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HEALTH EFFECTS OF VEHICLE EMISSIONS

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ABSTRACT

All over the world concern is growing over the health effects of emissions from internal combustion engines in the transport fleet. Studies conducted using air pollution exposure information and various health indicators, such as hospital admissions, are invariably showing up real and dramatic effects. Some work carried out in Australia and New Zealand has confirmed that a similar level of health effects occur here, even though we are generally have good air quality relative to many other parts of the world.

Is this real? What causes these effects? Who is most affected? Can we - should we - do something about it?

The Health Research Council, Ministry of Transport and Ministry for the Environment have jointly funded a project to examine the range of social, health, economic and environmental effects from vehicle emissions in New Zealand, and also those from other sources. A large collaborative group, including central government, local government and several research institutes has 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 paper presents an overview of the work and results to date.

1. THE AIR POLLUTION CONCERN

Globally urban air pollution is recognised as an important environmental risk and a major focus of public health concern and regulatory activity in developed and developing countries. In particular concern is growing over the health effects of emissions from internal combustion engines in the transport fleet. Media releases such as “vehicle pollution major killer” have also sparked public health concerns within communities regarding exposure to ambient air pollution, especially in anticipation of increasing emissions and population growth (Figure 1).

1.1 HISTORY

Following the infamous London smog episode on 4th December 1952 or what has been termed “darkness at noon” (Peace, 2002), worldwide research has explored the relationship between health and pollutants such as particles, carbon monoxide, sulphur dioxide, nitrogen dioxide, ozone, and others. Effective actions to reduce the most extreme air pollution was put in place during the 1950s to 1970s, but the concern was rekindled when epidemiological studies in the 1980s, using new statistical methodology, found increased mortality at levels far below the air quality standards or guidelines (Schwartz et al., 1992). Air quality indicators derived from the World Economic Forum suggest New Zealand has clean air relative to other countries such as United Kingdom, United States, Netherlands, and Australia (Ministry of Research Science and Technology, 2002). However studies conducted in New Zealand suggest similar levels of health effects occur here.

Figure 1. Vehicle-related air pollution in Auckland

1.2 NEW ZEALAND

A national risk assessment commissioned by the Ministry of Transport, estimated that the number of people above 30 years of age who experience pre-mature mortality in New Zealand due to exposure of emissions of PM_{10} (particles less than 10 micrometers in diameter) from vehicles is 399 per year (with a 95% confidence interval range of 241-566 people). This compares with 970 people above 30 experiencing pre-mature mortality due to particulate pollution from all sources, and with 502 people dying from road accidents (all ages) in 1996 (Fisher et al., 2002). This result, which followed a similar methodology used in Europe (Kunzli et al., 2000), suggests mortality due to vehicle related air pollution is similar to the accident road toll. A ratio between air pollution-related deaths and fatal motor vehicles accidents approximately between 1:1 and 2:1 is also consistent with overseas findings (Table 1). Analysed on a regional basis the number of deaths per year due to exposure to emissions of PM_{10} from motor vehicle emissions was 253 (95%CI: 153-359) in Auckland, 56 (95%CI: 34-80) in Wellington, 41 (95%CI: 25-58) in Christchurch, and 6 (95% CI 3-8) in Dunedin, and 40 in other cities and towns (with over 5,000 people)

Table 1. Air pollution pre-mature mortality (for adults ≥ 30 years) and the road toll

Country	Population (m) 1996	Traffic accident deaths	Mortality due to traffic air pollution	Ratio
France	58.3	8,919	17,629	1:2.0
Austria	8.1	963	2,411	1:2.5
Switzerland	7.1	597	1,762	1:3.0
New Zealand	3.7	502	399	1:0.8

1.3 UNANSWERED QUESTIONS

Many questions regarding the effects of air pollution remain unanswered and overall the effects of air pollution have not been fully quantified in New Zealand (or overseas). A key question that remains is whether increases in mortality associated with air pollution reflect a short-term shift in deaths that would otherwise have occurred a few days or weeks later. This concept is known as mortality displacement. The most recent study (within the Air Pollution and Health, European Approach-2 (APHEA-2)) found that most of the effect of air pollution is not simply advanced by a few weeks and that effects persists for more than a month after exposure (Zanobetti et al., 2003). A remaining question of debate is whether or not effects demonstrated by time-series studies or short-term (daily) exposure also occur after long-term exposure. For example the increased number of deaths due to short-term peaks of air pollution could possibly have little impact on longer-term mortality in the affected communities. Conversely higher yearly average of air pollution may create a public health impact in subsequent years. Risk assessments based on short-term studies can only estimate acute mortality effects due to air pollution and therefore capture only one part of the problem. In contrast risk assessments based on long-term exposure studies incorporate chronic as well as short-term effects. Other questions that remain unclear in New Zealand include: What are the full health effects associated with air pollution including hospital admissions and restricted activity days? What specific-source emissions are causing these effects? Who is most affected? What is air pollution costing New Zealand? Finally, What policy measures can be taken by central and local governments to improve the current situation?

