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ESTIMATING TRAFFIC-RELATED AIR POLLUTION EXPOSURE: THE HAPINZ STUDY

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ABSTRACT

Emissions of contaminants to the air from vehicles have been shown to lead to a variety of health effects on the public. Relatively little is known about the situation in New Zealand, although a recent preliminary analysis of the mortality associated with vehicle emissions of PM_{10} in New Zealand found that approximately 400 such deaths occurred each year and the annual car crash mortality is around 500 (Fisher et al., 2002).

More recently studies have attempted to quantify the impact of traffic pollution on health, in terms of number of people affected and associated economic costs. The most complex part of this quantification is identifying the nature of pollution exposure. Researchers need to answer the question "How much pollution are people actually exposed to?".

This paper will present details of an ongoing research project looking at the health impacts of air pollution, specifically traffic-related, in New Zealand. The Ministries of Transport, Health and Environment are funding this project to the tune of $1m jointly.

This paper presents details of the methods that will be used to assess air pollution exposure, along with some preliminary results. An overview of the whole research project will be presented in an alternative paper (Fisher and Scoggins).

1. INTRODUCTION

1.1 BACKGROUND

A recent study carried out for the Ministry of Transport (Fisher et al, 2000) has estimated that 399 people aged 30 and over die prematurely each year from exposure to microscopic particles from vehicle emissions. It also estimates that 970 people of the same age group die prematurely each year from air pollution derived from all sources (including fires for home heating). In comparison, in 2001, 454 people died from road accidents, of which 243 were aged 30 years and over.

As a result of these preliminary findings the Ministries of The Health Research Council, Ministry of Transport and Ministry for the Environment have jointly funded a project to examine in more detail the issue in New Zealand. A large collaborative group, including central government, local government and several research institutions have commenced a 3-year programme that addresses all the components. The outcomes include a better definition of the problem, an analysis of the effects and costs, and recommendations for policy options to improve the situation. The project has been assigned the acronym HAPINZ – Health and Air Pollution in New Zealand.

One of the key aspects of this research is identifying the level of pollution the population is exposed. A significant proportion of this will be traffic related pollution.

1.2 ASSESSING POLLUTION EXPOSURE

Research into relationships between road traffic pollution and health has adopted two contrasting approaches, each based on different premises. Time-series studies of the acute effects of traffic-related pollution have usually assessed pollution exposure based on measured data from one or, at best, a few monitoring stations within a city (Pope *et al.,* 1991; Schwartz, 1991, 1993). This assumes limited spatial variations in pollution exposures, and that single, daily average estimates can be applied to the whole study population. In contrast, geographical studies, which have generally focused on chronic effects of exposure, have typically used measures such as distance from road (Murakami *et al.,* 1990; Nitta *et al.,* 1993; Edwards *et al.,* 1994; Livingstone *et al.,* 1996; Brunekreef *et al.,* 1997), local traffic density (Wjst *et al.,* 1993; Weiland *et al.,* 1994), or modelled concentrations (Pershagen *et al.*, 1995; Oosterlee *et al.,* 1996; Elliott and Briggs, 1998; Briggs et al 1997, Briggs et al, 2000) as indicators of exposure to traffic-related pollution. Such studies assume that spatial variations in traffic-related pollution occur across areas are related to distance from source, and the indicators used subsequently represent these.

2. METHOD

A variety of methods will be used to attempt to accurately assess pollution exposure. These will endeavour to build upon the methods adopted by Fisher *et al* (2002) to produce more accurate measures of exposure.

2.1 PREVIOUS APPROACHES

The earlier study by Fisher *et al* (2002) used some fairly simplistic methods as a result of limited available data and time. The method used was as follows.

The basic working unit of area was the Census Area Unit (CAU) as defined by Statistics New Zealand. Only CAUs having a population density exceeding 500 people per square kilometre were used. This covered all the main centres, including approximately 80% of New Zealand's population. The final calculations, and reporting, were on a 'city' basis. The choice of the density criteria was made in order to only include 'cities' and urban areas that were likely to experience exposure to vehicle emissions. The CAUs have been aggregated to a more natural 'city' size, which includes most centres with more than 5000 residents.

