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Rātonga Hauora ā Iwi o Tamaki Makaurau
Working with the people of Auckland, Counties Manukau and Waitemata

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21st August 2009

Rapunzel Mulawin
Ministry for the Environment,
PO Box 10-362,
Wellington, 6143

The Review of National Environmental Standards for Air Quality: Request for Submission

1. Thank you for the opportunity for the Auckland Regional Public Health Service (ARPHS) to provide a submission to the Review of National Environmental Standards for Air Quality: Request for Submission.

2. The following submission represents the views of the Auckland Regional Public Health Service and does not necessarily reflect the views of the three District Health Boards. Please refer to Appendix 1 for more information on ARPHS.

3. ARPHS understands that all submissions will be available under the Official Information Act 1982, except if grounds set out under the Act apply.

4. The primary contact point for this submission is:

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1.0 EXECUTIVE SUMMARY AND KEY RECOMMENDATIONS

5. ARPHS is appreciative of the opportunity to provide information to support the objectives of the review of the Resource Management (National Environmental Standards Relating to Certain Air Pollutants, Dioxins, and other Toxics) Regulations 2004 (the Air Quality Regulations).

6. ARPHS does not support any reduction in the standards permissible for PM_{10} particulates due to the consequential increased damage to population health.

7. ARPHS believes that currently available evidence around the health costs of air pollution is likely to substantially underestimate the costs to the economy and individuals (both short and long term).

8. In the Auckland region the main sources of air pollution are transport and domestic fires (in the winter). Industry also contributes a significant proportion of total air pollution in the region.

9. Increasing population (density and numbers) mean that air pollution from transport, fires, domestic heating and cooking and industry is likely to increase. It is not appropriate to permit an increase in industrial emissions until there is clear evidence that emissions from other major polluting sectors have declined.

10. ARPHS believes that there are ‘whole of government’ policy opportunities which should be utilised to both improve air quality in the Auckland region and to enable the ‘blanket’ ban on new consents contained in Regulation 19 from 2013 to be relaxed.

11. Initiatives directed at domestic heating and transport sourced air pollution have the potential to improve air quality, stimulate the economy and deliver benefits for health.

12. The decline in air pollution from non industrial sources must be greater than the increase allowed for industry if overall air quality is to improve.

13. It is not appropriate for people living and working in industrial areas to be exposed to greater levels of PM_{10} as a result of increasing industrial pollution and the review needs to give adequate attention to ensure that the issues affecting such populations are fully understood and resolved.

2.0 AIR QUALITY IMPACTS ON PUBLIC HEALTH

14. The Auckland region is home to over 1,371,000 people and is projected to be home to nearly 2 million people by 2031[1]. The urban part of the region contains the country’s largest concentration of people and is “also the engine for the country’s economic growth”[2].

15. Every Aucklander breathes in an average 11,000 litres of air everyday. Auckland's air quality is relatively good but, despite this, pollution is seriously affecting the health of substantial numbers of individuals in the region.

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[1] Statistics New Zealand http://wdmzpub01.stats.govt.nz/wds/TableViewer/tableView.aspx

[2] Making Auckland Greater
http://www.auckland.govt.nz/web/cms_rcauckland.nsf/vwluResources/making_ak_greater_report_v1/$file/Making%20Ak%20Greater%20final%20WEB_v2.pdf

16. In Auckland, air pollution has been estimated to cause:

- 436 premature deaths due to air pollution per year, with 58% of these (253) are due to motor vehicle emissions[3]
- 368,000 restricted activity days lost region wide due to illness or poor health[4]

The Auckland region has one of the highest asthma rates in the world, with:

- 12% to 23% of adults are asthmatic
- 25% of children are asthmatic

Asthma is the fourth highest cause of hospitalisation in the region and in the period 2002 – 2006 there were:

- 9059 admissions of children aged 0 – 14yrs, and
- 1825 admissions of young people 15-24 years to hospital[5]

By way of example for the Auckland District Health Board in 2004 diseases of the respiratory system caused 8% of deaths and accounted for 4% of bed days[6].

Health and Air Pollution in New Zealand

17. The leading study on the effects of air pollution is the Health and Air Pollution in New Zealand (HAPiNZ) study[7]. This study was designed to explicitly identify the effects of air pollution throughout New Zealand, to link these effects to the various sources of air pollution, and to provide information that will help to formulate effective policy options that lead to real and measurable improvements in the health of New Zealanders.

18. To summarise the conclusions of the HAPiNZ study; a large number of epidemiological studies carried out worldwide have shown associations between ambient air pollution levels and adverse health effects, including increased mortality. The short-term mortality increase in relation to daily levels of particulate matter (PM10 or PM2.5) is approximately 0.5−1% increase per 10 µg/m3 PM10 increase. A variety of statistical methods have been used, and they all come to similar conclusions. The epidemiological analysis demonstrates that the mortality effect of high air pollution lasts longer than the first day of exposure. The resulting long-term mortality increase associated with long-term exposure is substantially higher than the short-term increase. Recent advanced statistical analysis indicates that the mortality increase per 10 µg/m3 PM10 may be as high as 5–10%.

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[3] ARC http://www.arc.govt.nz/environment/air-quality/aucklands-air-quality/aucklands-air-quality_home.cfm and HAPiNZ Study http://www.hapinz.org.nz/

[4] Kuschel G & Macmillan A (2009) *2010 RLTS WP20 Environmental Sustainability and Public Health Policies,* ARC accessible through http://www.arc.govt.nz/albany/fms/main/Documents/Transport/RLTS/RLTS%202010WP20%20Environmental%20sustainability%20and%20public%20health%20policies.pdf **N.B.** this estimate is for vehicle related pollution, not all pollution.

[5] Craig E, Jackson C & Han DY (2007) *The Health of Children and Young People in the Auckland Region,* Paediatric Society of New Zealand.

