ANNEXURE 8

TUNNEL VENTILATION SYSTEM TECHNOLOGY REVIEW AND BEST PRACTICE

Section 8 of the WAA provides an overview of contaminant management techniques adopted in Australia and overseas for the management of in-tunnel air quality in road tunnels, and the impact of emissions of tunnel air on external air quality. This Annexure provides a more detailed analysis of these techniques and their applicability to the EastLink tunnels.

1. Contaminant Management Technology Review - Overview

Contaminant management technology has been used in tunnels for many years. The range of projects involving contaminant management technology spans all continents – but the underlying objective remains constant – air quality both inside and outside tunnels must be delivered.

The use of contaminant dispersion techniques is overwhelmingly favoured over the use of contaminant removal techniques for managing external air quality.

The principal application of contaminant removal technologies has been to improve in-tunnel air quality where visibility has to be maintained and access to fresh air is problematic. Electrostatic precipitators (ESPs) have been used for the removal of the particles which affect visibility from air in tunnels. Over the last decade nitrogen oxides (NO_x) removal technologies have also been trialled and refined for in-tunnel air quality purposes.

More recently, ESPs have been used in Japan, ostensibly to help manage external air quality. ESPs have been used in urban areas in Japan, where external air quality is very poor. ESPs were also installed in one Norwegian road tunnel solely for external air quality purposes in around 1990, although these ESPs are no longer used. There is no data available which demonstrates the effectiveness of ESPs in improving external air quality in either Norway or Japan.

Italy has commenced construction of a tunnel in Cesena incorporating ESPs for external air quality management purposes. The tunnel is not yet operational, and no data is available as yet which demonstrates the effectiveness of ESPs in improving external air quality. However a watching brief will be maintained in relation to the effectiveness of the ESPs in the Cesena tunnel in managing external air quality.

Spain has just committed to at least 3 ESPs and two NO_2 removal plants as part of its M30 Ring Road Project.

In Australia the RTA of New South Wales, although having announced trials of contaminant removal technology early in 2004, has neither commenced the trials nor recently given any indication that they will proceed, although there remains considerable political pressure to do so..

There have been discussions about the use of contaminant removal technologies in most urban road tunnels currently under design around the world. These discussions have occurred on projects such as in Paris and Chicago, as noted in the review undertaken by Child & Associates for the New South Wales RTA, in September 2004.

In Chicago the primary driver behind the consideration of contaminant removal technologies is poor ambient air quality and heavy truck use. In Paris, poor ambient air quality and high traffic numbers have drawn designers' attention to the possible use of contaminant removal technologies. As a result of these factors, emissions from road tunnels in these cities have difficulty meeting external air quality objectives (which is not the case for the EastLink tunnels, as demonstrated by the modelling results discussed in Section 6 of the WAA). TJH understands that it was ultimately decided not to install contaminant removal technology, both in Paris and Chicago.

In those rare instances where contaminant removal technologies have been used to manage external air quality, there has been no data released on the effectiveness of their use in improving external air quality. Modelling results of the effects of these technologies, when used in combination with contaminant dispersal technology (such as stack dispersion), demonstrates that any reduction achieved by the use of the contaminant removal technologies is marginal when compared to the levels of these contaminants that are present in ambient air.

However the fact that contaminants can be removed from tunnel air qualifies these technologies for consideration when designing a tunnel to achieve environmental performance objectives, and when considering whether the tunnel air is being managed in accordance with best practice.

2. Technologies for Contaminant Removal

There are a number of technologies available which could be used to remove particulate and/or specific gaseous contaminants from tunnel air.

Assessments have been undertaken of a selection of these technologies through a combination of literature reviews, dialogue with manufacturers, dialogue with operators and inspections.

Recent inspections of contaminant removal technology have been undertaken in Japan, Italy, Austria and Norway for the purpose of ensuring this WAA includes the most up to date information. These investigations are ongoing.

The review of contaminant removal technologies has broadly been conducted by:

- Detailing the approach to manage air from urban road tunnels around the world;
- Reviewing the application of contaminant removal technology in road tunnels;
- Assessing the application of contaminant removal technology in the Eastlink tunnel context; and
- Providing a summary of recent Australian investigations and studies into the application of contaminant removal technologies (details of which are contained in Section 5 of this Annexure 8).

3. Identification of available contaminant removal technologies

Companies were identified that produce contaminant removal technologies for a range of industries and applications. The companies contacted are known to have either supplied contaminant removal technology installed in road tunnels, or are looking at developing technology for this application.

The companies contacted included:

Companies with technologies currently installed in road tunnels -

- Aigner
- CTA
- Kawasaki Heavy Industries
- Mitsubishi Heavy Industries
- Matsushita

Companies promoting or developing applications for road tunnels –

- Alstom
- Indigo Technologies
- Dyna Filtration
- Fujita

- Filtrontec
- Cleanteq
- Hyder

It is now understood Fuji (Japan) are considering entering the overseas market as an ESP manufacturer.

A useful summary of the state of contaminant removal technologies and a list of potential technology manufacturers is contained within the Child & Associates technology review (for the New South Wales RTA) of September 2004. This study along with other studies undertaken in Australia on contaminant reduction technologies is summarised in Section 5 of this Annexure 8.

In general, there are two forms of contaminant removal systems that have to date been used to reduce contaminants in tunnel air from road tunnels around the world. They include:

- Electrostatic precipitators, commonly known as ESPs, to reduce dust and particulate levels in tunnel air; and
- Technologies for reducing nitrogen oxides in tunnel air.

A number of emerging technologies have been trialled or promoted as being suitable to reduce contaminants in tunnel air, although they have not as yet been installed (other than for trial or testing purposes) in any road tunnels around the world. They include:

- Biofiltration, which uses biological processes to reduce contaminants
- Gas turbines, to reduce contaminants by passing tunnel air through a gas fired turbine
- Agglomeration, which aggregates very small particles into larger particles, which can then be more effectively removed using other technologies such as ESPs
- Gas/liquid scrubbing, whereby contaminants (in air) are collected in the scrubber liquor, which is subsequently removed for off-site treatment.

There are very few examples of the use of contaminant removal technologies principally for external air quality purposes in the world. Only Japan, Norway and soon Italy and Spain have taken this approach to meeting environmental performance objectives. In each instance where they are used, there are circumstances which make their use appropriate in the local context. High ambient air pollution levels are the main factors driving their use in Japan, while in Norway mobilised dust generated by the use of studded snow tyres in winter was the principal reason for installation of ESPs.

These circumstances do not exist in the case of the EastLink tunnels, which will achieve the applicable environmental air quality requirements by using the Capture, Containment, Dilution and Dispersal (CCDD) technique.

The following table lists the contaminants that will be contained in the EastLink tunnel air, and summarises the possible contaminant removal technologies available for reducing ground level concentrations of each of these contaminants for external air quality purposes.