The primary source of PM_{10} data was from local Council monitoring programmes. Results have to be used carefully, as many monitoring sites may not be truly representative of the areas being considered. For instance the Auckland Khyber Pass site is situated at a major intersection, and results are not necessarily representative for residential areas. In the analysis, a conservative approach was adopted, using all data, and assuming a general degree of representativeness. The secondary source of PM_{10} data was from airshed modelling estimates. For some cities - Auckland, Christchurch and Hamilton - extensive airshed modelling has been conducted which gives a more detailed indication of PM_{10} concentrations over the city. Model results were also used to aggregate CAUs into larger units, in order to reduce the amount of data processing.

Measured and modelled data were separated into two components - total PM_{10}, and PM_{10} due to vehicle emissions - using emissions inventory information. The ratio of vehicle emissions to other emissions has been estimated for New Zealand, by Territorial Local Authority (TLA).

Where neither monitoring nor modelling data were available, an estimation of PM_{10} concentrations was made using census data on vehicle numbers and population density in the city.

It was assumed that all of the people in the city area were exposed to the annual average PM_{10} concentration calculated. This is a conservative assumption, which follows overseas methodology (Kunzli *et al*, 2000). The following PM_{10} exposure categories were used (consistent with Künzli *et al*, 2000). 0-5, >5-10, >10-15, >15-20, >20-25, >25-30, >30-35, >35-40, >40 • g m^{-3}. The final output was the number of people exposed to each category, for each city.

2.2 HAPINZ APPROACHES

The HAPINZ project proposes to go beyond the work of Fisher et al (2002) and produce more accurate measures of pollution exposure. In the first year the HAPINZ project will be focusing on Christchurch. Christchurch is relatively data-rich in terms of air pollution data and the aim is to develop an accurate estimate of exposure. As data is more limited in other parts of New Zealand it is hoped it will be possible to identify a reasonably accurate surrogate for exposure, based on more readily available data for the rest of New Zealand, such as census data. This is very much *work in progress* and so is constantly evolving and changing. Much of the data manipulation and analysis will be carried out within a Geographical Information System (GIS). Simply put a GIS is a series of computer maps that enable the

overlaying of maps onto each other and comparison of their characteristics. Each map or coverage, as they are more usually referred to, can also have attribute data attached. One of the key ways GIS will be used is to relate the estimates or surrogates of pollution to the real monitored values. One technique that will be used is spatial regression, which calculates which combination of surrogates can best predict the real monitored values of pollution. The data sources being used in the HAPINZ study are varied but include census, estimated emissions, vehicle fleet emissions and pollution monitoring.

2.2.1 Census data

Data are available from the 2001 census for a variety of useful indicators of pollution. These include data for home heating, indicating whether households use electricity, gas or, more importantly form an air pollution perspective, wood or coal. From this information, it is possible to produce maps of *chimney density*. This is being done at Census Area Unit (CAU).

Data is also collected in the census on vehicle use and ownership. Vehicle ownership data can be used to produce maps of *vehicle density*, by CAU. In addition, data in matrix form is also now available for all origins and destinations of commuter journeys based on CAU, i.e. the number of commuter journeys from every CAU to every other one. A network of all routes by straight line and by road is being produced in GIS format (see 2.2.5). Attached to this, as attribute data will be vehicle volumes. The GIS will then be used to calculate the number of vehicle kilometres going through each CAU on commuter journeys. This could produce a good indicator of traffic emissions, particularly at the times of day when some of the highest levels of pollution are produced, morning and early evening.

2.2.2 Emissions inventory data

Regional Councils estimate pollution emissions in their regions. Environment Canterbury does this for the Canterbury region based primarily on survey data. This data is collected periodically (the last occasion was 2001, although this data is not available in its final form). It is generally available for ten areas in Christchurch that are amalgamations of CAUs. This will be estimated back down to all CAUs based on other available data.

2.2.3 Vehicle fleet emissions data

This dataset is available down to route segment and gives values for emissions for a variety of traffic pollutants. This data will be available in GIS format. This part of the work is in its early stages.