[6] ADHB Health Needs Assessment http://www.adhb.govt.nz/healthneeds/

[7] Accessible through http://www.hapinz.org.nz/

Child health

19. Air quality scientists, however, believe that the information and figures quoted in the HAPiNZ study are highly conservative, for example: it only includes adults over 30 years, does not include young children who are the most vulnerable group, does not include the entire population (73% only) and employs an outdated and overly conservative dose-response relationship.

20. ARPHS has recently undertaken an extensive literature review as part of an inter-sectoral working group with the Ministry of Education, Ministry for the Environment, Ministry of Health, NIWA, ARC and University of Auckland on air quality issues affecting children. Appendix 2 presents further information on the health consequences for children from air pollution summarised from this investigation.

21. Internationally, there is growing concerns that the impacts of air pollution on children are significantly greater than was previously thought to be the case.

Health consequences from PM_{10} particulates

22. The current review focuses solely on PM_{10} particulates. The health consequences from PM_{10}s relate to two elements:

- The small size of the particulates that allow deep penetration into the respiratory system, and
- The nature of some of the particulates which may bring additional health consequences, e.g. PM_{10} particulates derived from sea salt may have less adverse health consequences than PM_{10} particulates derived from combustion products.

23. Ill health caused by air pollution may be due to PM_{10} particulates, it may also be due to other pollutants. The impact of air pollution may also be dependent on whether or not an individual suffers from some underlying health issue that makes them more vulnerable to air pollution.

24. Further research would be needed to better identify the actual costs of poor health resulting solely from PM_{10} particulates for the Auckland region.

Future Health Issues

25. ARPHS has recently commissioned a research project to identify the health consequences of climate change on the Auckland region. Climate projections indicate that the incidence of heat waves will increase. A likely consequence of this is that urban air pollution concentrations will increase during heat waves with significant consequences for mortality. This is because high temperatures and solar radiation stimulate the production of photochemical smog as well as ozone precursor biogenic volatile organic compounds[8].

[8] Lyne M (2009) *The Impact Of Climate Change On Population Health In The Auckland Region.* Auckland Regional Public Health Service

26. Heat waves resulting from climate change should not be viewed as an issue for some distant time in the future. This February Auckland experienced its hottest day since records began and it is likely that more frequent and longer duration heat waves will occur in the near future.

3.0 ECONOMIC COSTS OF AIR POLLUTION

27. Measures to reduce air pollution and its effect on public health have costs. Effective management and policy therefore needs detailed information on exactly what air pollution occurs and what effects it has. Set out below is a high level summary of the economic conclusions of the HAPiNZ study.

28. The costs of air pollution effects can be estimated using the new statistics from the study, previous research in New Zealand, and results from overseas studies adjusted for New Zealand conditions. The summary below lists specific health effects, and their cost per case. These are not personal costs, but costs to the New Zealand health system and economy – the external costs of air pollution.

29. Estimated costs of specific health effects used in the HAPiNZ analysis:

- Effect Cost per case
  - Mortality $750,000
  - Cancer $750,000
  - Chronic bronchitis $75,000
  - Admission (cardiovascular) $3,675
  - Admission (respiratory) $2,700
  - Restricted-activity day $92

30. The total costs of health effects of air pollution can be estimated from the health effects and the cost per case of those effects. By far the largest component of the 'economic health burden' is the loss of life-years as a result of premature mortality, followed by restricted-activity days and then chronic bronchitis.

31. When considered across the study areas, these amount to the following costs per person per year:

- total effects: $421 per person per year
- effects associated with domestic emissions: $186 per person per year
- effects associated with vehicle emissions: $165 per person per year
- effects associated with industrial emissions: $70 per person per year.

32. The HAPiNZ study estimates total cost of air pollution in New Zealand as being in the order of at least $1.139 billion per year, based on 2001 statistics.

33. The recently released Genuine Progress Indicator for the Auckland region estimates the total cost of air pollution at $2.976 billion for the period 1990-2006[9], with annual costs as set out on the graph below.

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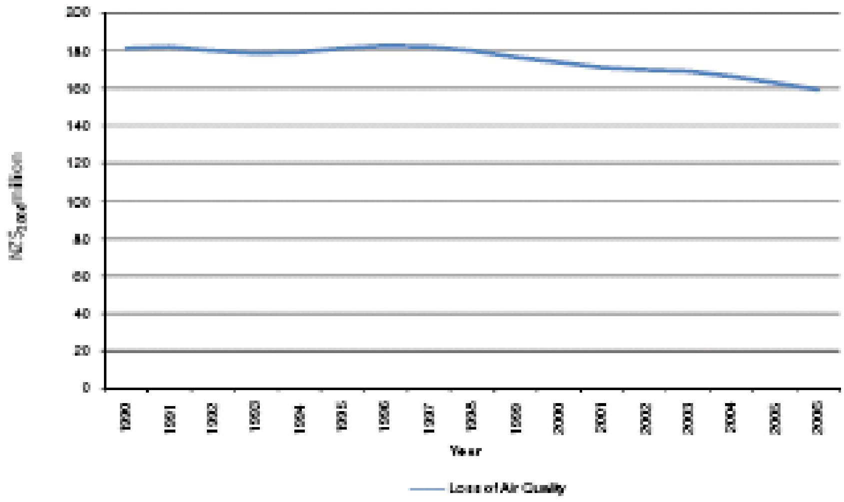
[9] McDonald G, Forgie V, Zhang Y, Andrew R & Smith N (2009) *A Genuine Progress Indicator for the Auckland Region – Summary Report* Market Economics, ARC NZCEE http://www.arc.govt.nz/albany/fms/main/Documents/Auckland/Population%20and%20stats/GPI%20summary%20report.pdf Figures expressed in 2006 dollars.



34. The recently completed Auckland Regional Land Transport Strategy Health and Wellbeing Impact Assessment Appraisal Report[10] estimates the cost of vehicle air pollution health events in 2006 as being at least $251M (the calculation does not include all potential costs due to data gaps). As transport sourced air pollution only accounts for a proportion of all air pollution the actual cost would be considerably higher.