Contaminant	**Removal technology**
Carbon monoxide	No known contaminant removal technology currently available for use in road tunnels
Nitrogen oxides	Nitrogen oxides removal systems have been developed. Yet to be installed in road tunnels anywhere in the world for external air quality purposes, but the decision has been made to install two types of nitrogen oxides removal system in a road tunnel in Japan. See Section 3.2 below and Section 8.3.3 of the WAA for more detail.
PM_{10} and $PM_{2.5}$	ESPs can reduce particulate levels in road tunnel air. ESPs used in a number of countries for in-tunnel air quality management, but used only in Japan and Norway for external air quality purposes. The application of

	ESPs to road tunnels for external air quality management purposes is discussed in detail in Section 3.1 below and Sections 8.3.2, 8.4 and 8.5 of the WAA.
Benzene	No known contaminant removal technology currently available for use in road tunnels
Toluene	No known contaminant removal technology currently available for use in road tunnels
Formaldehyde	No known contaminant removal technology currently available for use in road tunnels
PAH (as BaP)	Particulates act as a carrier for PAHs, therefore ESPs could potentially be used to reduce PAH levels in road tunnel air. See Section 8.5.4 of the WAA for a discussion of the application of ESPs in reducing PAH emissions from the EastLink tunnels.
1,3-butadiene	No known contaminant removal technology currently available for use in road tunnels
Xylenes	No known contaminant removal technology currently available for use in road tunnels

3.1. Electrostatic Precipitators

The modelling results discussed in Section 6 of this WAA demonstrate that the ground level concentrations of particulates (both PM_{10} and $PM_{2.5}$) from the EastLink tunnel air will be well below the design criteria set in SEPP (AQM). This is achieved through the EastLink tunnel ventilation system's use of the CCDD contaminant management technique. ESPs are not required to achieve compliance with the requirements of SEPP (AQM).

However ESPs were nevertheless considered in the design process for the EastLink tunnel ventilation system, in order to determine whether best practice required the use of these technologies. It was determined that best practice did not require the use of ESPs. The reasons for this are set out in the following discussion of the technology used in the road tunnel context.

ESPs are contaminant removal devices which are able to remove particles from air using electrostatic forces.

All ESPs have – as a minimum – the following three stages.

1. Air containing particles, is passed through a device which places a “charge” on the moving particles.
2. The charged particles pass through a strong electromagnetic field which draws the charged particles from the air onto a collector.
3. The collected particles are removed for off-site disposal.

There is a large range of “types” of ESPs, but the concept remains essentially a three stage process.

ESPs have been used in various industrial applications for many years. More recently, ESPs have been used in road tunnels to remove particles from tunnel air. In the road tunnel context, they are primarily used for the purposes of maintaining in-tunnel air quality, but more recently ESPs have been installed in road tunnels in Japan, Norway and (most recently) Italy and Spain for external air quality reasons.

When used in industrial applications typically involving concentrated waste streams, ESPs can achieve high contaminant removal efficiencies (design efficiencies can range up to 99.9% on a mass basis). However ESPs are substantially less efficient at removing particles that are present in much lower concentrations and smaller particle sizes, as in the case of road tunnels. ESPs therefore operate less efficiently in the road tunnel context than in typical industrial applications. This is discussed in more detail in Section 3.1.7 below.

The following sections discuss the application of ESPs in overseas road tunnels.

3.1.1. Japan

ESPs were first introduced into Japan in 1979 in the Tsuruga tunnel (2.1 kilometres long).

While Japan has the largest number of ESPs installed in road tunnels in the world, only between 35 and 40 of the total of around 9,000 road tunnels in Japan have been fitted with ESPs.

From inspections of tunnels throughout Japan and discussions with road officials, the most common reason for the introduction of ESPs in Japanese road tunnels is to maintain in-tunnel visibility in tunnels employing comparatively simple longitudinal ventilation systems.

Long tunnels combining longitudinal ventilation and ESPs were pioneered in Japan with the Kan'etsu tunnel (11 kilometres) in 1985. This tunnel combines longitudinal ventilation using intake and exhaust shafts, and ESPs which operate to filter the air within the tunnel for in-tunnel visibility purposes. The installation of ESPs at an intermediate point in the tunnel is considered more economical than to have a ventilation shaft to draw fresh air into the tunnel to achieve the required in-tunnel visibility requirements.

Over the last 3 years or so several Japanese road tunnels have been fitted with ESPs to achieve external air quality objectives. In Japan there are now at least 7 tunnels which use ESPs to reduce particulate emissions for external environmental reasons. For example ESPs have been installed in the base of ventilation stacks in the Tennozan (2 kilometres), Kanmon (3.5 kilometres), Asukayama (0.6 kilometres), Midoribashi (3.4 kilometres), Hanazonobashi and Hasumiya tunnels.

Japan is a densely populated, heavily industrialised country with generally much poorer air quality in its cities than is the case in Australian cities. Extensive areas of the major cities of Japan are subject to poor air quality, primarily due to emissions from motor vehicles and industry. ESPs are thought to be required in these Japanese tunnels in order to enable emissions from road tunnels to meet external air quality objectives (although their effectiveness in doing so is as yet unproven – see Section 3.1.5 below).

Measures by the Japanese government to address ambient air quality have been directed at the pollution source, including tough new laws requiring a reduction in particulate matter and NO_x emissions from vehicles. Under the new laws, vehicles that do not comply with the standards will need to be replaced or fitted with particle filters. It is estimated that about 2.2 million trucks, 300,000 buses and one million diesel powered cars will need to be replaced over several years.

The introduction of these new laws has been postponed (due to economic issues), however in areas such as the Tokyo Metropolitan Region the new standards have been applied. Indeed the effect of these laws has been to improve air quality within the Tokyo region because diesel vehicles (unless fitted with these technologies) are effectively banned from the region.

Tokyo's new ring road will include tunnel componentry with ESPs and NO_2 removal technologies.

3.1.2. Norway

Of the 900 tunnels in Norway, only 7 have ESPs. Of these several are for urban road tunnels, and all bar one were principally designed to maintain in-tunnel (rather than external) air quality.

With the exception of the Laerdal tunnel, ESP systems used in Norway are used to principally address in-tunnel visibility problems, which are caused by high dust levels associated with the use of metal studded snow/ice tyres in winter.

The Laerdal tunnel requires ESP technology both for in-tunnel air quality and in-tunnel visibility reasons. This is because the tunnel is extremely long (over 22 kilometres) and due to its depth under a mountain cannot readily be supplied with fresh air to maintain in-tunnel air quality. ESPs also help to maintain visibility in the Laerdal tunnel, especially in winter when cars are fitted with studded snow tyres.

