

# Understanding the sources and trends of roadside air particulate matter pollution

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#### **Mission**

GNS Science has been researching the composition and sources of air particulate matter in NZ (and overseas) for over 20 years.

**Drivers for this research include:** 

- Understanding human health effects (particle size and composition)
- Air quality management (sources and source contributions to total PM)
- Changes over time (trends and step changes)
  - policy evaluation
  - effectiveness of regulation
  - impact of technology

## Air particulate matter composition and derivation of sources

- A complex mix of elements and compounds from multiple emission sources and atmospheric chemistry (gas↔particle)
- Compositional analysis by nuclear analytical techniques (elements Na to U), black carbon (BC) by light reflectance
- Each source or source type of particulate matter has a distinctive particle size range and chemical composition
- Multivariate and other data analytics across multiple samples to identify sources





## Air particulate matter speciation monitoring sites

- Data from 1997 onwards (> 50,000 time integrated (24-hour) samples ≈ 1.25 M datapoints)
- Majority have been short duration (1-2 years) as part of source apportionment studies for air quality management (NES driven)
- Auckland dataset across 5 sites (mostly) continuous since 1998 → trend information



# Transport metrics that impact on air quality?

Light passenger — Light commercial — MCycle — Trucks — Bus

Source: Annual Fleet Statistics 2017, Ministry of Transport

#### Fuel economy/efficiency Day 75.00 B 60.000 Diesel (L/100km)? 45,000 30.000 Figure 9.5a : Petrol economy trend by engine size 15.000 Fleet composition (diesel/petrol)? 12 10 km Figure 1.1 : Fleet composition 4,500,000 4.000.000 NZ new or used import? 3.500.000 3,000,000 Figure 2.2 : Fleet used import percentage 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2,500,000 Year registered 50% Light used % =4000+cc -2000-2999cd 2.000.000 Truck used % 1600-1999cc 1300-1599cc <1300cc 1,500,000 Bus used % 1,000,000 ₽ 40% Fleet age? 500,000 ď 2001 2003 2005 2007 2009 2011 2013 2015 2017 Figure 2.3 : Fleet average age ē 30% Light passenger Light commercial MCycle Trucks ■Bus Light fleet average age 20 Truck fleet average age Figure 1.2 : Fleet increase since 2000 Bus fleet average age 18 20% 2000 2002 2004 2006 2010 2012 2014 2016 in years 2008 Fleet size (diesel/petrol)? Vehicle kilometres travelled? Land Transport Rule Vehicle Exhaust Figure 1.4 : Travel 50 Figure 1.2 : Fleet increase since 2000 **Emissions 2007** 140% 45 2000 2002 2004 2006 2008 2010 2012 2014 2016 120% Ê 40 100% ių 35 80% Billion 30 -60% 40% 25 20% 0% 20 2000 2002 2004 2006 2008 2010 2012 2014 2016 2003 2013 2015 2017 2001 2005 2007 2009 2011

Fuel consumption?

Petrol

Figure 14: Observed Oil Products Consumption

135.000

120,000

90,000

Light travel Other travel

#### What are the main sources of air particulate matter?

Queen Street PM<sub>2.5</sub>, Auckland example (no particular reason for picking this site)







-05 Jun-06 Dec-06 Jun-07 Dec-07 Jun-08 Dec-08 Jun-09 Dec-09 Jun-10 Dec-10 Jun-11 Dec-11 Jun-12 Dec-12 Jun-13 Dec-

# **Composition of transport source PM**

Motor vehicle related emissions of particulate matter include:

- Tailpipe emissions (BC dominant, Fe, Ca, Zn)
- Wear of brakes and mechanical parts (Cu, Fe, Ba, Sb)
- Tyre wear (Zn, S, BC)
- Road surface abrasion (Al, Si)
- Re-entrainment of any dusts that end up on the road surface

#### Ship emissions characterised by S, V and Ni content

#### Davy PK, Ancelet T, Trompetter WJ, Markwitz A. 2017. Source apportionment and trend analysis of air particulate matter in the Auckland region. GNS Science. 80 p. (GNS Science consultancy report; 2014/194)



0

a

d

d

u

S

## Black carbon is a combustion source emission

# Queen Street BC, Auckland example (represents the ultrafine PM component)

- BC from incomplete combustion
- BC consistently 40% PM<sub>2.5</sub> concentration in Auckland



Dec-05 Jun-06 Dec-06 Jun-07 Dec-07 Jun-08 Dec-08 Jun-09 Dec-09 Jun-10 Dec-10 Jun-11 Dec-11 Jun-12 Dec-12 Jun-13 Dec-13

Rising levels of 'black carbon' in Queen St heighten health risk for Aucklanders



Soot or 'black carbon' is something to be aware of in Auckland's Queen St. It's emitted from diesel vehicles and is on the rise again. Photo / Brett Philbbs