35. The economic costs for the Auckland region from air pollution are uncertain. ARPHS believes that there is a need for further research to fully identify the health costs (both social and economic) from ill health caused by PM_{10} particulates and to better understand the range of confounding factors that may be contributing to ill health.

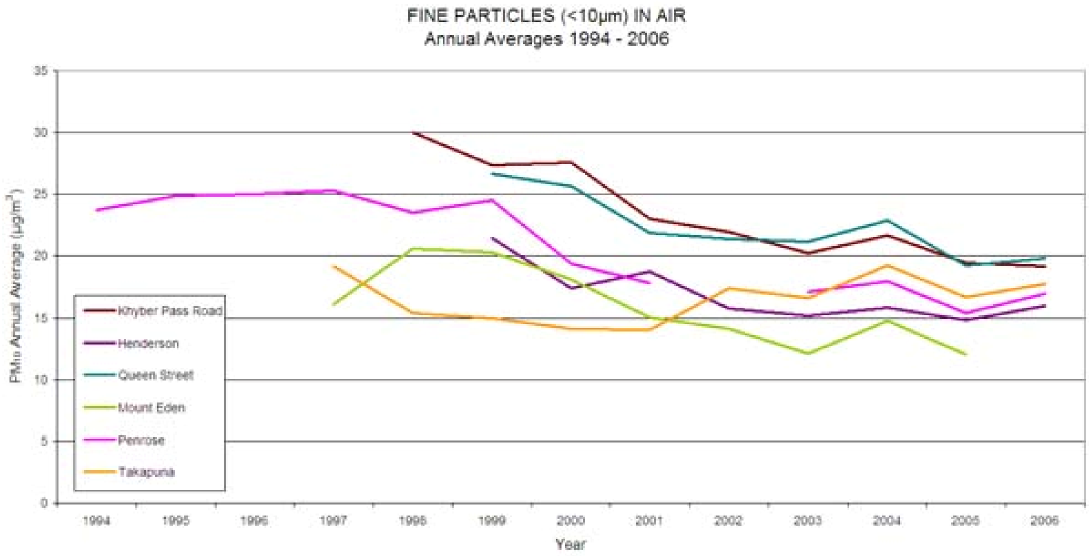
36. In the absence of this research the HAPiNZ study, while providing the best assessment of health impacts and costs from air pollution should be viewed as an under estimate.

4.0 TRENDS IN AIR QUALITY IN THE AUCKLAND REGION: AUCKLAND AIRSHED

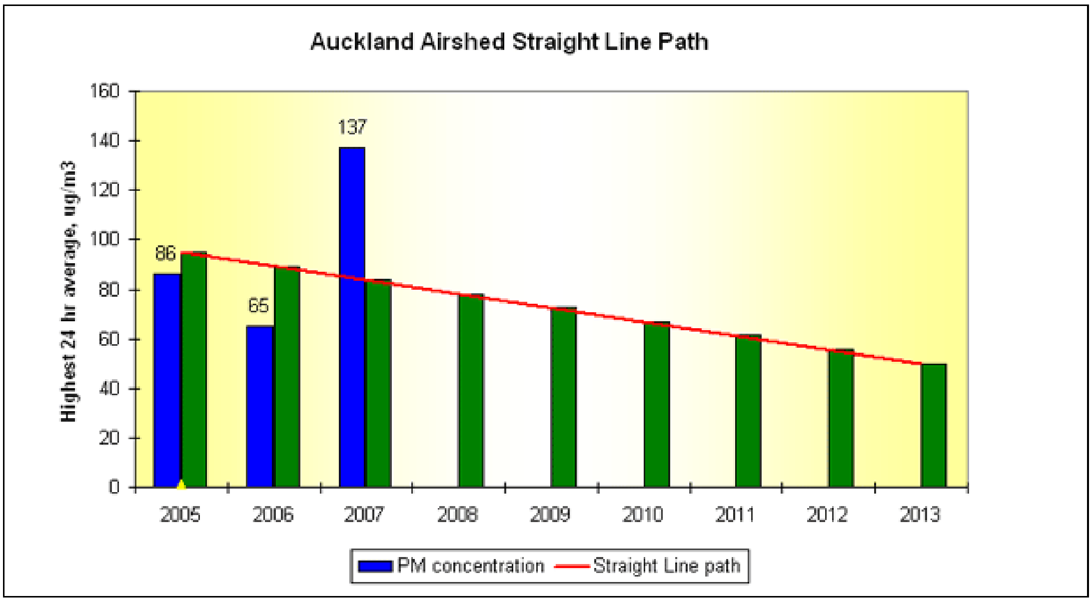
37. Air quality in the Auckland airshed is not improving[11]. PM_{10} concentrations have decreased over recent years (with the exception of the Takapuna monitoring site) but have now levelled off.

