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Mortality due to motor vehicle air pollution in the Wellington Region

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Contents

1. Introduction

In January 2002 the Ministry of Transport published a preliminary NIWA study quantifying the health effects, in terms of mortality, of motor vehicle pollution in New Zealand. This included an estimate of air pollution deaths in the Wellington Region: 79 from all pollution sources, of which 56 were due to motor vehicle sources[1].

People dying from the effects of air pollution have typically lived longer than those who die in motor vehicle accidents. To compare the traffic air pollution toll with the road toll requires a comparison of the average years of life lost. The NIWA study found that road toll victims live approximately half as long as those killed by air pollution. Thus, the road-toll-equivalent deaths from motor vehicle air pollution would be 28 in the Wellington Region[2].

With a 2001 road toll for the region of 30[3], the NIWA results indicate that the hidden mortality cost of motor vehicles has a similar impact as the official count.

However, evaluation of the underlying data and analysis suggests that the NIWA report over represents the contribution of vehicles to air pollution deaths and the significance of such deaths with respect to the road toll. That report's method was reproduced to include these identified improvement areas, generating updated Wellington Regional mortality figures.

[1] Fisher et al. (2002) p33-34
[2] Fisher et al. (2002) p10-11, 33
[3] Land Transport Safety Authority (2002)

2. Mortality (Population ≥ 30 years old)

2.1 NIWA Calculation

The NIWA report utilises the calculation methodology of Künzli[4] to assess mortality figures due to ambient concentrations of PM_{10} and the exposed population. This method assumes annual average PM_{10} concentrations represent the average exposure that each individual will experience.

Based on a linear dose-effect relationship the "Künzli" equations employ a derived mortality increase rate for each 10 μgm^{-3} increment of PM_{10} over a threshold. This increase in mortality is applied to the population over 30 years old and older to give the deaths due to amplified pollution levels.

The contribution of vehicles to ambient PM_{10} was assessed via an emissions inventory; the percentage of pollution due to vehicles is applied to the overall deaths to give traffic-related mortality.

Appendix A contains a summary of the "Künzli" equations.

2.2 Discussion

The Künzli methodology was replicated to calculate the air pollution deaths in each population within the Wellington Region, taking into account the following differences from the NIWA study:

- Variations in the monitored ambient PM_{10} levels
- Increased ≥30 year old populations
- Lower base mortality
- Changes to the contribution of vehicles to ambient PM_{10} levels

These are elaborated below.

2.2.1 Ambient PM_{10} Levels

Whilst the annual average PM_{10} concentrations used in the NIWA study appear to agree with Greater Wellington's monitoring results, the small number of sites and short monitoring times within Wellington city is unfortunate. The study uses data from a site that was sampled for only two months and extrapolated out to the annual average.

The large over 29 population in Wellington city makes it the principal source of pollution exposure deaths. However, the single PM_{10} concentration reading, located in a particularly busy traffic area, is unlikely to represent the pollutant levels experienced by the majority of the population.

Improved reliability with respect to the measured PM_{10} concentrations and any indication of geographical variation would aid this calculation; additional monitoring may be available in 2004.

4 Künzli et al. (1999)

Where appropriate the annual average ambient PM_{10} values were updated to reflect recent monitoring in the wider Wellington Region. A summary of the updated calculation data is located in Appendix B.

2.2.2 Population

The NIWA study uses 1996 over 29 population data, as suitable 2001 values were not available at the time[5]. This approach underestimated the Greater Wellington over 29 population growth and the figures were replaced with the actual 2001 census numbers[6].

Despite indicating that tabulated results were for the Wellington Region the NIWA study does not include the calculated figures for the Kapiti or Wairarapa populations. This was corrected in the revised calculation and primarily increases the overall pollution mortality.

2.2.3 Base Mortality Rate

One of the inputs into the Künzli equations is the observed mortality rate for the ≥ 30 population. The NIWA study gives this figure as 12.8 per 1000 people[7]; this was recalculated for 2001 as 12.08 [Deaths for the year ending 31 Dec 2001, Age>29 (26747) / Mean estimated resident population for the year ending 31 Dec 2001, Age>29 (2214970)][8].

2.2.4 Vehicle Contribution to Air Pollution

The proportion of deaths due to motor vehicles was estimated in the NIWA study from the 1997 National Emissions Inventory completed also by NIWA[9]. This inventory predates the Ministry of Transport's Vehicle Fleet Emissions Model (VFEM) and its resulting emission rates.