2.2.4 Pollution monitoring

Available previously collected data will be collated for all regions of New Zealand for a variety of pollutants. A full dataset for Christchurch for PM_{10} is available, and currently being analysed. Other datasets for all pollutants for all sites in Christchurch are being supplied by Environment Canterbury. A big disadvantage of these datasets is that they include little spatial coverage in small areas. To help counter this problem for Christchurch, results from allied research that has carried out air pollution monitoring will be used (the funding remit for the HAPINZ study does not allow for pollution monitoring). This research is focusing on particulate matter, and involves significant monitoring of PM_{10} at locations in Christchurch. Sampling is carried out using Airmetrics MiniVol samplers for periods of 24 hours. Some limited

preliminary sampling was carried out in July/August 2002. Initial sampling was carried out at nine sites across the whole of Christchurch, and then more densely in an area to the north-east of the city centre. More detailed sampling was carried out throughout July 2003, with 24 hr measurements taken each day at twelve sites in Christchurch. The sites were chosen based on ECan emission inventory areas centroids and two additional sites, one at ECan's permanent monitoring site at Coles Place, St. Albans and one extra site.

3. RESULTS

3.1 PREVIOUS RESULTS

The earlier study by Fisher et al (2002) estimated the number of people in each PM_{10} exposure category for total emissions and vehicle only emissions (see tables 1 and 2). Ranges are based on the full range of predicted high pollution and low pollution years. Regional variations in predicted pollutant exposure levels can also be seen (see figure 1). As previously indicated these translate into a total of 399 people aged 30 and over dying prematurely each year from exposure to traffic related PM_{10} (970 people from all source PM_{10}) (Fisher *et al*, 2002).

Table 1: Number of people (over 30) exposed (000s), by category, for total annual average PM_{10} ($\mu g\ m^{-3}$).

Exposure	**0-5**	**>5-10**	**>10-15**	**>15-20**	**>20-25**	**>25-30**	**>30-35**	**>35-40**	**>40**
Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Low exposure year	0	320	248	373	297	314	0	0	0
Best estimate - average year	**0**	**282**	**168**	**326**	**322**	**340**	**114**	**0**	**0**
High exposure year	0	178	190	276	266	215	313	114	0

Table 2: Number of people (over 30) exposed (000s), by category, for vehicle only annual average PM_{10} ($\mu g\ m^{-3}$).

Exposure	**0-5**	**>5-10**	**>10-15**	**>15-20**	**>20-25**	**>25-30**	**>30-35**	**>35-40**	**>40**
Category	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
Low exposure year	129	788	305	130	200	0	0	0	0
Best estimate - average year	**95**	**562**	**460**	**235**	**200**	**0**	**0**	**0**	**0**
High exposure year	30	485	453	383	0	200	0	0	0

3.2 HAPINZ RESULTS TO DATE

3.2.1 Census data

Density of vehicle owning households is presented in figure 2 (from the 2001 census). This seems to suggest a greater density of vehicles in CAUs to the north and west of the city centre. The city centre, where fewer people live, has lower vehicle densities (this area also includes Hagley Park). Lower vehicle densities can

also be seen in the less affluent areas to the east, and the more rural outer suburbs. This data accounts only for absence or presence of vehicles. Of possibly greater interest will be the journey to work matrix data. This is work currently in progress and no results are currently available. A combination of vehicle ownership and journey to work data could however produce an effective surrogate of vehicle pollution.

Density of households using wood burners is presented in figure 3 (from the 2001 census). Higher densities of wood burner use can be seen to the north of the city centre, with lower densities in the more rural areas.

3.2.2 Emissions inventory data

Predicted PM_{10} emissions for Christchurch, 1996 are presented in figure 4. Higher vehicle emissions appear top exist to the centre and west of the city, with an additional area to the north. The significant difference between this and figure 2 is that the emissions data accounts for the movement of traffic rather than merely the absence or presence of vehicles. Limited analysis is being carried out on currently available emissions data – rather the research team is waiting until the data for 2001 is available.

3.2.3 Vehicle fleet emissions data

This work is currently in progress and at the time of writing it is not possible to show any results.