[10] Awaiting publication

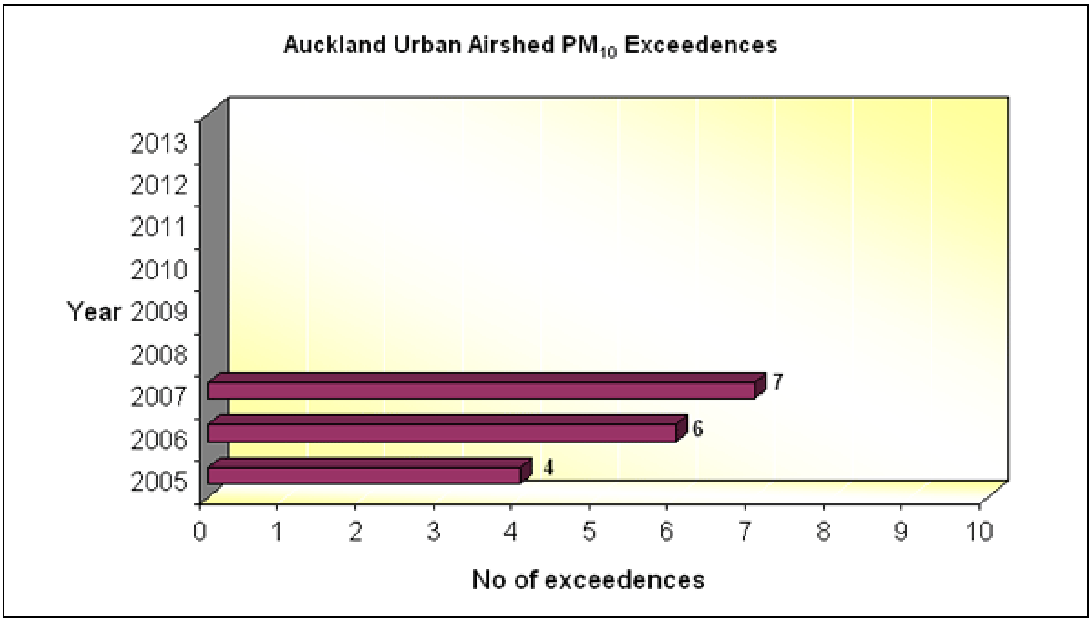
[11] See ARC State of the Region's Air Quality 2007
http://www.arc.govt.nz/albany/fms/main/Documents/Environment/Pollution/airfacts4.pdf



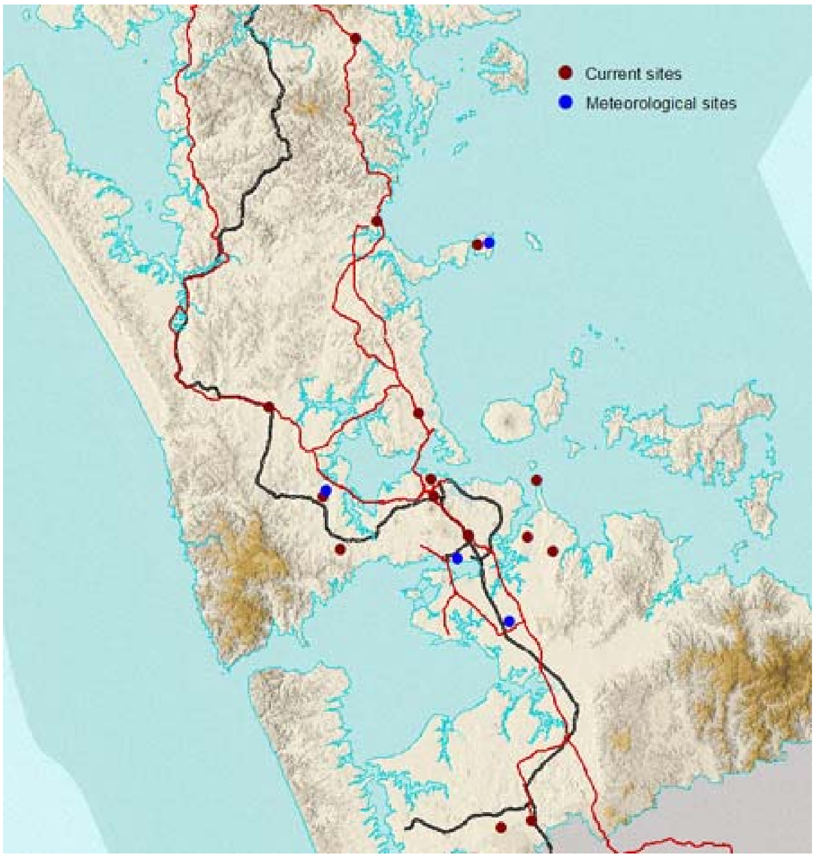
38. Recent data suggests that air pollution is moving further above the 'straight line' path and that the number of annual exceedences continues to rise[12].



[12] MFE State of the Environment Report accessible through
http://www.mfe.govt.nz/state/reporting/air/nes/auckland/auckland.html



39. Air quality monitoring across the Auckland airshed is based on a relatively small number of sites[13].

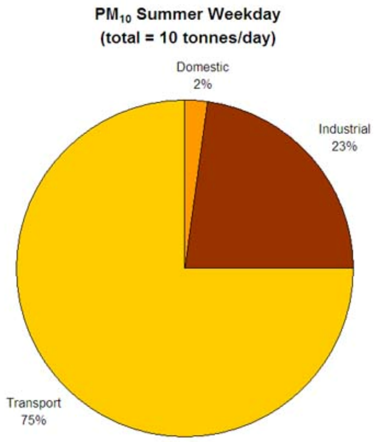


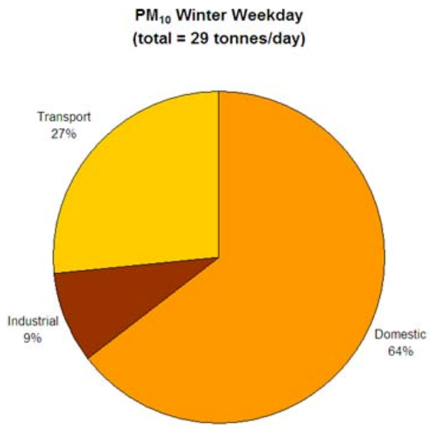
[13] Accessible through http://www.arc.govt.nz/environment/air-quality/monitoring-and-research/monitoring-and-research.cfm#Auckland's%20air%20quality%20monitoring%20network

40. Assessments of pollution levels based on a limited sampling pattern cannot be viewed as providing the most accurate evidence of overall air quality in the airshed. This means that the proportion of air pollution identified as due to industry in the charts above may be underestimated as a number of the air quality monitoring sites are in areas relatively remote from concentrations of industry.

5.0 CAUSES OF AIR POLLUTION IN THE AUCKLAND AIRSHED

41. Routine monitoring of air quality in the Auckland airshed is undertaken by the Auckland Regional Council (ARC). This work[14] indicates that air pollution in Auckland has the following sources:





42. The ARC analysis suggests that industrial air pollution is one of the smaller contributors to overall air quality. It is, however, the only source of air pollution that is subject to regulatory control through the Air Quality Regulations.