## Motor vehicle source activity

- Difference in weekday/weekend PM concentrations due to vehicle activity
- Less HCV (diesel) activity during weekends
- Mondays affected by public holidays (≈15%)
- Difference between PM<sub>2.5</sub> and PM<sub>10</sub> contributions is road dust component



Davy PK, Trompetter WJ, Markwitz A. 2011. Concentration, composition and sources of particulate matter in the Johnstone Hills Tunnel, Auckland GNS Science. 64 p. (GNS Science consultancy report; 2010/296)

## **Evaluation of regulatory effectiveness**

- Reduction in urban PM sulphur concentrations in Auckland as a consequence of removal of S in fuels
  - Petroleum Products Specification Regulations 2002



# Trends in motor vehicle contributions (all of Auckland)

- Decrease due to tailpipe emissions improvements (trend is all PM<sub>2.5</sub>)
  - Better engine design/technology
  - Reduction of sulphur in fuels and other fuel improvements
- Difference between PM<sub>2.5</sub> and PM<sub>10</sub> is road dust component
- Motor vehicle tailpipe emissions account for ~75% PM<sub>2.5</sub> trend across Auckland



# **Trends in PM contributions and traffic volumes**

#### Takapuna

- No significant trend for PM<sub>2.5</sub>
- Upward trend for traffic volume and PM<sub>10</sub> → road dust increase
- Emissions improvements offset by local traffic volume increase (busway, Smales Farm hub)
- Road dust component will remain for EVs



Takapuna: PM<sub>2.5</sub> and PM<sub>10</sub> from vehicles and traffic volumes







Xie, S., Davy, P., K., Sridhar, S. & Metcalfe, J. Quantifying trends of particulate matter emissions from motor vehicles in Auckland. Air Quality and Climate Change Volume 50 No.2. May 2016

### Auckland's CBD: Context for considering a congestion charge of \$10

- The CBD area is the social and economic heart of Auckland
- Rapidly expanding resident population 53,000 in 2018
- About 75,000 people commute into the CBD every day



10-year annual averaged date for  $PM_{2.5}$  (blue) and  $NO_2$  (red) at Auckland Council's urban background site (Glen Eden), Citywide (Penrose, Takapuna and Henderson) and Queen Street. The averaged data is to compensate for short term changes to emission sources such as traffic flow closer to monitoring sites.

#### C40 Modelling impacts of a congestion charge for Auckland CBD

The estimated reduction in Pollution concentrations when you remove **11,000** vehicles



## Modelled Social and Economic Impacts from car reduction



#### SOCIAL IMPACT

0

Number of deaths averted annually across the total population:

days per person

Life expectancy across the total population increased by:

days per person

#### ECONOMIC IMPACT Approximate costs avoided due to reduced premature mortality from change in PM2.5 levels: NZ \$40,291.15 Per Year



#### SOCIAL IMPACT

Number of deaths averted annually across the total population:

6

Life expectancy across the total population increased by:

31 days per person

#### ECONOMIC IMPACT

Approximate costs avoided due to reduced premature mortality from change in NO2 levels:

NZ \$1,051,099.51

year

NO<sub>2</sub> rather than  $PM_{x}$  is the best metric to assess vehicle impacts

Shipping Emissions contribute 5% Almost 10 million pedestrians were counted at PM<sub>2.5</sub> and 10% Black Carbon at lower Queen St / Customs street in 2017. **Queen Street** Research shows this area to have highest the NO<sub>2</sub> concentrations in CBD Parks have far lower air pollution levels than neighbouring Streets Diesel emissions account for 40% PM<sub>2.5</sub> and 66% Black Carbon in CBD Key factors to consider for Auckland CBD air pollution Industrial sources account for just 11% of PM<sub>2.5</sub> across Auckland Over 38,000 private vehicle journeys into the CBD each month Active modes accounted for just 8% son inbound traffic in 2017



#### Looking at NO<sub>2</sub> concentrations in relation to wind speed and direction: **2017**

NO<sub>2</sub> concentrations are highest with light- moderate winds from the South

The direction of upper Queen Street



#### Bus patronage in relation to peaks in NO<sub>2</sub> concentrations



### Relevance for AC policy decision-makers

- Auckland Council's Fossil Fuel Free Commitment (mayors office/ AT)
  - Electric bus purchases by 2025 &
  - ✤ A designated Fossil Fuel Free area
- The City Centre Masterplan refresh soon to go to committee
- The Downtown Programme
- Auckland Transport Alignment Project (ATAP)
  - Bringing back light rail
  - Extending cycleways
  - Smart road signalling
- Auckland Transport safer streets approach
- Ports of Auckland Sustainability plan (Shore Power?).
- Construction of Auckland's city rail link.
  - doubling rail capacity in the city
  - enabling 30,000 people an hour to move during peak time.

#### A sneaky peak into the future structure of Auckland's CBD



#### Developing a low-cost sensor network for Auckland's Central Business District to monitor changes

