

TP08:
**Options for treating
road tunnel emissions**

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Summary

Very few tunnels around the world are equipped with air treatment systems. There are around 60 installations of electro-static precipitators (ESP) to remove particulate matter (PM).

There are five installations of de-nitrification systems to remove nitrogen dioxide (NO₂).

Evidence to date suggests that the effectiveness of such controls when applied to road tunnels is limited to specific situations, and that the technologies are rarely used.

The M5 East filtration trial removed 200 kilograms of particulate matter (PM) at a cost of \$760,000 (operating costs only) (AMOG, 2012). In comparison, the estimated health benefit of removing 200kg PM is \$56,000.

An assessment of a range of other PM reduction measures found that the introduction of Euro5/6 standards for new passenger vehicles would reduce emission of PM by 131 tonnes annually at a cost of \$209,000 per tonne, with a health benefit of \$280,000 per tonne.

This is consistent with the conclusions of the National Health and Medical Research Council that the most effective way to manage air quality both in and around tunnels is through vehicle fleet emission reductions.

1. Options for treating road tunnel emissions

Since the late 1980's, technology has been developed for cleaning tunnel air. This development has been mainly in Norway, Austria, Germany and Japan.

The use of these technologies to help achieve external air quality goals in the past was experimental or extremely rare (PIARC 2008). Very few tunnels around the world are equipped with air treatment systems. There are around 60 installations around the world, 35 of which are in Japan and eight in Norway (CETU 2011).

The use of these technologies remains rare – however some improvements in their efficiency and reliability now place them as another 'option' that can be evaluated in the range of tools for managing air quality on some specific target pollutants.

Filtration of tunnel air in general terms is used to either;

- treat in-tunnel air to improve the air quality for tunnel users, or
- treat air at the ventilation outlet point to remove pollutants to improve ambient air quality around the tunnel.

Regardless of whether in-tunnel or ambient air quality is to be managed, the current available systems are used for both cases.

Options for treating road tunnel emissions

There are two types of pollutant removal systems for tunnel air filtration;

1. Electro-static precipitation

An electro-static precipitator (ESP) is used to remove particulate matter (PM).

The first installation of an ESP for air cleaning in road tunnels was in the Tsuruga tunnel (Japan) in 1979. Typically an ESP was installed to manage haze within a tunnel due to smoky vehicles which was considered a safety issue in terms of visibility.

There are 9,000 road tunnels in Japan with an approximate combined length of around 3,000 kilometres of which 35 have ESP's (PIARC 2008).

There are approximately 1,000 tunnels in Norway – of these 8 have installed electrostatic precipitators over the past 15 years. Installation of ESP's in Norway was driven by the need to improve visibility due to the studded tyres used in cold climate conditions.

Germany, Austria, Italy, Spain, France, South Korea and Vietnam have all installed either small pilot systems or more extensive systems such as within the M30 in Madrid.

There are approximately 60 ESP installations around the world in total. It is difficult to obtain information on the operating time of these systems. However, available information indicates they are rarely used. For example, the Tokyo Bay “Aqualine” tunnel only records 12 to 13 hours of operation per year (CETU 2011).

2. De-Nitrification (Denox)

De-Nitrification (Denox) is primarily for the removal of nitrogen dioxide (NO₂).

Denox is used even less than electro-static and remains a little used system implemented in five tunnels worldwide: Laerdal (Norway), Chuo-Kanjo-Shjijuku (Japan), Umberto (Italy), M30 (Spain) and M5 East (Australia) (CETU 2011).

There is little published independently reviewed evidence available regarding the performance of tunnel air treatment systems.

Technologies are pollutant specific, only address local and not regional road transport-related air pollution, generate chemical waste and have significant capital and operational costs (NZ Transport Agency 2013).

2. Australian experience with tunnel air treatment

Australia has a single ESP and Denox installation within the M5 East tunnel. This was installed and trialled from March 2010 to September 2011.

The system was installed with the intention of improving the air quality at the western end of the westbound tunnel by reducing haze caused by particulate pollution.

The ESP filters approximately 200m³/second of air, at a distance of approximately 500m from the end of the westbound tunnel (Figure 1). This rate of filtration represents approximately half of the air flowing along the westbound tunnel at this location.

The Denox filtered approximately 50m³/s of air from the westbound tunnel. The trial was over an 18 month period and during this period an extensive measurement and assessment exercise was carried out by the CSIRO and AMOG Consulting.