2. ASSESSING EXPOSURE

There are many different ways to measure overall exposure to ambient air pollution, which will depend on the duration, frequency and magnitude of exposure. Ambient air quality monitoring data is usually used as a surrogate indicator for personal exposure measurements. A challenge for epidemiological research on air pollution has been that often no one air quality monitoring site is representative of a region due to complex coastal environments, topography, and variations in climatic factors over relatively small areas. Furthermore, in some towns no ambient air quality monitoring network exists so emission inventories and/or census-derived indicators (such as chimney density) must be used to indicate ambient air pollution exposure (Kjellstrom et al., 1999).

2.1 URBAN AIRSHED MODELS AND GIS

Recently, detailed understanding of complex urban air quality processes has been aided by the application of urban airshed models (Gimson, 2001). Although urban airshed models are used widely overseas, for New Zealand this modelling approach is relatively new. Recently in Auckland pollutant concentrations have been modelled on a 3km by 3km grid over almost the entire region compared with observed measurements that can only be provided at a few places (Figure 2). The urban airshed model, CALGRID, takes into account surface and upper air meteorology (such as wind speed and direction, temperature, humidity, cloud cover and rainfall) (supplied from New Zealand National Climate database) along with complete emissions data (supplied by Auckland Regional Council), to simulate the urban air quality of Auckland. Other models such as TAPM (The Air Pollution Model) are currently being used to produce longer-term air quality simulations (e.g. a ten-year period) and predict future air pollution scenarios.

A validation exercise was carried out to evaluate CALGRID's performance. Modeled hourly NO_2 concentrations were compared with observed hourly concentrations from the ambient air quality monitoring sites in Auckland (Table 2). The urban airshed modeling carried out in Auckland gave an Index of Agreement (IOA) above 0.75, except at the peak site, which is good validation result (Willmott, 1982).

Table 2. Comparison of hourly NO_2 observed and modeled values at air quality monitoring sites in Auckland

Monitoring site	Type of Site	Correlation	IOA[1]
Khyber Pass	Peak Traffic	0.18 (n=8296)	0.502
Mt. Eden	Residential	0.65 (n=8636)	0.766
Musick Point	Remote	0.77 (n=6333)	0.803
Penrose	Industrial	0.60 (n=7988)	0.752

[1] Index of Agreement (Willmott, 1982)

$$IOA = 1 - \frac{\sum_{i=1}^{N} (P_i - O_i)^2}{\sum_{i=1}^{N} \left(|P_i - O_{mean}| + |O_i - O_{mean}| \right)^2}$$

O = observed
P = predicted or modelled

Urban airshed modelling output, coupled with GIS techniques have refined the assessment of exposure to ambient air pollution and are providing a more detailed exposure measurement able to be linked with health outcomes. GIS-techniques have enabled information that is typically displayed on a grid (such as VKTs) to be translated to a census area unit (CAU) (Figure 3). Health and Census information is widely available at a CAU level. For example the domicile code, which represents the deceased's usual residence address, is the same as the CAU code and can be used to map mortality data to place of residence. Residence location has long been assumed to indicate air pollution exposure in many epidemiological studies (Huang et al., 2000). In New Zealand there is limited information on time-space patterns which is a major personal determinant of exposure to air pollution. While Statistics New Zealand has completed time-use surveys, these estimate amount of time spent in unpaid/paid work or the use of time by recipients of government income support, rather than time spent indoors/outdoors or near major traffic routes and intersections. This data may be available in the future by tracking peoples time-space patterns using Global Positioning System (GPS) receivers.

