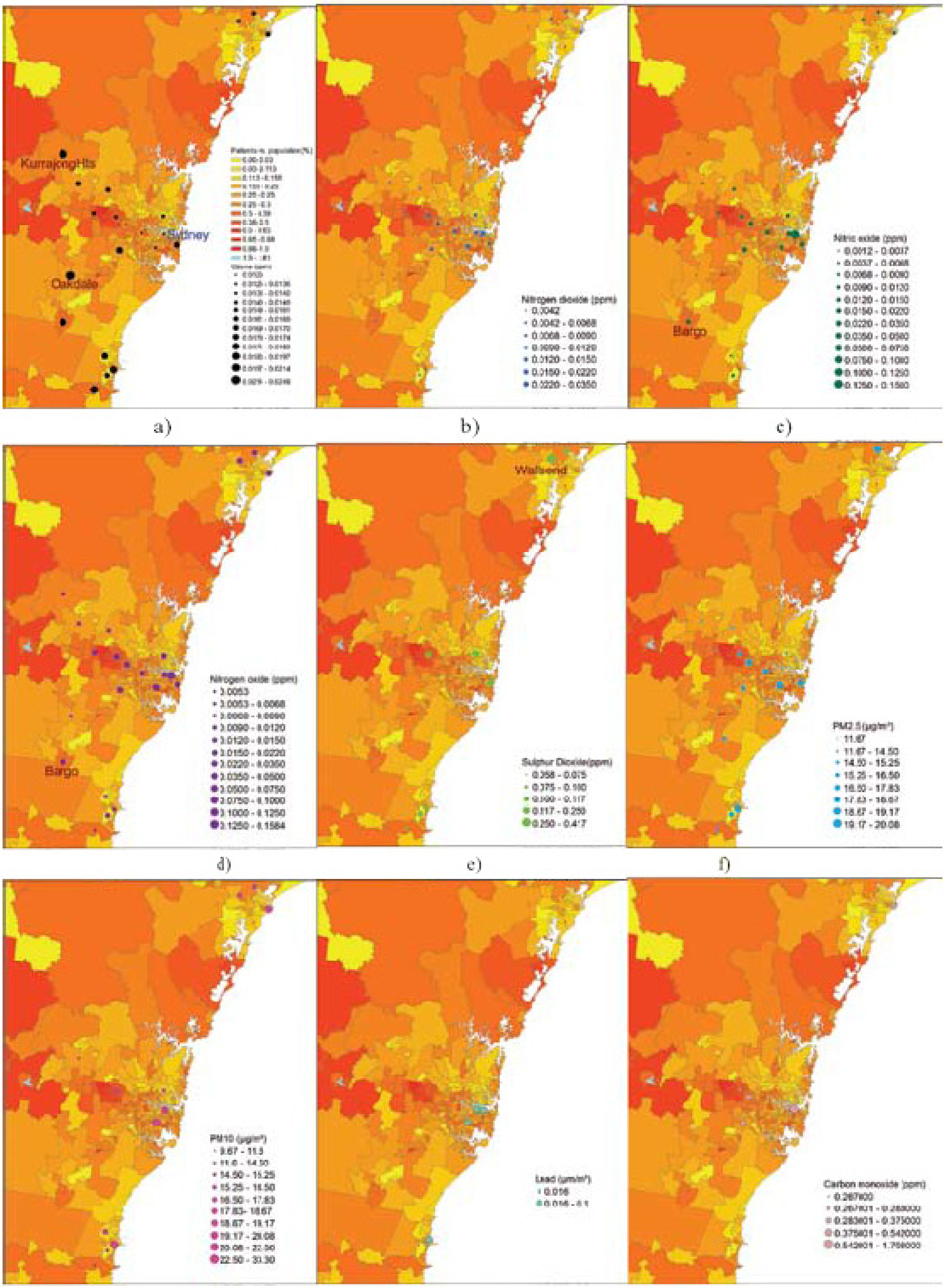


**Figure 5: Pollutants overlaid with percentile patient data:**
**a) $O_3$, b) $NO_2$, c) NO, d) NOx, e) $SO_2$, f) $PM_{2.5}$, g) $PM_{10}$, h) Pb, i) CO.**