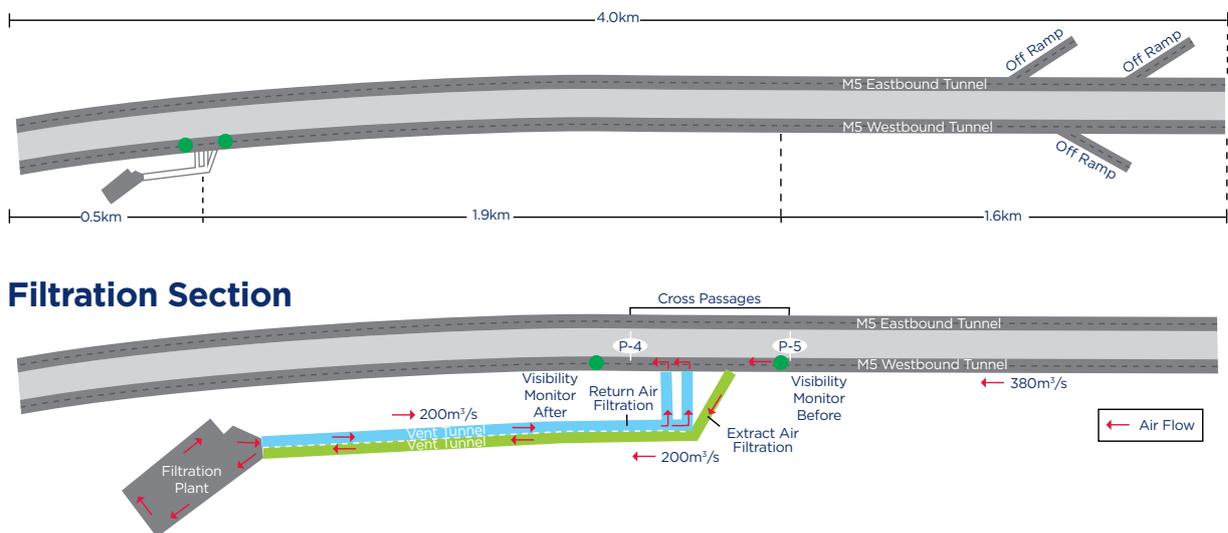
The results of the trial indicated that the ESP removed around 65% of the PM from the extracted tunnel air at the location of the filtration plant. AMOG hypothesised that the ESP acted as an agglomerator of particles and did not capture or collect a significant amount of PM.

The Denox system removed approximately 55% of the NO₂ from the air. AMOG found that the system acted as a catalyst which converted the NO₂ to nitrogen oxide (NO) rather than collecting or absorbing the NO₂.

The M5 East filtration trial removed 200 kg of PM₁₀ per year, at a cost of around \$3.8 million per tonne (operating costs only) and \$17.4 million per tonne (total costs including civil and machinery) (AMOG 2012).

Table 1 compares the costs and PM₁₀ reductions for the M5 East filtration trial and a range of other PM abatement measures. The then NSW Department of Environment Climate Change and Water (DECCW) engaged Sinclair Knight Merz (SKM 2010) to undertake a study to identify and analyse a range of emission abatement initiatives. In the Sydney Region, SKM identified 12 emission-reduction measures, with costs ranging from \$1,000 per tonne to \$274,000 per tonne of PM₁₀ removed¹. The cost of removing PM₁₀ using vehicle particle filters was \$151,000 per tonne.

Figure 1: M5 East Filtration Plant



2. Australian experience with tunnel air treatment

Figures 2 and 3 present the information in Table 1 as a marginal abatement cost curve. Each box on the curve represents a different opportunity to reduce PM emissions. The width of each box represents the emissions reduction potential that the measure can deliver, and the height of each box represents the average net cost of abating one tonne of PM through that activity. The vertical scale is logarithmic. The cost curves highlight the fact that the M5 East filtration trial is the most expensive measure, with the least abatement potential, of all the measures in Table 1.

In 2013 the NSW EPA commissioned PAEHolmes (PAEHolmes, 2013) to develop a valuation methodology that accounted for the health impacts associated with changes in PM emissions.