Figure 2. Maximum 24-hour NO_2 µg/m^3 during 1999 and exposed population in Auckland (Scoggins, 2003)

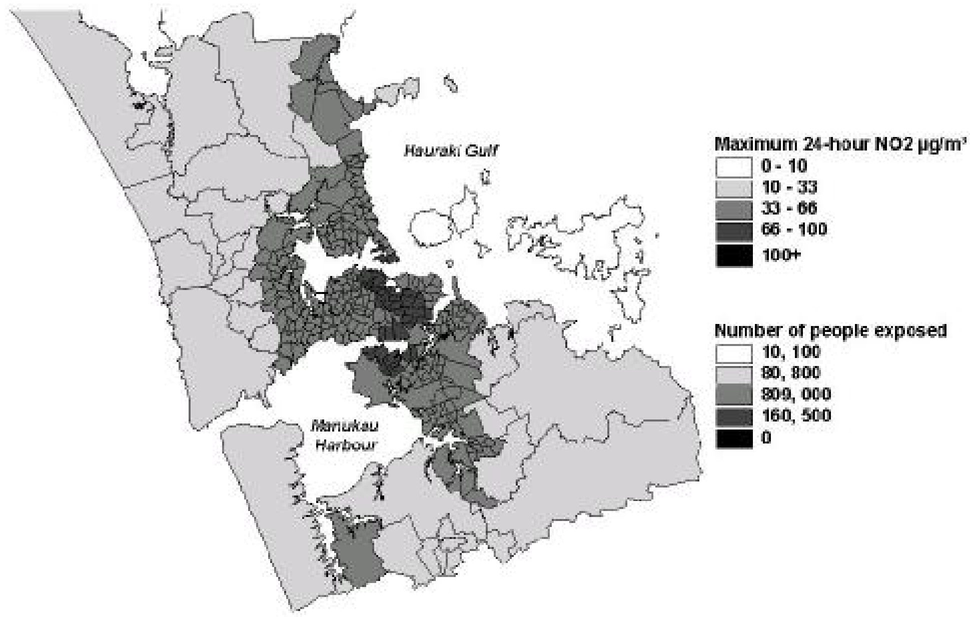
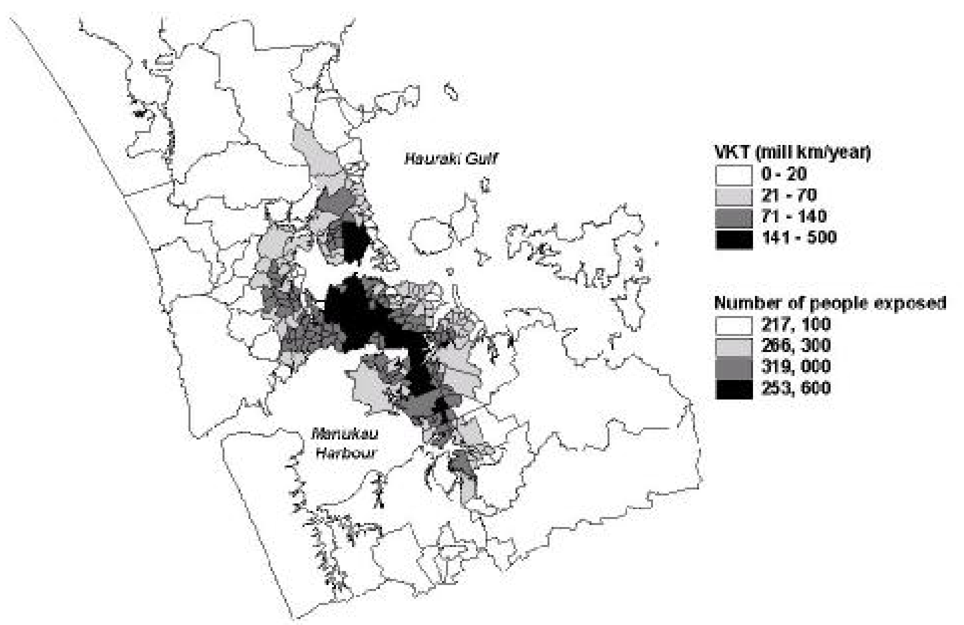


Figure 3. Vehicle Kilometers Traveled (millions km/year) and exposed people in Auckland (ARC, 2000)



2.2 AUCKLAND'S LATEST RESULTS

The latest research undertaken was an ecological cross-sectional study in the Auckland region for the period 1996 to 1999 which integrated the use of urban airshed models with GIS to establish the relationship between mortality and long-term annual exposure to air pollution and estimate the number of deaths per year attributed to air pollution. At an annual average NO_2 threshold for mortality effects of 13 µg/m^3, and controlling for age, sex, ethnicity, socio-economic status, and urban/rural domicile the estimated number of people per year in the Auckland region dying from non-external causes and circulatory and respiratory causes that may be associated with air pollution was 268 (with a 95% confidence range of 227-310) (3.9% of total all-cause deaths) and 203 (with a 95% confidence range of 169-237) (5.9% of total circulatory and respiratory deaths) (Scoggins, 2003), respectively. This compares with an average of 103 people dying per year from road accidents in the Auckland region. However while the car crash death rate consistently peaks in the 15-24 year age group, the average age of people dying from non-external causes possibly associated with air pollution is more likely to occur in the very young (less than 5 years old) or elderly (greater than 65 years old) (WHO, 2000).