The one tunnel in Norway that was fitted with ESPs for external air quality management was the Festning tunnel in Oslo. The ESPs are, however, no longer operated, although the tunnel is still used. Refer to Section 5.3 below for more detail.

Most of the tunnels fitted with ESPs in Norway use the ESPs on an as needs basis - they are only turned on when visibility in the tunnel may become poor in congested or high traffic flows. Electrical reliability issues have resulted in most of these systems no longer being operational.

3.1.3. Italy

A new and refined ESP technology is currently being installed into a tunnel in Cesena (south of Bologna in Italy and in three tunnels on the M30 Project in Madrid, Spain). The technology has been developed by the Austrian company Aigner and full scale testing of its actual effectiveness is expected to commence in May 2006.

Aigner specialises in industrial contaminant removal technology, and retained the services of the Technical University in Graz in Austria (the technical university of the internal combustion engine) to undertake performance testing of a prototype version of this technology for use in road tunnels.

Important features of this technology are:

- It produces no liquid waste streams (has a continuous filter medium system) – and liquid recycling;
- It is of apparently robust design;
- It uses a novel electrostatic charged filter type technology as an alternative to the traditional highly charged electrostatic plate technology;
- It has comparatively low power consumptions;
- It has a comparatively low pressure loss characteristic; and
- It can be coupled to NO_x removal technologies.

Information about the effectiveness of these new generation ESPs is expected in 2006, and a watching brief will be maintained over that information as part of the Tunnels Environment Improvement Plan.

It is understood that in the two of the three Madrid projects the ESPs are being coupled with NO_2 removal technology of the same type used in the Laerdal Tunnel.

3.1.4. Other Locations

ESPs have also been installed in tunnels in Korea and Vietnam. The basis of these installations is to maintain visibility in the tunnels. Due to the length and grade of the tunnels in mountain ranges there is limited ability to construct ventilation stacks or fresh air inlets to manage the in-tunnel air quality. ESPs provide a means of maintaining in-tunnel visibility and air quality without access to fresh air to dilute the tunnel air.

3.1.5. No data on the actual effectiveness of ESPs in improving external air quality

To TJH's knowledge, no technical data is available from anywhere around the world where ESPs have been installed in road tunnels for external air quality reasons (to date, only Japan and Norway – but soon Italy and Spain), which demonstrates the actual contribution of ESPs to improving ambient air quality.

Some data is expected to become available when the ESPs being installed in the Cesena tunnel in Italy and Madrid, Spain become fully operational in mid to late 2006. This data will be reviewed as part of the Tunnels Environment Improvement Plan (TEIP).

3.1.6. Hours of Operation of ESPs

In Norway and Japan, the operation of ESPs is on an *as needs* basis. The ‘need’ is determined in Japan by actual air quality measurements, while in Norway it is usually more dependant on a time clock which corresponds with peak hour traffic.

As of March 2006, only one tunnel in Norway regularly uses its ESPs. Despite the ESPs not running the tunnels have remained open for traffic.

In the Japanese Kan’etsu tunnel ESPs operate in the northbound tunnel on average 143 hours per month (this is about 20% of total hours) and in the southbound tunnel on average 40 hours per month (about 3% of total hours). In the Tokyo Aqualine tunnel, ESPs operate only 12 to 13 hours per year (about 0.15% of total hours).

Tunnels using ESPs for external air quality purposes use the technologies more extensively. In the Hanshin Expressway tunnel tube they have been used on a 24 hour 7 day a week basis for the last 2 years.

As indicated above, no information is available to demonstrate the effects on external local air quality as a result of ESP operation from any of the identified tunnels in Japan, or the one tunnel in Norway in which ESPs were installed (although they are no longer used) for external air quality purposes, or any tunnel with air cleaning technologies.

3.1.7. Efficiency of ESPs

ESPs do not remove all particles. Their removal efficiencies vary according to factors such as air speeds, contaminant composition, particle size and particle concentration.

Particulate removal efficiencies of ESPs used in tunnels are typically of the order of 70%. When compared to efficiencies typically achieved by ESPs used in industrial applications (which can be up to 99.9%), efficiency rates of around 70% are low. A removal efficiency of 99.9% means that only 0.1% of particulates in the airstream are emitted. An efficiency removal rate of 70% means that 30% of particulates in the airstream are emitted. This means that the typical removal rate achieved by ESPs in road tunnels (at 70%) is 300 times lower than the typical removal rate achieved by ESPs in many industrial applications (achieving 99.9% removal rates).

There are a number of reasons why ESPs operate less efficiently in the road tunnel context than in industrial contexts.

Firstly, ESPs operate more efficiently when the concentration of particulates in the air is high. Concentrations of particulates in the air in road tunnels is very low when compared to the concentrations commonly present in airstreams in industrial situations. This is because air in road tunnels is diluted by drawing fresh air into the tunnel portals, in order to maintain in-tunnel air quality to protect the health and safety of tunnel users and maintenance personnel and meet stringent in tunnel air quality standards.

Secondly, ESPs are more efficient at removing larger particles than smaller particles. The particles contained in motor vehicle exhaust emissions are at the smaller end of the scale (typically less than one micron).

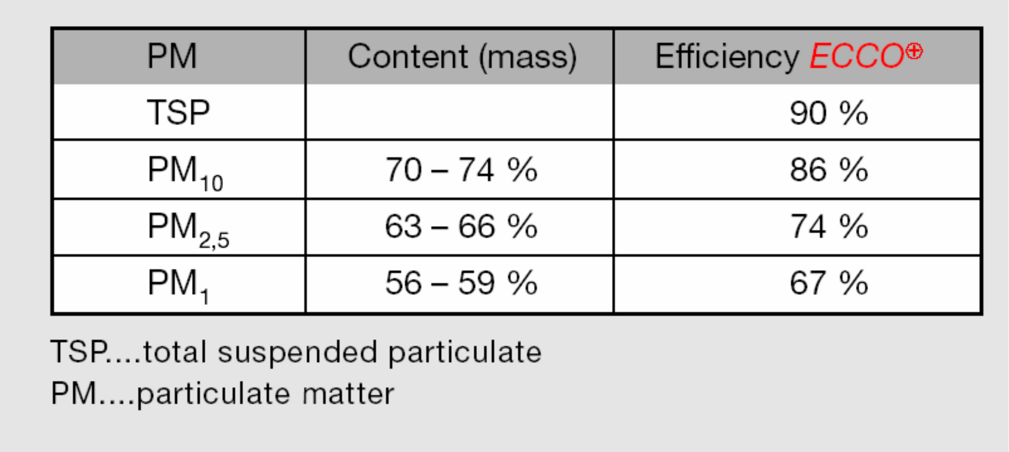
Furthermore, from an external air quality (health) perspective, it is generally considered that the efficiency of removal of smaller particles ($PM_{2.5}$ and perhaps PM_1 and smaller) is as relevant, if not more relevant, than the efficiency of removal of larger particles (PM_{10}).