6.0 REGULATION REVIEW

43. The purpose of the Resource Management Act 1991 ("RMA") is to promote sustainable management, by "managing the use, development and protection of natural and physical resources in a way … which enables people and communities to provide for their social, economic, cultural wellbeing and for their health and safety[15] while …safeguarding the life supporting capacity of air …"(Section 5(2))

44. Increasing population (density and numbers) mean that air pollution from transport, fires, domestic heating and cooking and industry is likely to increase. It is not appropriate to permit an increase in industrial emissions until there is clear evidence that emissions from other major polluting sectors have declined.

45. ARPHS believes that the objective of air quality regulation in the Auckland region should be to provide a 'sinking lid' on the overall level of air pollution.

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[14] Accessible through http://www.arc.govt.nz/albany/index.cfm?6901EAA9-14C2-3D2D-B939-BF1991A4D1E7
[15] Emphasis added.

46. ARPHS sympathises with concerns around where the cost of compliance currently falls. Economic development as it translates into living standards is one of the determinants of health. In general people with higher living standards enjoy better health than those people suffering high socio-economic deprivation.

47. Rather than reduce the regulatory standard or defer the 2013 date when Regulation 19 comes into force it would be better to take stronger action around the other causes of air pollution. Such an approach could provide for the issuing of additional industrial air pollution resource consents, with the proviso that the decline in air pollution from non industrial sources was greater than any increase allowed from industry.

48. Such an approach would support public health aims and also economic development. Any additional emission consents should still be subject to normal consenting processes to ensure that more localised issues arising from work and domestic exposure to industrial air pollution were considered and resolved.

49. To adopt this approach however, would require that the largest causes of air pollution received far greater attention. Addressing each in turn ARPHS wishes to make the following comments.

Domestic Air Pollution

50. Wider government strategies such as the Energy Conservation and Efficiency Strategy and recent initiatives such as the 2009 Budget announcement of support for home insulation grants provide an avenue through which air pollution sourced from domestic winter fires can be addressed.

51. It is suggested that rather than relax the air quality regulations to provide more support for economic development, that it would be far better to continue and extend such initiatives as the home insulation grants. As the Energy and Resources Minister stated in the Budget announcement "This scheme is also intended to play an important role in stimulating the economy. It will generate jobs for New Zealanders involved in producing and installing insulation and clean heating"[16].

52. Further initiatives in this area would generate further growth in the economy and at the same time reduce emissions. This would support the objectives of the Air Quality Regulations review as announced by the Minister for the Environment[17] by assisting in ensuring that industry didn't bear a disproportionate share of the costs of air pollution control.

Transport Air Pollution

53. The ARC estimates that in the Auckland region transport generates between 75% (summer) and 27% (winter) of the PM_{10} pollution. The amount of future air pollution produced by the transport sector will be affected by a number of factors[18:]

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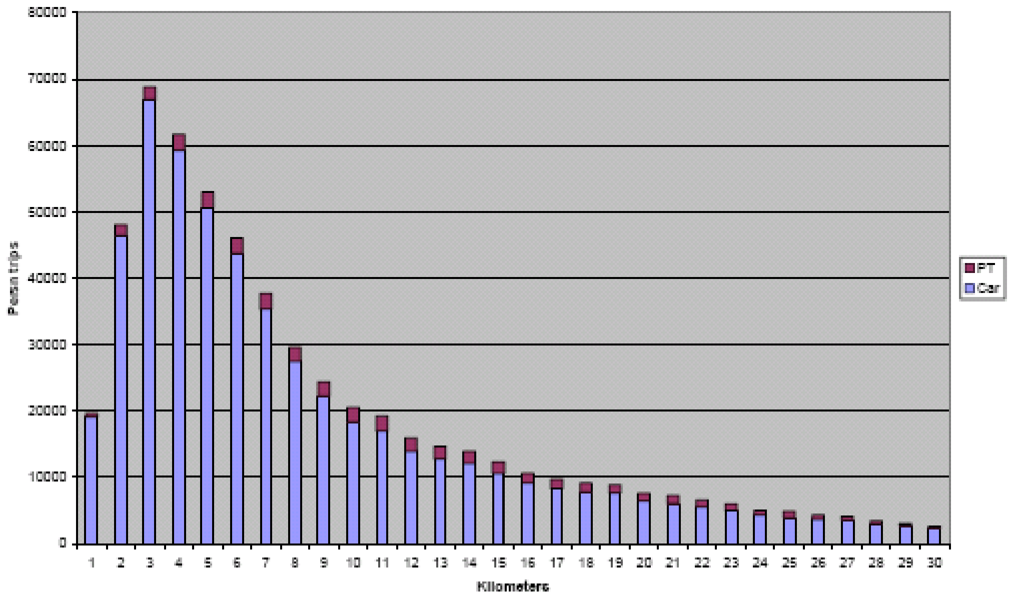
[16] Gerry Brownlea http://www.beehive.govt.nz/release/boost+warmer+drier+healthier+kiwi+homes

[17] Nick Smith http://www.beehive.govt.nz/release/air+quality+standards+be+reviewed

[18] Wong-Toi K (2009) *Trends and Issues (Transport Challenges),* ARC accessible through http://www.arc.govt.nz/albany/fms/main/Documents/Transport/RLTS/RLTS2010WP08%20Trends%20and%20Issues%20(Transport%20Challenges).pdf

- Population growth to 2 million persons (effectively the addition of the population of Christchurch to the Auckland region) driving a consequential increase in the vehicle fleet (albeit that the growth in vehicles per capita is slowing)
- An increasing proportion of diesel vehicles (both commercial and light diesel) in the fleet (diesels disproportionately contribute to PM_{10} levels)
- Increasing annual vehicle kilometres travelled per vehicle
- Increasing age of the vehicle fleet meaning that the benefits of cleaner burning engines from more modern vehicles will take longer to affect pollution levels

54. The net consequence of these factors is that the contribution to air pollution from transport sources seems unlikely to decrease. This need not be the case; active transport provides alternative options for many journeys. The chart below (from the ARC Trends and Issues (Transport Challenges) paper provides evidence of the average vehicle based journey distance in the morning peak traffic period.