3. WHO IS AFFECTED BY AIR POLLUTION?

National data on health status provide clear evidence that differential mortality and morbidity exists by ethnicity, age, gender, and socio-economic status (Ministry of Health, 1999). For example Maori and Pacific peoples have poorer health status than the rest of the population (Ministry of Health, 1999; Smartt et al., 2002; Thomas, 2001). It is unlikely that everyone in the population is affected to the same extent by air pollution, and overall little is known about susceptibility. The movement towards "environmental health equity" suggests there should be provision of adequate protection for all people, regardless of age, gender, health status, socio-economic status, or ethnicity.

3.1 ENVIRONMENTAL HEALTH EQUITY IN NEW ZEALAND

In New Zealand it is likely that Maori and Pacific peoples in urban areas are more exposed than the average. Relatively deprived populations may have higher exposure to traffic-related pollution given they are more likely to reside close to busy roads or major arterial routes. A study which assessed the relation between traffic-related air pollution and mortality in 5000 participants of the Netherlands Cohort study on Diet and Cancer found cardiopulmonary mortality was associated with living near a major road (relative risk 1.95, 95% CI 1.09-3.52) (Hoek et al., 2002). Further the cost of home heating, which is essential for healthy indoor climates, can lead some families to heat inadequately or use inefficient and polluting heating systems (Kjellstrom et al, 2002).

Hales (2000) found that relative social and economic deprivation (as measured by the New Zealand Deprivation Index 1996) may increase the vulnerability to the effects of particulate air pollution on daily mortality in Christchurch, independent of the effects of age, and local variation in exposure. Results from the Auckland study, which carried out a spatial analysis of annual air pollution exposure and mortality, found different socio-economic groups are affected differently (Scoggins, 2003). In Auckland the increased risk of dying from air pollution was relatively less for those in the most deprived area (NZDep96 5) compared with those in the least deprived areas (NZDep96 1) (Scoggins, 2003).

There have been several epidemiological studies of the effects of air pollution on health outcomes that have found vulnerable sub-populations are at higher risk of premature mortality induced by air pollution (e.g. people with existing health condition such as chronic cardiac and respiratory conditions, pregnant women, the elderly and infants) (Bobak et al., 1999; Dickey, 2000; Pikhart et al., 2000; Zanobetti et al., 2000). In New Zealand defining those sections of the population that are more vulnerable to air pollution needs to be investigated which will assist development of further health protection strategies against vehicle or wood smoke effects.

4. AIR QUALITY MANAGEMENT: NEW ZEALAND CASE STUDIES

Levels of vehicle-related air pollution and associated health effects have received increased attention in environmental impact assessments for road designation decisions. Two examples are given below.

4.1 Nelson's Southern Link

A proposed $13.4M highway by Transit New Zealand to enable heavy traffic, going to and from the port, to by-pass the city instead of traveling through it was rejected in a council hearing in February 2002. This case has been appealed. Transit New Zealand and residents now await a final decision to be made in the Environment Court in November 2003 as to whether the proposed "southern link" will be developed. This case is one of the first times air quality has been pivotal in a road designation application.

Although many residents were in favour of the road being built there is strong opposition from those residents and schools who are situated along the proposed route. The highway was rejected because of existing air quality problems in the area, which would be enhanced if the proposed link went ahead. The proposed "southern link" failed a key aim of the Resource Management Act (RMA), to promote sustainable management of natural and physical resources in a way that enabled communities to provide for their health and safety while "safeguarding the life supporting capacity of air". Air quality monitoring in Nelson have indicated that PM_{10} levels (mostly due to domestic heating) during the past two winters exceeded the ambient air quality guideline on 81 days (The Nelson Mail, 2002; Nelson City Council, 2002).