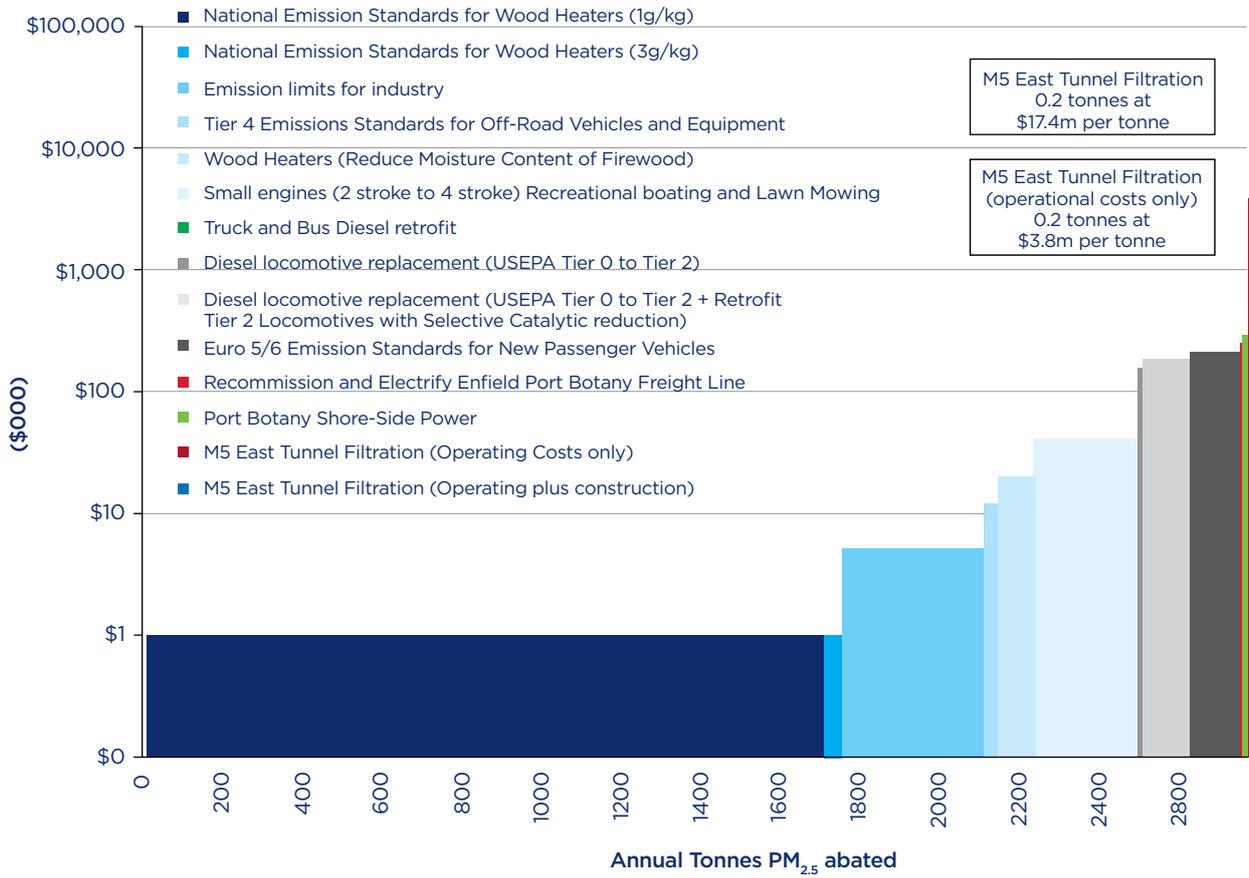
PAEHolmes estimated the health benefit of removing one tonne of PM_{2.5} in Sydney to be \$280,000. Nearly all of the particles removed in the M5 East trial would be PM_{2.5}. Hence, the M5 East filtration trial had operational costs of more than ten times the health benefit. All the measures examined by SKM cost more than ten times less, and would remove substantially more PM, delivering a much greater health benefit to the people of Sydney than tunnel filtration.

This is consistent with the conclusions of the National Health and Medical Research Council that the most effective way to manage air quality both in and around tunnels is through vehicle fleet emission reductions (NHMRC 2008).