The removal efficiencies described above (typically in the order of 70% for road tunnels) are usually expressed as a percentage of the total *mass* of particles removed from tunnel air, rather than the total *number* of particles removed. Mass removal calculations do NOT necessarily reflect particle number removal efficiencies. A removal efficiency of 70% is likely to be significantly weighted in favour of the heavier, larger particles removed, while the percentage of smaller particles making up the total mass of particles removed is likely to be small.

Particles in the $PM_{2.5}$ to PM_1 range are extremely small. Measurement of efficiencies of removal of actual particles in these size ranges is problematic. All manufacturers recognise this in their removal performance statistics. Claims for specific efficiencies of varying manufacturers can be found in the Appendices of the Child & Associates report.

The only data available on PM particle removal, based on actual numbers of particles removed from real tunnel air, comes from analysis of removal efficiency for the Plabutsch Tunnel Graz. Although limited to a single days measurements, and found only in the manufacturers promotional material, it provides a useful insight into the relationship between removal efficiency and particle size.

These results indicate removal efficiencies in the order of 74% for $PM_{2.5}$ and in the order of 67% for PM_1 (Expressed as a % of the removal of the Mass). The manufacturer does not warrant this performance – the figures are provided as indicative.



PM	Content (mass)	Efficiency *ECCO*⊕
TSP		90 %
PM_{10}	70 – 74 %	86 %
$PM_{2,5}$	63 – 66 %	74 %
PM_1	56 – 59 %	67 %

TSP....total suspended particulate
PM....particulate matter

These efficiency rates are well below the efficiency rates commonly achieved by ESPs in industrial applications, and are well below the efficiency rates commonly expected of various forms of industrial pollution control technologies.

It is anticipated that results on actual numbers of particles removed (not mass) for a range of particle sizes will become available in 2006 from analysis conducted in Cesena, Italy and perhaps the M30 Project in Madrid, Spain.

When considering whether best practice requires the installation of ESPs for external air quality management in the EastLink tunnels, these efficiency rates need to be put in context. Even if it is assumed that ESPs are able to remove 70% of particulates (including $PM_{2.5}$) from tunnel air emitted from the EastLink stacks, this would result in negligible benefits in terms of the reduction of the cumulative ground level concentrations of particulate emissions. See Section 8.5.3.1 of the WAA for more detail.

3.1.8. Environmental issues arising from ESP use

As is the case with all methods for dealing with motor vehicle emissions in tunnels, there are a number of environmental costs associated with using ESPs. Of most importance are:

- Waste stream creation
- Energy costs (greenhouse)

Energy (Greenhouse)

ESPs must have tunnel air forced through them and be electrically charged. This means significantly more energy is required to run the tunnel ventilation system (both to power the exhaust fans and to run the ESPs) than if ESPs are not installed.

Based on the Energetics calculation for energy in the Greenhouse Gas Emissions Report contained in Annexure 6, the approximate power consumption penalty for inclusion of ESPs in the EastLink tunnels can be calculated. The fan operating scenario is unchanged and produces a proportionate increase while the ESP collectors would operate continuously. After making an appropriate allowance for the pumps and other equipment in the ESPs cleaning systems the increase in power consumed is approximately 5,400 MWh per annum (a 33% increase). This translates into a corresponding added emission of greenhouse gases of some 7,500 tCO2-e per annum.

Concentrated Wastes

The particulate matter removed from the air stream by the ESPs is removed from the collectors in either a dry or liquid form. The quantity of waste produced depends on a variety of factors, including the volume of air treated and the concentration of particulates in the air stream. Washdown or dry wastes would have to be collected and disposed of to an approved treatment plant or disposal area. The type of disposal will be determined following analysis of the waste material collected and with the agreement of the EPA.

This illustrates another environmental cost of the use of ESPs.

It should also be noted that where ESPs have been installed in road tunnels around the world, the tunnels are commonly operated without the ESPs being operated (see Section 3.1.6 above). This has been highlighted in Norway where most of the ESPs have been out of service this year. The tunnels are, however, still operational.

3.2. Nitrogen Oxides Removal

The modelling results discussed in Section 6 of this WAA demonstrate that the ground level concentrations of NO_2 from the EastLink tunnel air will be well below the design criteria set in SEPP (AQM). This is achieved through the EastLink tunnel ventilation system's use of the CCDD contaminant management technique. Nitrogen oxides removal technology is not necessary to achieve compliance with the requirements of SEPP (AQM).

However nitrogen oxides removal technologies were nevertheless considered in the design process for the EastLink tunnel ventilation system, in order to determine whether best practice required the use of these technologies. It was determined that best practice did not require the use of nitrogen oxides removal technology. The reasons for this are set out in the following discussion of the technology used in the road tunnel context.

3.2.1. Nitrogen oxides removal technology - overview

NO_x removal technologies are complex and by comparison with ESP technology relatively immature. It is clear that there is a limited application of NO_x removal technology to road tunnels worldwide. However, Japan's decision to install three competing NO_2 removal technologies in tunnels along the new Tokyo Ring Road, and Spains decision to include two NO_2 removal plants in th M30 Madrid Ring Road Project suggests the technology is maturing.

NO_x removal technologies require cleaning of particulates from the air prior to NO_x removal. Recent improvements to ESP technologies (primarily higher removal and aerodymanic efficiencies, and the production of solid rather than liquid waste streams), have allowed the further development of the NO_x removal technologies. If it were not for the improvements in the ESP technologies it would not be possible to further refine the NO_x cleaning equipment because the particles would compromise the longevity of the NO_x removal process.

3.2.2. Japan

The Metropolitan Expressway Public Corporation has decided to install NO_x removal systems in the ventilation stacks of Central Circular Shinjyuka Tunnel in Tokyo. The tunnel is approximately 10 km long, and has 9 stacks. The tunnel is located in a crowded city area with poor ambient air quality, and the systems are thought to be needed to assist emissions from the tunnel to meet external air quality standards for NO_2.

The NO_x removal systems to be trialled in the Tokyo tunnel will be the first such systems installed anywhere in the world.

The Central Circular Shinjyuka Tunnel will be fitted with at least two types of NO_x removal systems: systems using the absorption method (to be installed at the base of four of the vent stacks), and systems using the adsorption method (to be installed at the base of the remaining 5 stacks). It has also recently been indicated that a third system may also be used in this project. The systems are combined with ESPs, which remove some of the particulate matter in the tunnel air before the tunnel air is treated in the NO_x removal systems (allowing the NO_x removal systems to operate more efficiently).

A schematic of the system is shown in Fig.1. SPM refers to suspended particulate matter.