4.2 Auckland - "Roads Roads Roads"

The Auckland region has several major roading projects underway, which is consistent with the Auckland State Highway strategy. These include major rural highway improvements, major urban highways, rural town bypasses, urban motorways and expressway improvements and urban priority lanes. A key Transit New Zealand programme is Auckland's Central Motorway Improvements, which includes the Central Motorway Junction (CMJ), Harbour Bridge to City (HBTC), and the Grafton Gully Project (GGP). These priority projects aim to reduce current and future vehicle congestion south of the Harbour Bridge and through the central motorway network. Increasing the use of public transport facilities via priority bus lanes and pedestrian and cyclist facilities alongside motorways, wherever feasible, is also under consideration. The "Eastern Corridor" project is also underway, which aims to reduce heavy traffic using residential streets through the Eastern suburbs. Currently phase two of the study is being completed which includes an assessment of environmental effects, scheme assessment, and community consultation. Transit New Zealand must comply with the relevant environmental regulations, most notably the RMA, to apply for resource consents or designations. Ensuring the benefits of the road (economic and social benefits) outweigh the environmental costs (increased air pollution levels and adverse health outcomes), or are properly balanced, is a key component for environmental impact assessments.

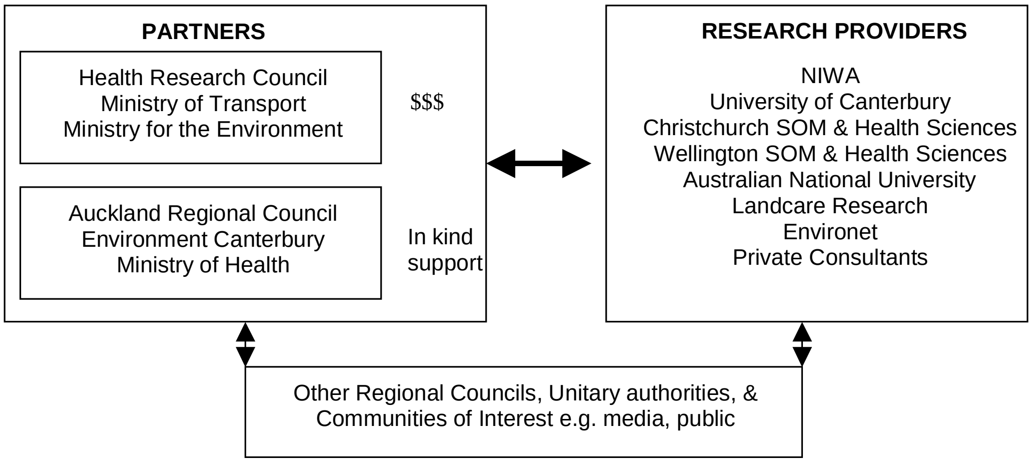
5. ECONOMIC COSTS?

There are both intangible and tangible costs likely to be associated with air pollution. Tangible costs include health-care costs associated with pollution-caused illnesses; such as hospital costs and primary health-care including medicines, and also estimates of lost production costs. Intangible costs are probably more important but also more difficult to estimate. They include both lost years of life due to pre-mature mortality, and also lost quality of life due to pollution-caused illnesses. To date, these costs have not been quantified for New Zealand. A study carried out by the Ministry of Transport on the overall health damage due air pollution from motor vehicles on roads cost the country $700M per year (Fisher, 2002; Ministry of Transport, 1996). The cost was adjusted after a more recent study was conducted on the health effects of PM_{10} emissions from motor vehicles (Fisher et al., 2002) to $760M per year or $440M from vehicle PM_{10} alone. A further study has suggested air pollution makes up 58 percent of the total external costs arising from transport in the Auckland region in 2001 (Jakob, 2003).

6. HAPINZ

The Health and Air Pollution in New Zealand (HAPINZ) project is determining the environmental, health, social, and economic costs of air pollution from all sources in New Zealand. The project is funded by the Health Research Council, Ministry for the Environment, and Ministry of Transport, and supported by Ministry of Health, Auckland Regional Council, and Environment Canterbury. The three-year research programme, which began early 2003, involves a large collaborative multidisciplinary group (Figure 4).

Figure 4. HAPINZ collaborative group



Although particulates (such as PM_{10} and $PM_{2.5}$) are most commonly associated with the health effects, other studies also link these effects to CO, NO_2, SO_2, ozone, and others. As these pollutants occur together and are often closely correlated, it has been difficult to clearly identify effects of single pollutants, or potentially damaging combinations of them. There is also a wide range of sources that emit these pollutants including mobile (e.g. petrol and diesel cars and trucks), domestic (e.g. wood and coal burning heating), industrial (coal or heavy oil power stations) and biogenic sources.