This classification can be converted to a level of 0.00399 ppm as low and 0.00745 ppm as high by assuming that the volume is 24.5 liters at 25 degrees Celsius. Nitric oxide (NO) and nitrogen oxide (NOx) show a similar representation to each other (Figures. 5c and 5d, respectively). Sulphur dioxide ($SO_2$) has a far smaller representation than other pollutants. The level of 2.5 ppm is known as a potential asthma trigger. This level is represented by the largest circle in Figure 5e, and can be seen at postcode 2287 in Western Newcastle. Fine particles have been known as the major problem for respiratory diseases because, the smaller the particles are, the deeper they are able to penetrate into the lungs (Horstman, 2006). Therefore the distribution of $PM_{2.5}$ is of particular interest to asthma patients. As seen in Figure 5f, high readings of $PM_{2.5}$ are observed in many rural areas, whereas $PM_{10}$ are found in the central city areas only (Figure 5g). Therefore one can conclude that $PM_{2.5}$ is a serious threat to asthma patients in NSW. This important finding explains why there exist dense asthma occurrences in non-metropolitan areas (see Subsection 3.1). There is no suggestion that either lead (Pb) or carbon monoxide (CO) influences the asthma occurrences. These two substances are both classified as insignificant in this debate, and the overlay output supports the assertion (Figures. 5h and 5i, respectively). Both substances have readings of high levels in inner city regions. Buffering Analysis Spatial analysis used in this study includes devising a series of query functions to determine factors across datasets, and producing polygon overlays. Factors such as wind and weather conditions have an impact on the location of air pollution and how it travels is related to the land topography. Large particles are transported into the air up to distances of 50 metres, whereas fine particles and ozone can move across the region (Kuiper et al., 2003). Because air pollution sensors are sparsely located, the distribution of air pollution should be interpolated. The buffering function is used to estimate the distribution of air pollution in the study area. The asthma rate in Postcode 2770 is unexpectedly high (0.72%). This fact cannot be explained if the important factor $PM_{2.5}$ and other pollutants are examined. By the use of buffers for a known distance per ppm of $PM_{2.5}$, a strong correlation between the substance and the area is identified. Figure 6 is a result of the buffer analysis. High levels of readings in Blacktown (2148) and Greystanes (2145) with their wind direction towards Postcode 2770 explains the result.

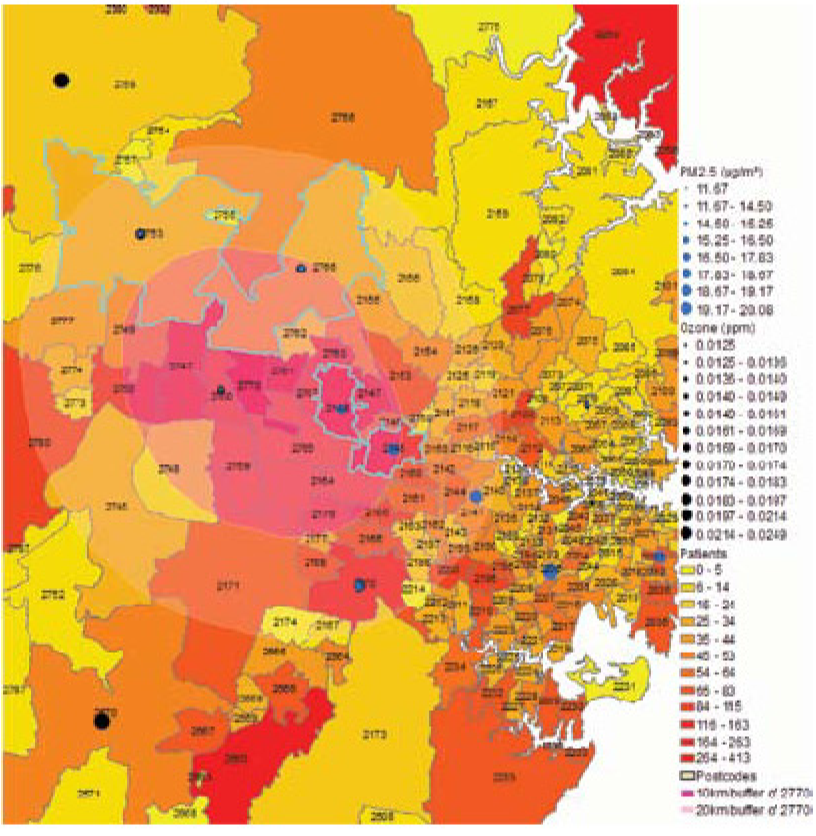


Figure 6: 10km and 20km buffer zones from postcode 2770 with surrounding monitoring stations

## 4. Conclusions

One of the main challenges to this study was to ensure the compatibility among the datasets. From previous study results in other countries e.g. US, influencing factors to asthma prevalence in NSW were hypothesized to be poverty/income levels and air pollution. However, this study indicates that no statistically meaningful correlation between poverty/income levels and asthma occurrences in NSW is found. Eleven suburbs in non-metropolitan areas exhibit a relatively high rate (greater than 1%) of asthma occurrences. This finding is also different from the previous study result that asthma patients are likely found in inner cities. Significant air pollution in close proximity to an area with a high rate of asthma patients is identified by a buffer analysis. Particulate matter of less than 2.5 micrometers is identified as a strongly contributing factor to the largest number of asthma patients. As there is no form of prevention for asthma sufferers, it would be valuable to develop an asthma trigger warning system by utilizing GIS that can incorporate the weather models and air pollution monitoring. This will allow asthma sufferers who concern air pollution as their asthma trigger to aware of the daily or even hourly level of pollution, weather details and the expected locations where high levels of an asthma trigger are expected. This research can also provide the health industry with innovative ways to integrate its data and access to GIS. It can be used for decision making such as finding locations of new clinics and hospitals, spending of public health funds, creating health policy and determining which areas require resource allocations.

## Acknowledgements

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