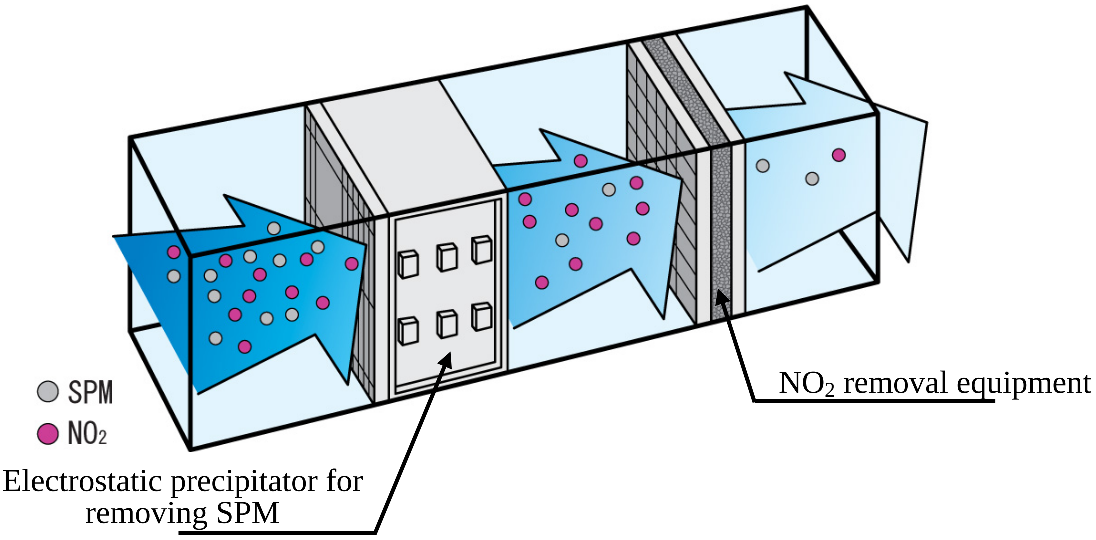


Fig.1 Schematic of air purification system

The NO_x removal system based on the absorption method removes NO_2 by chemically converting it into KNO_2 and KNO_3, using KOH on the absorbent material. The NO_x removal system based on the adsorption method uses pellets soaked in a solution of Na_2SO_4, which adsorb NO_2 physically into the pores of the pellets.

Early trials of the technology indicate that the efficiency of both types of system is likely to decrease with operating time, and the systems therefore require "regeneration". The removal efficiency of the absorption based system is expected to fall to less than 90% at 8 to 10 months after the start of operation. The absorbent materials need to be washed with water, dried, dunked in a solution of KOH, and dried again before being reinstalled in the NO_x removal system. The removal efficiency of the adsorbent pellet is expected to decrease at 12 days after the start of operation. Therefore, it is necessary to frequently regenerate the pellets by dunking them in a Na_2SO_4 solution before returning them to the NO_x removal system.

Monitoring of the operational performance of the NO_x removal systems to be installed in Tokyo will form part of the Tunnels Environment Improvement Plan (TEIP).

3.2.3. Norway

The Laerdal tunnel in Norway (22km) is equipped with a NO_x removal system – but this is for a long remote tunnel with low traffic volumes and difficulties in accessing fresh air to dilute in-tunnel vehicle emissions so as to maintain acceptable in-tunnel air quality – not an urban tunnel. The primary use of this system in the Laerdal tunnel (when it is operated) is to maintain in-tunnel (rather than external) air quality.

3.3. Emerging Technologies

There are a range of emerging technologies which may have the potential to remove contaminants from tunnel air. Most of the technologies are in the development phase and limited information is available to be presented publicly due to the need to protect the commercial interests of the developing company. These are detailed below.

3.3.1. Hyder Consulting Pty Ltd

Hyder Consulting has developed a novel contaminant removal technology which couples what is in substance a small gas turbine powered power station which uses tunnel air for combustion purposes. In essence the gas turbine combusts contaminants in the tunnel air including combustion particulates. However the power station generates its own contaminants.

Issues with NO_x production remain outstanding but are likely to be technically resolvable.

Such a system would not be suitable for Eastlink as it would require the establishment of a power station above each end of the tunnel.

3.3.2. Indigo Technologies

Indigo Technologies (Qld) in conjunction with Adelaide University have developed an electrostatic ‘agglomerator’ which, if used in conjunction with an ESP, could potentially increase the effectiveness of particle removal technologies. Importantly the technology is aimed at reducing the emissions of <2.5µm particles – a size range which has traditionally been problematic for particle removal.

It is currently unclear whether the agglomerator would significantly improve the efficiency of existing road tunnel ESPs.

3.3.3. Clean TeQ Pty Ltd

Clean TeQ uses a range of non thermal plasma and biofilter technologies to treat polluted air in industrial applications. These technologies have not been applied to road tunnels and it remains unclear as to what volumes of air could be ‘treated’ and what the outcome of such treatment would be for tunnel air.

3.3.4. Summary of Emerging Contaminant removal Technologies

While new technologies are developing, they are not sufficiently developed for robust and effective application in tunnels, where in-tunnel air quality requirements ensure contaminant levels are low and tunnel air volumes are high. An ongoing watching brief on the development of these technologies forms part of the TEIP.

4. Application of Contaminant Management Techniques to the Eastlink Tunnels

This section of the WAA analyses the application of contaminant dispersal techniques and contaminant removal technologies to the EastLink tunnels.

4.1. Australian Context – Recent Projects

The EastLink tunnel ventilation system, like other Australian road tunnels, uses contaminant dispersal techniques rather than contaminant removal techniques to manage tunnel air and to achieve compliance with in-tunnel and external air quality requirements. The various elements of the Capture, Contain, Dilute, Disperse (CCDD) design of the EastLink tunnel ventilation system are described in Section 8.2 of the WAA.

In Australia a number of recent tunnel projects have considered the use of contaminant removal technologies, either in combination with or instead of contaminant dispersion techniques. The two most significant are the Lane Cove Tunnel in Sydney, and the North South Bypass Tunnel in Brisbane.

4.1.1. Lane Cove Tunnel

In NSW a number of recent environmental assessments under the *Environmental and Planning Assessment Act* (NSW) have considered contaminant removal systems, most notably ESPs, and compared them with contaminant dispersal systems, as part of the air dispersion modelling exercise to assess the changes that may result in ambient air quality from installation of contaminant removal equipment.

The Environmental Impact Statement for the Lane Cove Tunnel in Sydney assessed the environmental implications of the project under a range of design alternatives. These included the following design scenarios:

- full portal emissions with no vent stacks and no contaminant removal technology;
- full portal emissions with no vent stacks, but with contaminant removal technology;
- emissions discharged via vent stacks, with no contaminant removal technology;
- emissions via vent stacks, and with contaminant removal technology.