3.2.4 Pollution monitoring

Interpolated pollution values based on PM_{10} measurements taken at nine sites in August 2002 can be seen in figure 5. The map on the left shows sample locations and interpolated values for sampling taken across Christchurch. The map on the right shows the same, but for the dense sampling period. The main conclusion that can be drawn is that there is significant variation in spatial patterns of PM_{10}, suggesting that one sampling site is not appropriate to get a useful indicator of pollution exposure.

The locations of PM_{10} monitoring sites in Christchurch for sampling carried out in July 2003 are presented in Figure 6. In addition to data collected by researchers at the University of Canterbury, the locations of samplers operated by Environment Canterbury (ECan) are also shown. At the time of writing, the results are stil being analysed and it is not possible to show any results for this sampling.

4. CONCLUSIONS

This research is very much in its early stages. The results presented are very preliminary. The HAPINZ project is aiming to assess the impact of air pollution in New Zealand. An important part of this is assessing exposure to traffic related pollutants.

6. REFERENCES

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Figure 1: Regional variations in PM_{10} exposure levels, by domestic and vehicle sources (Data from Fisher et al, 2002)

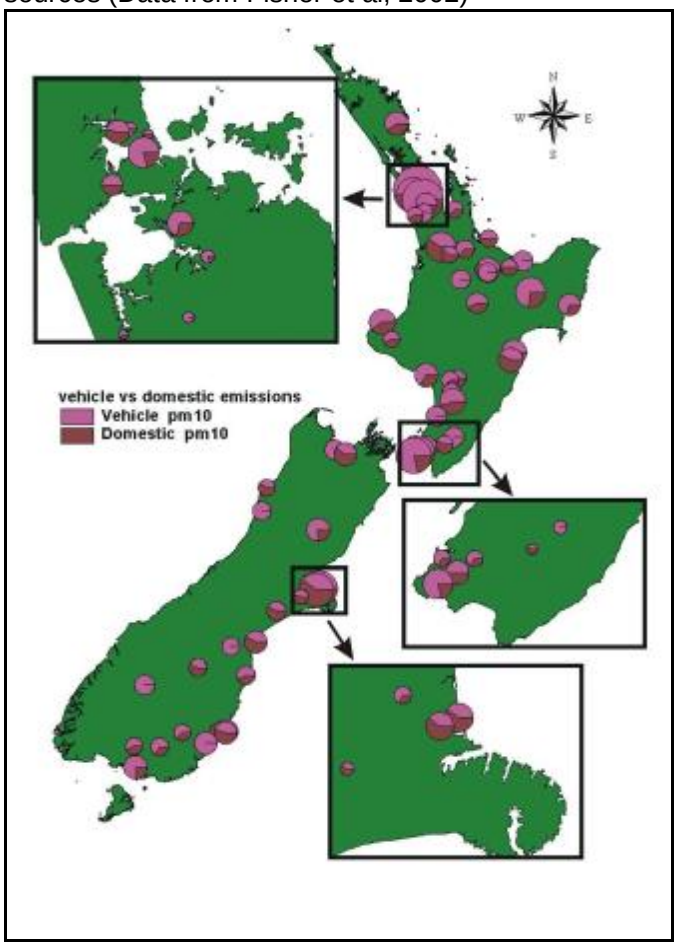

Figure 2: Density of motor vehicles in Christchurch (Census 2001).