Greater Wellington Regional Council has produced a specific Wellington Regional emissions inventory[10] that does incorporate the VFEM emission rates and it disagrees with the pollution proportions indicated by the NIWA study. Some of the NIWA proportions used are exceptionally high, 90 – 100% vehicle contribution in small city / rural areas, compared with their own documentation suggesting up to 30%[11]. Thus, the vehicle proportions were replaced with those indicated by the Greater Wellington emissions inventory.

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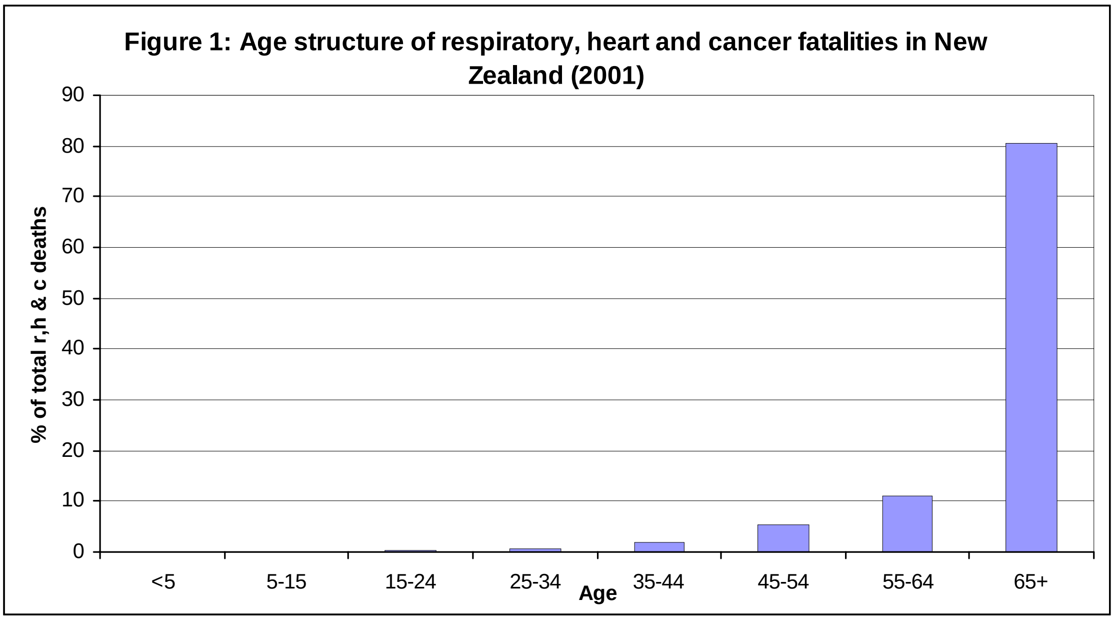
[5] Fisher et al. (2002) p25
[6] Electronic Resource: Statistics New Zealand: 2001 Census Regional Summary (05/05/03)
[7] Fisher et al. (2002) p27
[8] Electronic Resource: Statistics New Zealand: Demographic Trends 2002 (05/05/03)
[9] Fisher et al. (2002) p15
[10] Air and Environmental Sciences (2001)
[11] Fisher et al. (2002) p17

3. Mortality (Population < 30 years old)

3.1 Mortality (Population 1 - 29 years old)

The mortality impact of air pollution generally presents itself as cardiopulmonary disease and lung cancer[12]. It is possible to assume that these deaths follow the same age distribution as all occurrences of these diseases[13]. As illustrated in Figure 1 the contribution of persons under 35 to the total respiratory, heart and cancer deaths is minimal; figures in this younger age group are primarily due to cancer, which are unlikely to be pollution related[14].



3.2 Infant Mortality

The potential effects on new-borns and infants (<1 year) were not included by Künzli despite being identified as an additional source of air pollution deaths due to their 'at least' approach[15].

Infants represent a portion of the population with a comparable frailty to the elderly, so it is not surprising that their relative mortality risk is similar to the adult rate[16] regardless of the minimal exposure time. However, this similar relative mortality risk does not equate to equivalent numbers of dead since the population and base mortality rate for infants is significantly lower than for older adults.

The Künzli calculation was reproduced for an estimated Wellington population under 1 year old, with a relative risk equal to the adult rate (1.043) and utilising a base mortality

[12] Fisher et al. (2002) p2-5
[13] Künzli et al. (1999) p41
[14] Eletronic Resource: University of Otago, Injury Prevention Research Unit (05/05/03)
[15] Künzli et al. (1999) p42
[16] Künzli et al. (1999) p42, Ha et al. (2003)

rate of 5.29 per 1000 [Deaths for the year ending 31 Dec 2001, Age<1 (296) / Mean estimated resident population for the year ending 31 Dec 2001, Age<1 (55940)][17].