An extract of Working Paper Nine: Air Quality and Health Risk is provided below:

> *“With tunnel emissions vent via stacks there would be a significant local improvement in air quality. All model predictions have included emissions from surface traffic and, where applicable, from ventilation stacks or tunnel portals.*
>
> *Modelling of both the "no tunnel" [surface road] and "treated portal" emission cases results in areas where there would a significant deterioration (increase) in pollutant concentrations.*

Table 8-2. Summary of predicted compliance with air quality goals due to modelled sources

		POLLUTANT					
		Carbon monoxide (CO)		**Nitrogen dioxide (NO2)**		**Particulate matter (PM10)**	
Year of assessment	*Scenario*	*1-hour maximum*	*8-hour maximum*	*1-hour maximum*	*Annual mean*	*24-hour maximum*	*Annual mean*
1999	*Base case / Existing*	✓	✓	✓	✓	✓	✓
2006	*Tunnel with portal emissions*	X	X	X	X	X	✓
	Tunnel with treated portal emissions	X	X	X	X	✓	✓
	Tunnel with twin ventilation stacks	✓	✓	✓	✓	✓	✓
	Tunnel with emissions treatment and twin ventilation stacks	✓	✓	✓	✓	✓	✓
2016	*Tunnel with portal emissions*	X	X	X	X	X	✓
	Tunnel with treated portal emissions	X	X	X	X	✓	✓
	Tunnel with twin ventilation stacks	✓	✓	✓	✓	✓	✓
	Tunnel with emissions treatment and twin ventilation stacks	✓	✓	✓	✓	✓	✓
Relevant air quality goal		*25 ppm*	*9 ppm*	*12 pphm*	*3 pphm*	*50 g/m3*	*30 g/m3*

✓*: Compliance of modelled sources with air quality goal*
X *: Non-compliance of modelled sources with air quality goal*

> *An interesting conclusion drawn from the analyses presented in* ***Appendix H [of working paper 9]*** *was that the results indicated that little benefit at ground-level is achieved if emissions from stacks were to be treated compared with untreated stack emissions. Emissions released from groundlevel (from vehicles) are the overwhelming contributors to ground-level pollutant concentrations. The individual contributions to ground-level pollutant concentrations from the stacks is far less significant in comparison to emissions from vehicles on the surface roads.."*[1]

The conclusions of this assessment were accepted by the New South Wales regulator in granting approvals for the Lane Cove tunnels without requiring ESPs to be fitted but requiring properly designed and operated dispersion stacks. This is essentially the same design concept for achieving both in-tunnel and external air quality objectives as the design proposed for the EastLink tunnel project.

4.1.2. North South Bypass Tunnel

More recently, an environmental assessment was undertaken for the proposed North South Bypass Tunnel, Brisbane. The tunnel ventilation system is a similar design approach to that of Eastlink (longitudinal with a vent station near the end), but longer in length. An extract is provided below:

> *"Dispersion modelling has assisted with the analysis of the effects on ambient air quality arising from the NSBT both with and without some form of emission treatment. For the analysis it has been assumed that the emission treatment would remove 60% of the* NO_x *and 90% of the PM10 from ventilation outlets emissions.*
>
> *The modelled results show the ground level pollutant concentrations both without and with filtration [ie ESPs] to be very similar. Differences to ambient air quality arising solely from emission treatment for the tunnel would be difficult to detect. The model predictions suggest that pollutant concentrations in the study area are dominated by emissions from motor vehicles on the city surface roads and that emissions treatment for each of the five kilometres (approximately) of tunnels associated with the project would result in very similar ambient air quality implications to the Project without emissions treatment."*[2]

4.1.3. Conclusions

These studies both confirm that contaminant dispersion techniques are more effective in managing road tunnel air than contaminant removal technologies, and that the use of contaminant removal technologies in combination with an effective contaminant dispersal technique will result in no appreciable reduction in ground level concentrations of contaminants contained in road tunnel air.

5. Australian Studies into the Application of Contaminant Removal Technologies in Road Tunnels

A number of public studies have been completed in Australia reviewing the application of contaminant reduction technologies to road tunnels. The conclusions reached in these studies are consistent with the approach undertaken in the EastLink project for assessing the performance and appropriateness of contaminant removal technologies.

These public studies that have been undertaken include:

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[1] p. 30-31. Working Paper 9, Air Quality and Health Risk, Lane Cove Tunnel Environmental Impact Statement, October 2001

[2] P 9-36. Draft Environmental Impact Statement, North South Bypass Tunnel, February 2005

- International Workshop on Tunnel Ventilation, held in Sydney in June 2000
- "Review of Emission Control Technology on City Link Tunnels", Bernard Bongiorno, QC, November 2000
- "Road Tunnel Ventilation in Norway", RTA NSW, September 2001
- "Electrostatic Precipitators and Ventilation in Road Tunnels in Japan", RTA NSW, October 2003
- "Review of Emission Treatment Systems and Technologies – Road Tunnel Application", Child & Associates for RTA NSW, September 2004

5.1. International Workshop on Tunnel Ventilation, Sydney 2000

The NSW RTA instigated an international workshop in June 2000 to promote a detailed discussion of international experience of local conditions and alternative technologies with a view to assessing the appropriateness of using contaminant removal technology treatment systems for road tunnels in New South Wales.

"Tunnel ventilation experts from around the world and proponents of technology were brought together (for the first time) in a forum encouraging open discussion on tunnel air management strategies for Sydney”[3].

The findings of this workshop in relation to the application of filtration technologies were:

- *“Technologies exist which can alter the composition of polluted air from tunnels*
- *A holistic approach to addressing polluted air is required when assessing tunnel air cleaning technologies. Prudent use of financial resources demands that the use of technology to alter the composition of air has to be compared with other methods of improving air quality*
- *Information on the effectiveness of electrostatic precipitators at changing the [external] air quality around tunnels, their cost and operational performance should be obtained from countries such as Norway Japan and South Korea which use them*
- *The benefits of cleaning tunnel air with various technologies – as they emerge – must be compared with the benefits of other measures to improve air quality."*[4]

The recommendations made by the facilitator included:

> *I have not recommended air cleaning technologies be employed in the M5 East project. Nor have I recommended that works stop on the construction of the ventilation system. I have not made such recommendations on the basis that:*
>
> - *Such a conclusion was not reached at the workshop; nor could it be reasonably reached on the basis of material presented at the workshop*
>
> - *The M5 East system has been designed in a way that can accommodate both particulate and gas cleaning technologies should it be determined they are necessary and effective in the future”.*[5]

5.2. Bongiorno Review of Emission Control Technology on City Link Tunnels, 2000

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[3] Dix A, Partner, Maddock Lonie and Chisholm, *Facilitators Report:. International Workshop on Tunnel Ventilation 7 to 9 June 2000 – Sydney, Australia*, 26 July 2000 at p 10

[4] Ibid at page 2 - 4

[5] Ibid at page 2 - 4

A review was commissioned by the Victorian Government in April 2000, following a change of Government in mid 1999, to investigate the use of emission control technology in the Melbourne City Link tunnels. The review was undertaken by Bernard Bongiorno, QC, part time between May and November 2000.