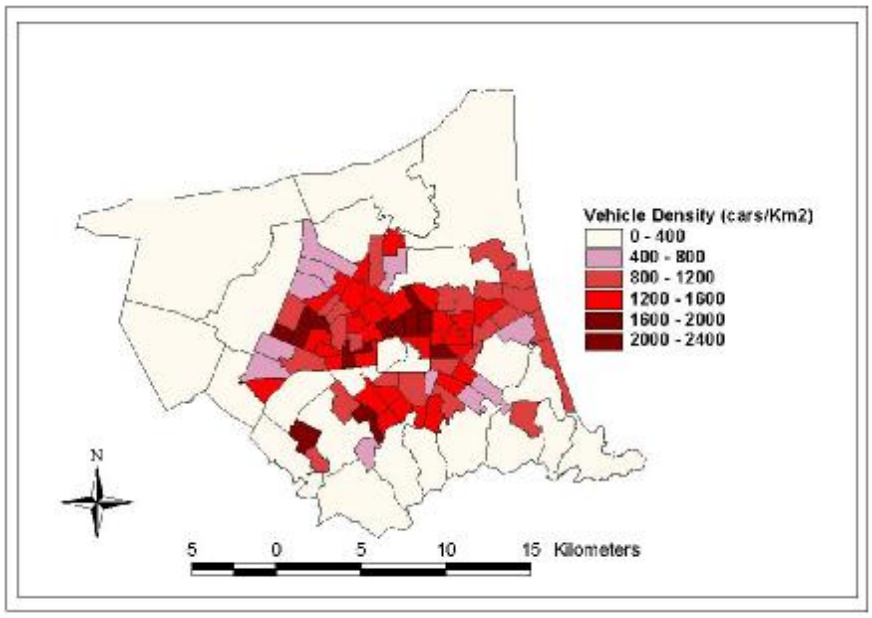

Figure 3: Density of wood burning chimneys in Christchurch (Census 2001)

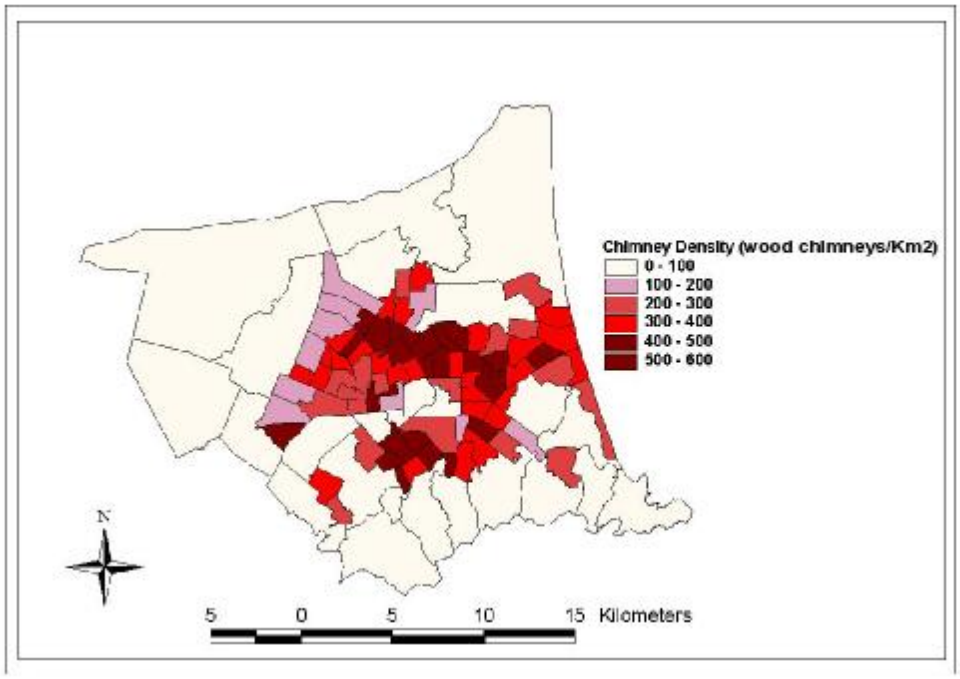

Figure 4: Predicted vehicle PM_{10} emissions for Christchurch, 1996 (Data from Ecan emissions inventory)