[17] Electronic Resource: Statistics New Zealand: Demographic Trends 2002 (05/05/03)

4. Results

4.1 Mortality (Population ≥ 30 years old)

Results for the revised Wellington Region calculation are given in Table 1. For comparison the results from the NIWA study are in Table 2.

The best estimate of vehicle related deaths, when the effect threshold is 7.5 $\mu g\ m^{-3}$, for the population over 29 is 47.6 premature deaths each year. 68% of these deaths occur in the Wellington city area.

However, the PM_{10} exposure in Wellington city is based on one reading in a central urban area which is unlikely to represent the average exposure that the whole population experiences. If the average Wellington city PM_{10} figure is lowered (from 19 to 16 $\mu g\ m^{-3}$) to mimic those recorded in the other comparable areas of the region, where monitoring was in primarily residential areas, the total number of vehicle related deaths would drop to 39.4 (62% from Wellington city).

The Künzli study was prepared for a World Health Organisation conference. In 2001 the WHO produced a similar piece of work, using the "Künzli" method, for eight major Italian cities. This study took a more conservative approach to the relative risk factor since the "latency time and length of the exposure period necessary to generate the observed effects are unclear"[18]. Therefore, the WHO utilised a relative risk 'RR' figure of 1.026 instead of 1.043, based on the same meta-analysis that Künzli performed.

When the 'RR' value of 1.026 is used in the Wellington Regional analysis the vehicle related deaths drops to 29.2. If this affect is combined with the possible lowering of the PM_{10} exposure levels in Wellington city the result becomes 24.1 deaths

Table 1 Estimates of deaths (over 29 year olds) per annum:

Threshold = 7.5 $\mu g\ m^{-3}$

	Due to TOTAL PM_{10}			***Due to VEHICLE RELATED PM_{10}***		
	Estimate	***95% CI***		***Estimate***	***95% CI***	
Low exposure year	83	51	116	39	29	54
Best estimate	**101**	**62**	**142**	**48***	**24**	**66**
High exposure year	122	75	170	57	35	79

47.6

[18] World Health Organisation (2001) p18

Table 2 NIWA estimates of deaths (over 29) per annum due to PM_{10} emissions[19]

Threshold = 7.5 $\mu g\ m^{-3}$

	Due to TOTAL PM_{10}			***Due to VEHICLE RELATED PM_{10}***		
	Estimate	***95% CI***		***Estimate***	***95% CI***	
Low exposure year	69	42	98	23	14	33
Best estimate	**79**	**48**	**112**	**56**	**34**	**80**
High exposure year	102	62	145	56	34	80

4.2 Infant Mortality

With a smaller population and lower base mortality rate the numbers of infant deaths for the region due to vehicle air pollution is significantly lower than for over 29 year olds, see Table 3.

It is estimated that 0.5 infant deaths occur each year due to vehicle related air pollution (assumed Wellington PM_{10} of 19$\mu g\ m^{-3}$).

Utilising the more conservative WHO Italian relative risk ‘RR’ value the number of infant deaths drops to 0.3 per annum.

Table 3 Estimates of deaths (under 1 year olds) per annum:

Threshold = 7.5 $\mu g\ m^{-3}$

	Due to TOTAL PM_{10}			***Due to VEHICLE RELATED PM_{10}***		
	Estimate	***95% CI***		***Estimate***	***95% CI***	
Low exposure year	0.9	0.6	1.3	0.4	0.3	0.7
Best estimate	**1.1**	**0.7**	**1.5**	**0.5**	**0.3**	**0.6**
High exposure year	1.3	0.8	1.9	0.6	0.4	0.9

[19] Fisher et al. (2002) p68

5. Mortality Significance

5.1 Evaluation of the NIWA Method

The NIWA study results suggested that 'each traffic accident death in this age range *[30-85]* has twice the impact on public health of the non-external deaths that include the "traffic air pollution deaths"'[20]. Thus, when comparing deaths by pollution and the road toll the NIWA report suggests reducing the pollution mortality by half.

However, the NIWA study compared the average years lost by traffic accident and all other deaths. Years lost were computed by subtracting the age at death from 85, an assumed "maximum" age[21]. However, the current life expectancy of males is 76 years and for females it is 81 years[22]. A years of life lost analysis was re-run using the 2001 male/female age at death statistics and employing life expectancies as the maximum age as suggested by Künzli[23].