The investigation included the following terms of reference:

> *“Whether technology exists for the removal of respirable particles or other noxious, harmful or undesirable gases or fumes from the exhaust emissions originating from motor vehicles using the Domain and Burnley tunnels so as to materially improve the quality of the air in the vicinity of the ventilation stack associated with those tunnels, having regard to the design of their ventilation systems and/or the measured or predicted levels of such particles, gases or fumes in emissions from the ventilation stacks and in the surrounding area.*
>
> *In enquiring into the above matters you should be mindful of the effectiveness of emission control technologies generally as applied to road tunnels locally and internationally”.*

In summary the findings relevant to the installation of contaminant removal technologies were:

- *“The installation of electrostatic precipitation equipment should not be considered for the Melbourne tunnels unless and until it can be demonstrated to a much greater degree of satisfaction than is possible at present that such equipment will perform in a field situation (as distinct from a test situation) to a satisfactory standard without harmful side effects.*

- *Such use as is presently made of electrostatic precipitators in tunnels in Norway or Korea does not provide proof that electrostatic precipitators represent proven technology effective in reducing particulates in air expelled to the environment from road tunnels.*

- *There is no proven technology currently available for the removal of carbon monoxide and oxides of nitrogen from motor vehicle emissions in tunnel air.*

- *Should the necessity arise to investigate electrostatic precipitators further, such investigation should, at least, involve examining their use in Japan and, possibly, Germany.”*

5.3. RTA NSW Study Into Road Tunnel Ventilation in Norway, 2001

A delegation from the RTA in NSW undertook a visit to Norway in September 2001. It was hosted by the Norwegian Public Roads Administration (NPRA) and included inspections in Oslo, Laerdal, Trondheim and Drammen. A report was prepared at the conclusion of the visit and signed by a number of RTA and NPRA representatives and is dated 31 August 2001. (It is assumed that the report date is incorrect and should be 31 September 2001).

A summary of the issues and findings extracted from the report are detailed below:

> *”In 1989 Norway began a research program to determine the possibility of cleaning air in road tunnels. The two key factors in the program were air emissions at tunnel portals and a problem unique to Norway – the widespread use of studded tyres in winter. The tyres cause large amounts of airborne dust, providing significant problems for visibility in tunnels.*
>
> *Electrostatic Precipitators have been installed in seven road tunnels (with more than 900 road tunnels) in Norway. Five are currently carrying traffic; two are currently under construction, with one to open later in 2001 and the other in 2002.*
>
> *The following table summarises Norwegian road tunnels with ESP*

Norwegian Road Tunnels with ESPs						
Tunnel	***Location***	***Length***	***Open***	***Daily Vehicles***	***ESP***	***Status***
Festning	*Oslo*	*1800*	*1990*	*60,000*	*Stack*	*Not operating*
Granfoss	*Oslo*	*2300*	*1992*	*15,000*	*Bypass*	*Not operating*
Ekeberg	*Oslo*	*1400*	*1994*	*45,000*	*Bypass*	*Business Day traffic peaks*
Hell	*Trondheim*	*3900*	*1995*	*10,000*	*Ceiling*	*Not operating*
Nygard	*Bergen*	*900*	*1999*	*28,000*	*Ceiling*	*Operational but use not required*
Laerdal	*Laerdal*	*24500*	*2000*	*1,000*	*Ceiling*	*Operational but use not required*
Stromsas	*Drammen*	*3700*	*Oct 2001*	*Est 12,5000*	*Ceiling*	
Bragernes	*Drammen*	*2700*	*2002*		*Stack*	

ESPs have produced promising results in short-term tests under optimal conditions. Measurements immediately before and after ESP plates have shown a reduction in particulates of 80-95 percent. While these tests produce an operational guarantee standard for the ESPs. They do not show a practical filtration effect in road tunnels or outcomes over the medium to long term.

Other countries should be cautious about applying a Norwegian tunnel solution in a Norwegian context to their own road tunnels. For example:

- *The use of studded tyres in winter in Norway typically produces 70 – 75 percent mineral particles in the air, a situation that does not exist with only conventional tyres*
- *The past and current use of ESP's in Norway on a seasonal and/or peak traffic period basis does not relate to full-time ESP's use. No ESP's have operated in Norway for 24 hours a day or treated 100 percent of tunnel air*
- *ESP's in Norway have operated in conjunction with emissions of air at tunnel portals. In some countries this could result in breaches of air quality standards*
- *Air quality standards can vary between countries: eg the Norwegian limit for carbon monoxide in side tunnels is 200 parts per million averaged over 15 minutes; the limit in tunnels in Sydney is 87 parts per million.”*[6]

5.4. RTA NSW Study into Electrostatic Precipitators and Ventilation in Road Tunnels in Japan, 2003

The NSW Minister for Roads directed the RTA to undertake a visit to Japan that formed part of the RTA's ongoing efforts to stay abreast of international developments in road tunnel ventilation.

A delegation comprising members of the RTA and Baulderstone Hornibrook Pty Ltd visited Japan from 30 September to 10 October 2003 to investigate current and emerging technology and practices relating to ventilation of road tunnels.

The delegation:

- Met senior representatives of key Japanese road authorities and research bodies.

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[6] RTA NSW. *Road Tunnel Ventilation in Norway* September 2001

- Held discussions with manufacturers of ESPs and other ventilation equipment, and visited their premises.
- Visited six major road tunnels.
- Inspected a trial of experimental equipment aimed at reducing nitrogen dioxide (NO_2) in road tunnels.

The delegation held discussions with representatives of:

- The Japan Highway Public Corporation (JH)
- The Metropolitan Expressway Public Corporation (MEX)
- The Public Works Research Institute
- The Advanced Construction Technology Centre (ACTEC)
- The Ministry of Land, Infrastructure and Transport (MLIT)
- Matsushita Electric Co Ltd
- Mitsubishi Heavy Industries
- Kawasaki Heavy Industries

The delegation visited the following tunnels:

- Kan'etsu Tunnel
- Tokyo Bay Aqua Line Tunnel
- Nishi-Shinjuku Line of the Central Circular Route
- Asukayama Tunnel
- Tennozan Tunnel
- Kanmon Tunnel

A summary of the key findings and recommendations of the study are extracted from the report below:

- Japan is a world leader in road tunnel construction and operation, with 8000 tunnels totalling more than 2500 kilometres in length.
- Most Japanese road tunnels are in rural areas. They generally have lower traffic volumes than tunnels in Sydney, but have higher percentages of heavy vehicles.
- The relatively high level of diesel heavy vehicles results in visibility problems worse than those experienced in Sydney.
- No specific environmental standards are set for Japanese road tunnels. Tunnels are required to meet general standards set by the Japanese Government.
- No monitoring of air quality around road tunnels in Japan is conducted by tunnel operators and no external reporting of the environmental performance of tunnels is required.
- Electrostatic precipitators (ESPs) have been used in Japanese road tunnels since 1979 and now operate in about 40 tunnels.
- There is no fixed policy on installation of ESPs, but tunnels are considered on a case by case basis.
- While there is no policy mandating ESPs in tunnels over 2 kilometres long, ESPs are generally only considered for tunnels over 2 kilometres long.
- Most ESPs are in rural tunnels; few are in urban tunnels.