55. The average trip length for urban areas is 6.7 km. Changing the mode (from private vehicles) used for such short journeys to active transport (passenger transport, walking and cycling) would deliver substantial benefits around:

- Reduced levels of PM_{10}s air pollution
- Increased economic development through the reduction in congestion

There would also be collateral benefits from:

- Reduced greenhouse gas emissions contributing to climate change
- Reduced requirements to import oil
- Improved social connection between residents
- Reduced incidence of non communicable disease such as obesity, type 2 diabetes and cardiovascular disease (from increased physical activity)
- Reduced incidence of respiratory disease

56. To better quantify the health benefits, a small 5% shift from cars to cycles (back to 1980s levels) has been estimated as delivering 116 fewer deaths due to increased physical activity, 6 fewer deaths due to air pollution and a net health benefit of $193 Million[19].

57. A recent study commissioned by the New Zealand Transport Agency[20] values the health benefits per person of active transport as:

Scenario	Annual benefit	Per km walking	Per km cycling	Per km skateboarding	Per km roller skating
Low	$3,112	$3.53	$1.77	$2.37	$3.53
Medium	$3,765	$4.27	$2.14	$2.86	$4.27
High	$4,417	$5.01	$2.51	$3.36	$5.01

The study concludes that these figures provide a "robust reflection of potential health benefits that can be achieved through transport projects that increase participation in active modes" and favours the adoption of the medium value for use in project evaluation.

58. There is likely to be a disproportionately large impact on traffic sourced air pollution (and associated respiratory illness) than the reduction in vehicle kilometres travelled suggests. Most of these shorter journeys are likely to be undertaken by vehicles with cold engines and there is evidence that cold engines produce far higher emissions than engines that have reached full operating temperature[21].

59. The recently released Government Policy Statement on Transport with its increased emphasis on the provision of road capacity to "reduce congestion, improve safety and support economic growth"[22] can be expected to further amplify the air quality impacts from transport through the investment in road capacity it will support.

60. The transport system dynamics of an urban area such as Auckland mean that any increased road capacity will largely be absorbed by the release of latent congestion leading to additional air pollution (see Appendix 3 for further details).

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[19] NZ Centre for Sustainable Cities - Four Cities in One Day: Travel and Urban Form Workshop Presentation http://sustainablecities.org.nz/wp-content/uploads/a-microsoft-powerpoint-a-woodward-changing-modes-handout.pdf N.B. the analysis also projected an additional 5 cycling fatalities.

[20] Centre JA, Donovan S, Petrenas B & Badland H (2008) *Valuing the Health Benefits of Active Transport Modes,* NZ Transport Agency Research Report 359, accessible through http://www.ltsa.govt.nz/research/reports/359.pdf

[21] Fisher G, Kjellstrom T, Kingham S, Hales S, Shrestha R, et al. Health and Air Pollution in New Zealand. A Research Project Funded by: Health Research Council of New Zealand for the Ministry for the Environment and Ministry of Transport. June 2007, accessible through http://www.hapinz.org.nz/

[22] Steven Joyce announcement of routes of national significance http://www.beehive.govt.nz/release/first+roads+national+significance+identified

61. In conclusion unless transport policy settings, vehicle fleet composition and travel behaviour changes it seems probable that the level of PM_{10} particulates from transport will increase.

Air Pollution Equity Issues

62. For many health issues there is a strong correlation between socio-economic deprivation and health. Air quality has also been demonstrated to exhibit elements of this correlation[23]. The authors of this study (Pearce & Kingham) went on to suggest that a simple regional 'bottom line' approach may no longer be adequate.

63. ARPHS shares their concerns that the current region wide based approach mandated by the air quality regulations may not deliver the optimum outcome for either health or the economy when a regional average may mask geographic areas of both acceptable and unacceptable air quality where a different regulatory standard could be imposed.

7.0 CONCLUSION

64. ARPHS believes that further reductions in PM_{10} levels are desirable to improve public health both at the 'airshed' level and at the more localised area level, due to the consequences for the health of individuals and the costs that decreased health status imposes on individuals, the community, industry the health budget and consequently on the national economy.

65. Rather than reduce the regulatory standard or defer the 2013 date when Regulation 19 comes into force it would be better to take stronger action around all causes of air pollution.

66. The more comprehensive use of policy settings and programmes at the whole of government level would allow the Minister's concerns around the impact of PM_{10} limits on industry to be addressed.

Yours sincerely

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Auckland Regional Public Health Service

Dr Denise Barnfather
Medical Officer of Health
Auckland Regional Public Health Service

[23] Pearce J, Kingham S (2007) *Environmental inequalities in New Zealand: A national study of air pollution and environmental justice,* Geoforum 39 (2008) 980-993

APPENDIX 1 - AUCKLAND REGIONAL PUBLIC HEALTH SERVICE

Auckland Regional Public Health Service (ARPHS) provides public health services for the three district health boards (DHBs) in the Auckland region (Auckland, Counties Manukau and Waitemata District Health Boards), with the primary governance mechanism for the Service resting with Auckland District Health Board.

ARPHS has a statutory obligation under the New Zealand Public Health and Disability Act 2000 to improve, promote and protect the health of people and communities in the Auckland region. The Medical Officer of Health has an enforcement and regulatory role under the Health Act 1956 and other legislative designations to protect the health of the community.

ARPHS' primary role is to improve population health. It actively seeks to influence any initiatives or proposals that may affect population health in the Auckland region to maximise their positive impact and minimise possible negative effects on population health.

The Auckland region faces a number of public health challenges through changing demographics, increasingly diverse communities, increasing incidence of lifestyle-related health conditions such as obesity and type 2 diabetes, outstanding infrastructure needs, the balancing of transport needs, and the reconciliation of urban design and urban intensification issues.