As stated previously the mortality effect of air pollutants manifests itself primarily as a proportion of respiratory, cancer and heart related deaths. However, the NIWA study's analysis involves "all deaths other than external causes" to represent the deaths due to air pollution. Since, the age profile of respiratory and heart disease deaths are especially centred towards the older generations the recreated analysis utilised data of the individual death causes between 1994 and 1998[24].

The Künzli report utilised the population 29 years and over in its calculation. Nevertheless, since the air pollution deaths under 29 are minimal this calculated mortality is effectively the result for the entire population. However, when analysing the years of life lost NIWA restricted the population age to 30 and greater for both air pollution and road toll deaths[25].

Since the age at death for traffic accidents is skewed towards the younger members of society the exclusion of under 30's in the "years of life lost" calculation does not adequately illustrate the difference between the road toll and air pollution deaths.

Taking the above into account a revised "years of life lost" calculation was conducted for the complete traffic accident death profile and for both the over 29 and under 1 deaths due to air pollution.

5.2 Calculated Road Toll Equivalent

The above age at death analysis found that the average 'years of life lost' for traffic accident victims was 41.9 years, when all ages were considered.

The combined respiratory/cancer/heart 'years of life lost' was found to have an average value of 6.2 years. In addition, when considering the variation between the respiratory,

[20] Fisher et al. (2002) p10, 33
[21] Fisher et al. (2002) p10
[22] Electronic Resource: Statistics New Zealand: Demographic Trends 2002 (05/05/03)
[23] Künzli et al. (1999) p41
[24] Eletronic Resource: University of Otago, Injury Prevention Research Unit (05/05/03)
[25] Fisher et al. (2002) p10-11

cancer and heart age profiles the'years of life lost' value could conceivably be lower if the proportion of pollution deaths was skewed towards respiratory causes, as one might expect.

Infant deaths were assumed to represent an average 78.1 'years of life lost'.

By weighting the combined respiratory/cancer/heart and infant 'years of life lost' with the calculated vehicle related air pollution deaths in both age groups the overall mean years lost were 7.0 per death.

A discount figure of 6.01, a significantly larger discount than the NIWA study, was created by dividing the traffic accident 'years of life lost' by the equivalent value for vehicle air pollution deaths. The total number of pollution deaths was divided by this figure to give the road toll equivalent of 8 deaths per annum.

6. Results

The revised Wellington Regional estimate, based on 2001 data, of vehicle related air pollution deaths is 48.1 including infant mortality.

Once the estimated mortality is adjusted to reflect a road toll equivalence the figure becomes 8 deaths per annum.

However, when the WHO's more conservative relative risk 'RR' factor is employed the total vehicle related air pollution deaths becomes 29.5 with a road toll equivalence of 5 per annum.

The Wellington Region road toll for 2001 was 30 deaths[26].

Table 3 Summary Results; Künzli relative risk 'RR' factor of 1.043

		Annual Figures
Vehicle Related Air Pollution Deaths (2001 Estimate)	Adult Mortality	47.6
	Infant Mortality	0.5
	Total Mortality	48.1
	Road Toll Equivalent Deaths (after using discount rate)	**8**
Road Toll (2001)		**30**

Table 4 Summary Results; WHO relative risk 'RR' factor of 1.026

		Annual Figures
Vehicle Related Air Pollution Deaths (2001 Estimate)	Adult Mortality	29.2
	Infant Mortality	0.3
	Total Mortality	29.5
	Road Toll Equivalent Deaths (after using discount rate)	**5**
Road Toll (2001)		**30**

[26] Land Transport Safety Authority (2002)

7. Discussion

The 2002 NIWA report suggests that 79 people in the Wellington Region, died from air pollution effects, with 56 of these deaths attributed to vehicle emissions. Thus, the picture was painted that on-road transport was responsible for the majority of air pollution deaths.

With the revised Wellington Regional calculation 101 people over 29 were estimated to die from the affects of air pollution, 48 from vehicle's contribution. Hence, the significance of the transport role in air pollution deaths is greatly reduced.

The modifications to the monitored ambient PM_{10}, population and base mortality values, as discussed in section 2.2, are responsible for the variation between the two 'total air pollution deaths' figures. These changes, coupled with the updated percentage of air pollution from vehicles, generated the lower value for vehicle related deaths.

However, the prevalent adjustment relates to the discount figure that jumps from 2 in the NIWA study to 6.01, see section 5, which greatly reduces the equivalence with the road toll.