Table 1: Comparison of PM₁₀ reduction measures

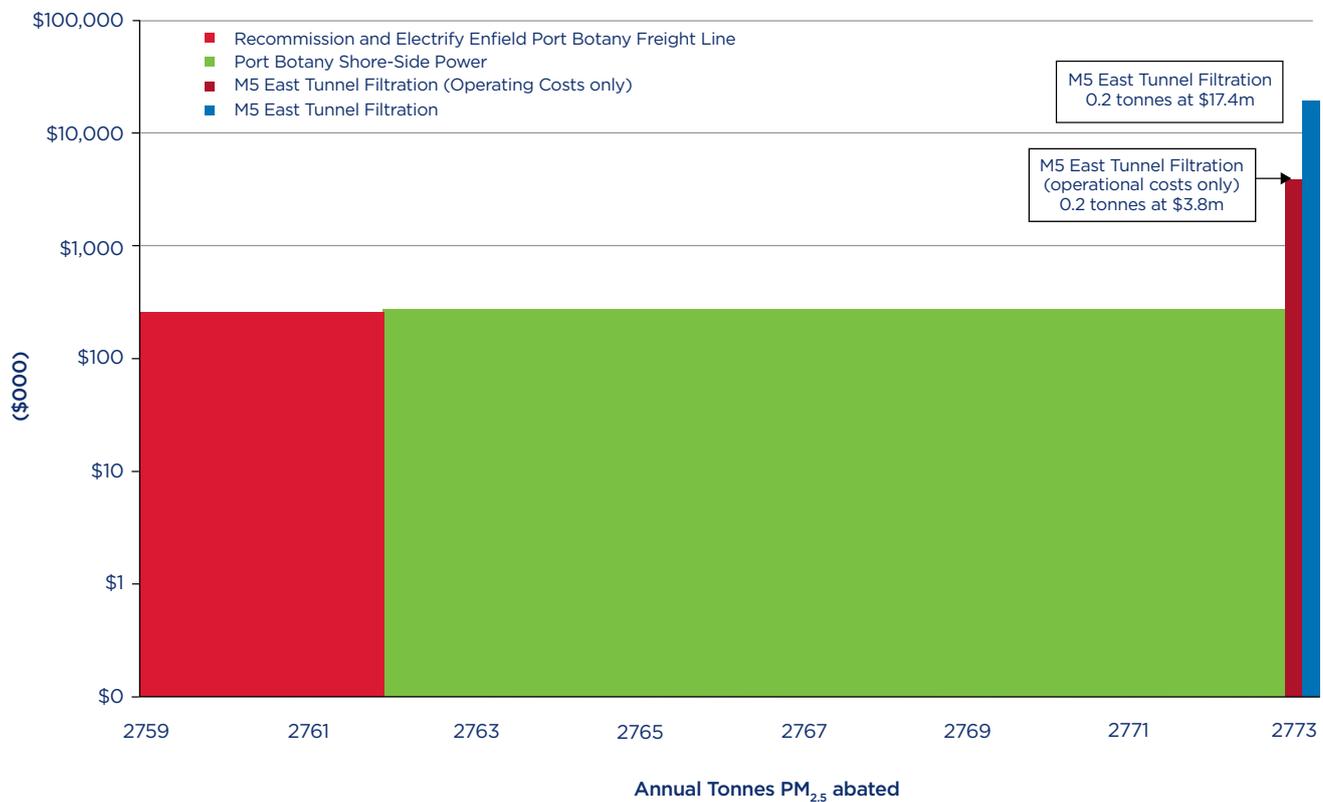
PM ₁₀ reduction measure	Cost of PM ₁₀ reduction (\$ per tonne)	Annual tonnes PM ₁₀ reduced
National emission standards for wood heaters (1 g/kg limit)	1,000	1,701
National emission standards for wood heaters (3 g/kg limit)	1,000	45
Emission limits for industry	5,000	359
Tier 4 emissions standards for off-road vehicles and equipment	12,000	31
Wood heaters - reduced moisture content of firewood	20,000	93
Small engines (2-stroke to 4-stroke) for recreational boating and lawnmowing	39,000	261
Truck and bus diesel retrofit program	151,000	1
Diesel locomotive replacement (USEPA Tier 0 to Tier 2)	156,000	53
Diesel locomotive replacement (USEPA Tier 0 to Tier 2 + Retrofit Tier 2 Locomotives with selective catalytic reduction)	191,000	72
Euro 5/6 emission standards for new passenger vehicles	209,000	131
Recommission and electrification of Enfield Port Botany freight line	244,000	3
Port Botany shore-side power	274,000	11
Approximate benefit of reducing PM (damage cost, PAEHolmes (2013))	280,000 per tonne	N/A
M5 East tunnel filtration (operating costs only)	3,800,000	0.2
M5 East tunnel filtration	17,400,000	0.2

Figure 2: Marginal Abatement Cost Curve for PM



Australia

Figure 3: Detail of Marginal Abatement Cost Curve for PM



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