The research involves evaluating the effects of specific source emission categories of air pollution. Creating effective evidence-based policy requires linking pollutants and the associated health and economic end-points back to specific source categories (Figure 5). Preventative policy options and recommendations can be tailored to address emission sources in order of their contribution to the air pollution problem. In this way, the major sources can be targeted and the biggest improvements achieved (Figure 6).

Figure 5. HAPINZ Schematic

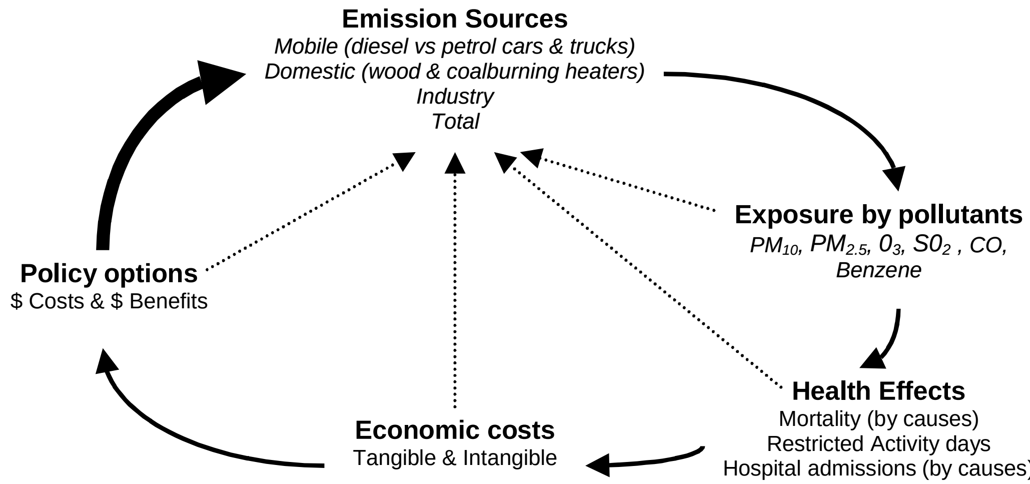
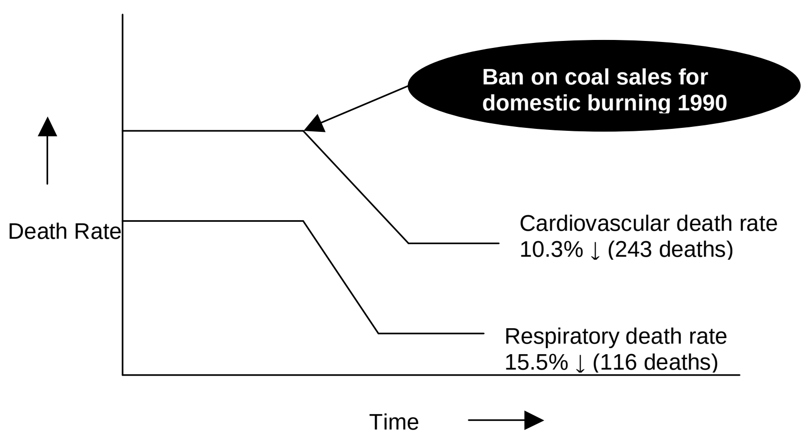


Figure 6. Case example in Dublin (Clancy et al., 2002)



A major output of this research will include a range of actions, policy options, and recommendations for policy makers in environment, transport and health ministries. In addition the results will influence planning by regional and city councils. For example policy recommendations could influence the following areas: public transport planning, banning the use of wood or coal burning fires, improving fuel specifications and emission standards, and town planning to influence travel demand and driver behaviour.

The first year of the project involves carrying out a pilot study on Christchurch to evaluate results and methods, with the implication this will then be applied to all New Zealand centers with populations over 5,000 in the following two-year period. The first phase of the research, which is nearing completion, has involved the collation of monitoring and emissions data, vehicle fleet emissions data and urban airshed exposure modeling. Other information such as census and mortality data is also being collated.

7. CONCLUSION

Air pollution has been shown to pose a public health problem for New Zealand. A national ambient air quality management research project (HAPINZ) will further quantify the public health effects and cost for New Zealand and will affect future local and central government policies to improve the current situation.

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