The combined adult and infant estimated mortality from vehicle air pollution, after adjustment for its unique age profile, is equivalent to a road toll of 8. This is significantly lower than the adult only figure reported by NIWA of 28. Therefore, the comparison with the actual road toll (30 deaths in 2001) no longer indicates a particularly close similarity.

The original Künzli study was conducted for Austria, France and Switzerland; three countries one does not necessarily associate with highly polluted air. Yet, 74.4% of the Austrian population, 62.6% of French and 61.3 of the Swiss were assessed to have average PM_{10} exposures above 20 $\mu g\ m^{-3}$ [27]. Wellington city had an average measurement at it's sole, high intensity, location of 19 $\mu g\ m^{-3}$. Naturally, the air pollution mortality per capita in these countries is higher than for New Zealand.

Comparison of the Wellington Region with Auckland and Christchurch is also favourable. The annual average PM_{10} measurements, as reported by NIWA, are 29 $\mu g\ m^{-3}$ for Auckland central and 31 $\mu g\ m^{-3}$ for central Christchurch[28].

Therefore, the Wellington Region has relatively clean ambient conditions and thus suffers from fewer air pollution deaths per capita than its counterparts.

[27] Künzli et al. (2000)
[28] Fisher et al. (2002) p58

8. Conclusion

The mortality impact of the road toll (30 deaths in 2001) in the Wellington Region is still appreciably more than the equivalent experienced from vehicle related air pollution deaths (8 estimated for 2001). However, as with the NIWA study, the calculation incorporates several assumptions and as such can only be considered an approximate indicator of the vehicle air pollution mortality.

Further ambient air quality monitoring, especially of PM_{10}, to gauge both temporal and spatial variations would assist future re-evaluations of these calculations. Thus, improving the accuracy in particular by clarifying the exposure profile in Wellington city.

This study signals a possible reduction in urgency and a lowering of priority for ‘vehicle related air pollution deaths’, compared to the actual road toll, in the Wellington Region. However, this should not be employed to negate cost-effective efforts to reduce the impact of transport on public health, since maintaining a relatively low death rate in the future would be desirable.

9. References

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University of Otago, Injury Prevention Research Unit (05/05/03)

http://www.otago.ac.nz/ipru/Stats/LC10FNZ2.html

Appendix A

Calculation methodology from the Künzli et al.[29] study

Step 1: Calculate the mortality rate that would have occurred if the pollution exposure level had been less than or equal to the assumed threshold.

$$Pb = \frac{Pa}{1 + [(RR - 1)(E - B)/10]}$$

Where
Pb = Calculated baseline mortality in the population after removing the impact of air pollution
Pa = Actual mortality rate in the population
RR = Epidemiologically derived relative risk of mortality for each 10 μg m^{-3} increment of PM10 over the assumed threshold (B)
B = Baseline exposure threshold level of 7.5 μg m^{-3} PM_{10}
E = Observed average PM_{10} exposure

Step 2: Calculate air pollution mortality rate

$$D_{10} = Pb * (RR - 1)$$

Where
D_{10} = Number of deaths per 1000 people for a 10 μg m^{-3} increase in PM_{10}

Step 3: Calculate the number of deaths

$$N_c = D_{10} * P * (E - B)/10$$

Where
Nc = Number of deaths due to PM_{10}
P = Population/1000

[29] Künzli et al. (1999)

Appendix B

Revised Calculation Data for Wellington Region:

	Population >29 years old[30]	Assumed Annual Average Ambient PM10			% PM10 from Vehicles[31]
		Average[32]	Low Exposure Year[33]	High Exposure Year[34]	
Wellington	**91041**	**19**	17	21	**63%**
Lower Hutt	**53529**	**13**	12	14	**20%**
Porirua	**24261**	**15**	14	17	**64%**
Upper Hutt	**20832**	**14**	11	17	**57%**
Kapiti	**28104**	**15**	14	17	**9%**
Masterton	**13569**	**16**	15	17	***20%**
Greytown / South Wairarapa	**9816**	**12**	10	14	***15%**

* Assumed based on NIWA Study[35]

[30] Electronic Resource: Statistics New Zealand: 2001 Census Regional Summary (05/05/03)
[31] Air and Environmental Sciences (2001)
[32] Assumed based on Greater Wellington Monitoring data
[33] Based on Fisher et al. (2002) p58
[34] Based on Fisher et al. (2002) p58
[35] Fisher et al. (2002) p17