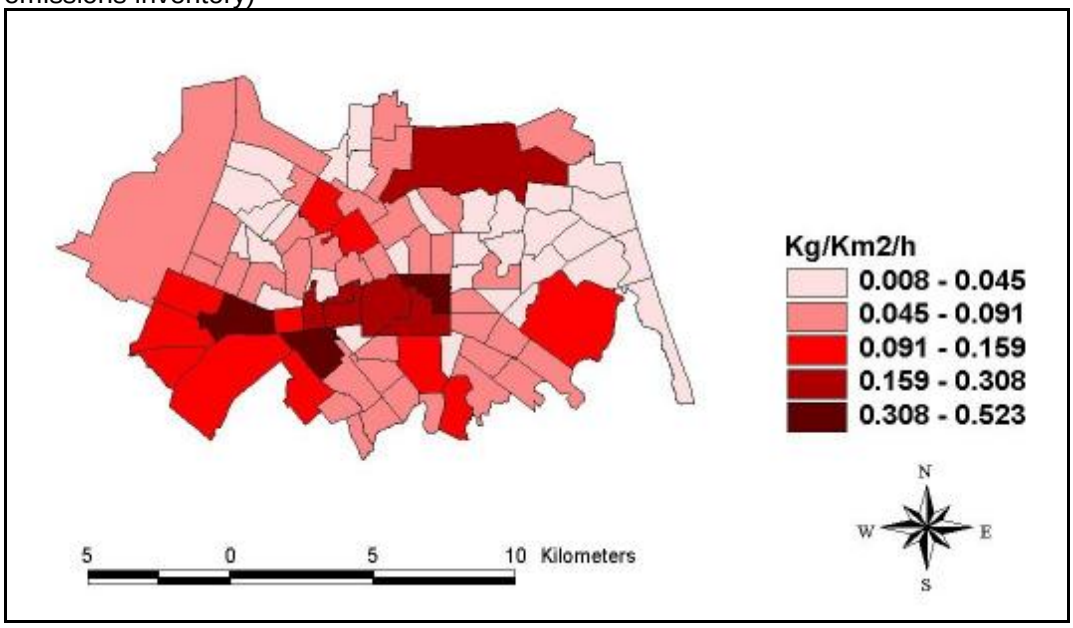

Figure 5: Mean PM_{10} values for Christchurch, August 2002 (based on sampling and spatial interpolation)

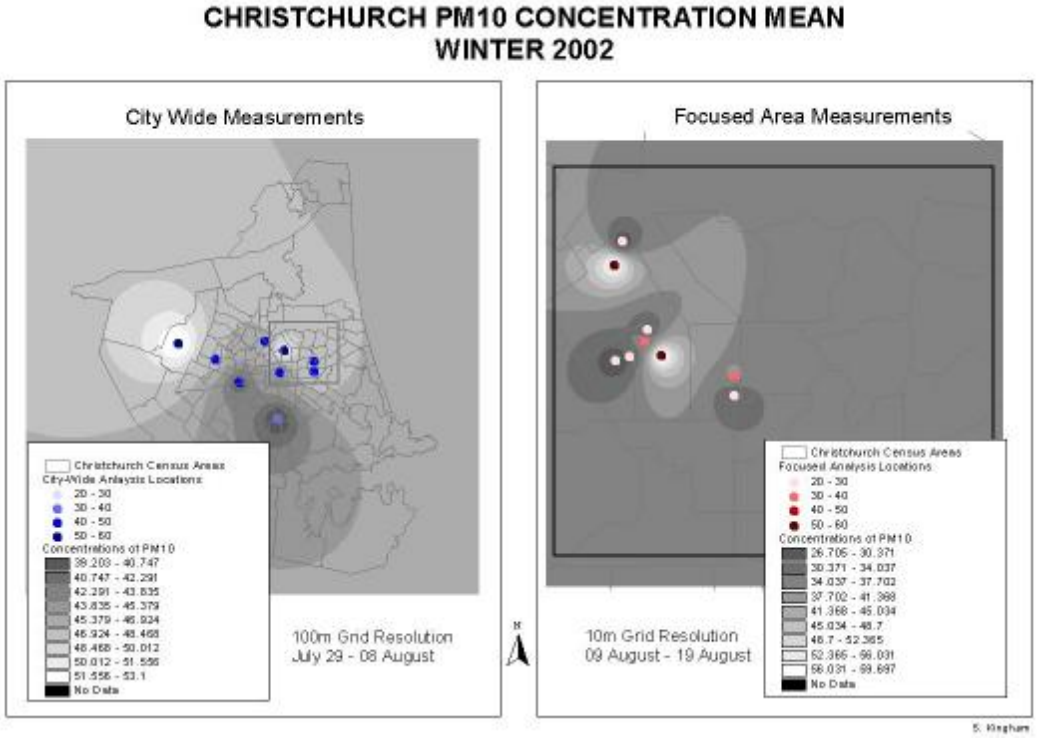

Fig 6: PM_{10} monitoring sites, July 2003