APPENDIX 2 Health Effects of Air Pollution on Children

HEALTH EFFECTS OF AIR POLLUTION

Evidence accumulated over the last 25 years confirms that long-term exposure to outdoor air pollution is an important contributor to morbidity and mortality in adults and in children.[1-6] The *Health and Air Pollution in New Zealand* (HAPiNZ) study estimated that air pollution was responsible for 1,079 cases of premature mortality in adults aged ≥ 30 years in New Zealand in 2001.[7] Of these premature deaths, 500 were thought to be due to vehicle emissions. Nationally in 2001, air pollution caused by vehicle emissions was considered responsible for 541 extra cases of bronchitis and related illnesses, 246 extra hospital admissions for respiratory and cardiac illnesses and 22 cases of cancer. In Auckland City, air pollution was estimated to be responsible for 7.2% of premature deaths.

Comprehensive summaries of literature linking air pollution to child health outcomes are freely available from organisations such as the WHO.[4, 5] In brief, particulate matter (like PM_{10} and $PM_{2.5}$)[24] is responsible for the bulk of adverse health effects from air pollution, although effects are also related to other pollutants like nitrogen oxides, carbon monoxide and carcinogenic volatile organic compounds such as benzene and 1,3-butadiene (which may be carried into the lungs by particulate matter [8, 9]). In adults, exposure to increased concentrations of air pollution through activities such as living near major roads is associated with increased respiratory symptoms and lower life expectancy – due particularly to cardiovascular and respiratory mortality, but also probably due to lung cancer.[4, 10] In children, exposure to increased levels of air pollution is associated with the following conditions:

- **Development of asthma.** While evidence of a relationship between childhood asthma development and ambient air pollution is mixed, there is strong and consistent evidence of an association between air pollution caused by traffic and development of asthma in children.[11-26] In general, studies looking at pollution from vehicle emissions and development of asthma have found around a 30% to 80% increase in the risk of asthma development in children spending large amounts of time (e.g. residing) near busy roads. Links between traffic pollution and asthma development have been stronger in girls than in boys[15, 19-21, 27, 28] and in younger children than in older children.[16, 22, 29-31] The relationship may also be stronger in children without a pre-existing family history of asthma.[16, 18, 32]
- **Exacerbation of asthma.** There is moderate-to-strong evidence in the literature of a causal association between air pollution and asthma exacerbation in children with pre-existing asthma.[5] Several papers have looked specifically at pollution caused by traffic and asthma exacerbation.[25, 33-38] On balance, these studies

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[24] Particulate matter less than 10 and 2.5 microns respectively

support the notion of a causal link between traffic-caused air pollution and asthma aggravation.

- **Lung development.** Development of the respiratory system begins at around 24 days after conception and continues through various distinct periods of development until adulthood.[5, 39] The first 18 months following birth are particularly critical to lung development, as a significant amount of structural change (including substantial alveolar proliferation) occurs during this period.[5, 40] Multiple cross-sectional and longitudinal epidemiological studies have examined the relationship between air pollution and lung function in children.[15, 41-57] These studies have generally demonstrated an association between high levels of pollution and low levels of lung function. Furthermore, while short-term deficits in lung function due to air pollution appear to be reversible [45, 55, 58], long-term exposure to high levels of air pollution may be associated with longstanding lung function deficits that persist into adulthood, although the evidence is currently unclear.[5, 59] A recent review by Gőtschi et al of the long-term effects of air pollution on lung function, published in the journal *Epidemiology,* concluded that:

> *"Support is strong for concluding that there are adverse long-term effects of air pollution on lung function growth in children, resulting in deficits of lung function at the end of adolescence. No study has, however, followed up adolescents until they reach the plateau phase of early adulthood. It therefore is not known whether growth deficits will be compensated by a prolonged growth phase, or whether these subjects will enter the lung function decline phase of later adulthood with reduced lung function"* [59]

The comprehensive review of literature related to air pollution and child health undertaken by the European office of the World Health Organization (WHO) concluded that:

> *"…the studies suggest that the effects [of air pollution] can be cumulative over a 20-year growing period, and there is uncertainty whether the chronic effects are reversible. Furthermore, even a small shift in average lung function can yield a substantial increase in the fraction of children with 'abnormally' low lung function, that is, small changes in the population mean can reflect large changes in a susceptible subgroup of the population (p.124)."* [5]

- **Respiratory infections.** Multiple studies have looked at the relationship between air pollution and respiratory infections in children. The WHO literature review mentioned above examines 71 such studies.[5] The studies reviewed by WHO included a variety of longitudinal and cross-sectional epidemiological studies which looked at both upper and lower respiratory tract infections. Specific infections examined in the studies included bronchitis, pneumonia, colds, sore throats and persistent cough, as well as doctor-diagnosed conditions like croup. The WHO literature review concluded that there was evidence of an association between air pollution and increased frequency of both upper and lower respiratory tract symptoms in children and that many of these symptoms were likely to be associated with respiratory infection. The review also concluded that although the effect estimates were often small, the population attributable risks were often high. In other words, although individual risk of respiratory infection may be only fractionally raised, the effect on the whole exposed population may be large.

- **Cancer.** The question of whether exposure to air pollution causes cancer in children is not yet resolved. Studies suggest that exposure to increased levels of traffic-related air pollution is associated with lung cancer in adults.[4] Volatile organic compounds found in vehicle emissions also include known carcinogens like benzene [60, 61] and there is epidemiological evidence suggesting that proximity to sources of benzene may be related to childhood cancers, in particular leukaemia.[62-67] The WHO literature review found only 15 studies which examined the hypothesis that air pollution may cause childhood cancer and concluded that there was insufficient evidence to infer a causal relationship between the two.[5]

Susceptibility of children to air pollution

Differential susceptibility to air pollution occurs within the general adult population. For example, research suggests that individuals with type two diabetes may be at increased risk of the cardiovascular effects of particulate matter.[68, 69] Children have several characteristics which make them more susceptible than adults to the effects of environmental stressors [70] and particularly to the effects of air pollution.[71]

Lung growth and cellular differentiation begins around 24 days after fertilisation and continues through various distinct periods until adulthood.[5, 39] A substantial amount of respiratory growth and development occurs in the first 18 months of life.[5, 40] Full functionality of the lung occurs at around six years of age.[71] The rapid changes in respiratory structure that occur during early childhood mean that the lung is particularly susceptible to the effects of potentially harmful substances during this time.[71] Children also have a larger lung surface area in comparison to their body weight than adults and (under normal breathing conditions) respire around 50% more air per kilogram of body weight than adults. Furthermore, young children also have incomplete metabolic and immune systems, and higher rates of respiratory infection than adults.[5]

Layered on top of the physiological differences between children and adults are different activity patterns that may increase exposure to air pollutants in children. Compared with adults, children spend considerably more time outside, especially in summer months and in the late afternoon.[72] Much of that time may be spent in vigorous activity related to play and exercise, with associated increases in respiratory rate and inspiratory volume.

Precautionary Principle

The Precautionary Principle is a policy tool which is used to justify measures that protect public health and the environment in the context of uncertain risk.[73] The principle has a long history in public health practice.[74] It acknowledges that environmental risks are often associated with both complexity and uncertainty, and that decisions in health sometimes need to be made before definitive evidence comes to light. As described by Gee in 2006:

> *"The Precautionary Principle provides justification for public policy actions in situations of scientific complexity, uncertainty and ignorance, where there may be a need to act in order to avoid, or reduce, potentially serious or irreversible threats to health or the environment, using an appropriate level of scientific evidence, and taking into account the likely pros and cons of action and inaction"*[75]

The Precautionary Principle has particular relevance to child health. Traditional approaches to risk assessment frequently fail to account for the extent of childhood susceptibility to environmental risks and children's unique patterns of exposure to environmental toxins.[74] Environmental stressors often affect children differently at different developmental stages and the impact of these stressors at each stage is often poorly understood in comparison with effects in adults.[73, 74] Furthermore, health impacts from environmental exposures are often characterised by delay between exposure and outcome. With more potential years of life than most adults, children also have more time to develop chronic diseases that may be triggered by early exposure.[73, 74]

It is important to take the Precautionary Principle into account when considering the potential impact of increased exposure to air pollution on child health.

7.1 TRAFFIC-RELATED POLLUTION AND PROXIMITY TO BUSY ROADS

Put simply, vehicle emissions originate on roads. It is reasonable to assume that individuals who spend large amounts of time in close proximity to busy roads will have greater exposure to traffic-caused air pollution and therefore greater health risk from this exposure than others. This assumption is supported by a significant body of evidence, although conclusions have not been reached on exactly what constitutes safe distance. This is partly because, for particulate matter at least, there is not a threshold concentration below which adverse health effects are not expected.[4] It is also due to the fact that pollutant concentrations are a function of traffic volumes, which vary between studies. A WHO review of the health effects of transport-related air pollution concluded that:

> *"Most primary pollutants typically show steep gradients with distance from roads. In general, the highest exposures are*

found within the first 50-100m from roadways, and exposures often fall to background levels by 300m or more (p.94)"[4]

Zhou and Levy quantitatively synthesized findings from peer-reviewed literature and government reports to examine distance from source at which health impacts would occur for various pollutants, termed 'spatial extent'.[76] These distances were influenced by several factors, including individual pollutant characteristics, background concentrations and local meteorology. As expected, spatial extent of impact for vehicle emissions was found to vary according to pollutant type, with distances of 100-400m for elemental carbon or particulate matter, 200-500m for NO_2 and 100-300m for ultrafine particles. The authors concluded that spatial extent was generally within a few hundred metres of major roads.

Multiple studies have examined the health effects of childhood exposure to air pollution at various distances from major roads.[11-13, 16, 18, 19, 21, 23, 25, 33, 34, 36, 41, 50, 77, 78] These studies have generally shown significant associations between children spending large amounts of time near major roads and adverse health effects such as asthma exacerbation and reduced lung function. Recent work undertaken in Auckland indicates that PM_{10} levels at early childhood centres located beside busy roads may be significantly elevated in comparison to centres located away from heavy traffic.[79, 80] Studies looking at the relationship between proximity to major roads and child health have used a range of different distances to assign children to exposure categories, based on knowledge of pollutant dispersion. Distances generally ranged from 50m to 300m from major roads. Evidence of adverse health effects is strongest for the largest and busiest roads, which may carry vehicles over 100,000 vehicles per day. However, there is also evidence of adverse health effects from pollution exposure near roads carrying upwards 25,000 vehicles per day or more.[81, 82]

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APPENDIX 3 Road Capacity and induced traffic

In the UK a major study found that in terms of the benefits to economic growth "the theoretical effects listed can exist in reality, but that none of them is guaranteed"[25].

A recent American meta-analysis has estimated that for every 1% increase in roading capacity that nearly three quarters of that increase is absorbed by induced traffic[26][27].

There are a number of reasons for the generation of induced traffic, these include[28]:

Short Term	Long Term
New trips	Higher car ownership
More distant destinations	Reduced public transport service
Mode shifts	Activity location shifts
Route shifts	

The New Zealand Transport Agency's Economic Evaluation Manual mirrors overseas experience and notes that:

> "Over the long run, generated traffic often fills a significant portion (50 – 90 percent) of added urban roadway capacity. …Generated traffic does not eliminate the benefits of capacity expansion projects, but it can significantly change the nature of their benefits. It often means that road traffic reduction benefits are smaller and shorter lived than projected…"[29]

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[25] Standing Committee on Trunk Road Appraisal (SACTRA) report on the effects on the economy of transport policies and projects http://www.dft.gov.uk/pgr/economics/sactra/transportandtheeconomyfullre3148

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