- Most ESPs have been installed to improve in-tunnel visibility in long tunnels, where visibility limits are reached well before carbon monoxide limits. It has been found to be more economical to treat air with ESPs at intermediate points to improve visibility rather than build additional deep ventilation shafts through mountains above the tunnels.
- Seven tunnels include ESPs aimed at improving external air quality. These ESPs have been installed to address community concerns, without support by technical assessment or air quality measurements. No monitoring data is available to indicate the impact of the ESPs on external air quality.
- Ventilation stacks continue to be used in conjunction with urban road tunnels in Japan.
- The quality of ESPs being manufactured in Japan appears to be more technologically advanced than those previously inspected by the RTA in Norway.
- An experiment aimed at removing nitrogen dioxide (NO2) from road tunnels has operated since April 2002 and is producing promising results.

The delegation recommended that:

- The RTA considers a pilot in a Sydney road tunnel of the latest generation of ESPs.
- The RTA further investigates the emerging technology in Japan to remove NO2 from road tunnels and considers incorporating the technology in any pilot of ESPs in Sydney.
- If recommendations 1 and 2 are accepted, a process be established to reach a considered decision on the best way to pilot ESPs in Sydney.

In March 2004, following an announcement by the NSW Minister for Roads, NSW RTA initiated a procurement process for the purposes of engaging an organisation to design, manufacture, install and commission a pilot filtration plant in an appropriate road tunnel in Sydney.

On 27 April 2004 RTA sought Registrations of Interest from organisations which had:

- the organisational and financial capability;
- the proposed technology and systems;
- the commitment and capacity to provide a detailed, fully costed proposal and the certainty associated with delivery of the proposal; and
- a proven track record of delivering and operating this type of equipment,

to design, manufacture, supply, install and commission a pilot filtration plant of the type and character required by NSW RTA and to establish procedures and train personnel to operate and maintain the pilot filtration plant.

Registrations of Interest closed on 30 June 2004. Thirteen registrations were received and the NSW RTA then selected three companies to provide detailed proposals. Matsushita , Kawasaki and Siemens have submitted detailed proposals in November 2004. The RTA is still considering these proposals and is yet to make a decision on which tunnel the trial will be held at and the company that will be selected to run the trial.

Recent announcements about not proceeding with the M4 project – and the lack of any technology testing despite the cross city tunnel and Lane Cove tunnel projects becoming operational since March 2004, suggests this initiative has lost favour.

5.5. Child & Associates Review of Emission Treatment Systems and Technologies, 2004

Child & Associates was commissioned by the NSW RTA to undertake a review of international developments in emission treatment systems in road tunnel applications. This was the fifth annual review required to be undertaken as one of the NSW Minister for Planning’s conditions of approval for the M5 East Project. A report was issued in September 2004.

The report provided an update of recent developments in emission treatment technology, and presented this information as part of a complete overview of key information presented in previous reports prepared annually to review the state of technology.

The methodology adopted during the conduct of the review, and the preparation of the report, included the following:

- A detailed review of past reports;
- A thorough survey of all relevant and available internet and literature sources;
- Correspondence, communications and meetings with the following organisations and individuals:
    - NSW RTA
    - PIARC Road Tunnel Sub Committee
    - Holmes Air Sciences
    - NSW Department of Health
    - Hideo Nakamura, President, Japan Institute for Transport Policy Studies
    - Norwegian Roads Authority
    - Mr Art Bendelius, Parsons Brinckerhoff, USA
    - Baulderstone Hornibrook
    - community groups
    - Canterbury City Council
    - Sydney City Council
    - Lane Cove Council
    - other relevant parties

Through this process of dialogue and research, a range of potential emission treatment systems and suppliers were identified. A detailed consideration of these options was undertaken and relevant information and findings were included in the report.

The following technologies and suppliers were considered as part of the process:

- Aigner GmbH - ECCO Air Filtration System
- Alstom Power – Air Cleaning Systems for Road Tunnels
- Clean Teq Pty Ltd
- Columbus Engineering – Jet Fan Enhancement Technology
- CTA International AS - EP Technology
- Deus Energie GmbH - Wandlunge® System
- Dynamic Filters (Aust) Pty Ltd – Electrostatic Filtration Systems
- EcoQuest International Pty Ltd
- FILTRONtec – CLAIR Filter System
- Flosep Australasia Pty Limited
- Fujita Corporation – Earth Air Purification System
- Hyder Consulting - Turbine Technology
- Indigo Technologies Group Pty Ltd - Particle Agglomeration Technology

- Ion Blast Limited – Electrostatic Precipitation
- Jord International – Wet Process Electrostatic Precipitation
- Kawasaki Heavy Industries Limited – NO2 Removal System
- Lloyd Energy Systems
- Matsushita Ecology Systems Ltd – Electrostatic Precipitation and Denitrification
- Matsushita – National Panasonic – Road Tunnel Environment Control Systems
- Matsushita Itochu - Hai Van Pass Tunnel in Vietnam
- Mitsubishi – Electrostatic Precipitation Technology
- Purified Water & Air Systems
- SMS Gas Turbine Technology
- TRG Biofilter – Biofiltration Technology
- UK Euro Group Plc – the OIKO-F Filtration Unit
- USC - Biofiltration Technology
- Xtor AS – Electrostatic Precipitation Air Cleaning Systems

A summary of key changes in filtration technology and its application, compared to previous reviews, extracted from the report is as follows:

Japan

- *Latest information indicates that electrostatic precipitators are installed in some 47 Japanese road tunnels, to augment the performance of longitudinal ventilation systems, and for environmental or contaminant reduction purposes*
- *Denitrification systems have been successfully trialled, and have now been approved for installation in 3 locations along the New Nishi-Shinjuku Tokyo Ring Road*

Vietnam

- *Electrostatic precipitators supplied by Matsushita Japan are being installed in the Hai Van Pass Tunnel project*

France

- *French road authorities are reported to be considering the installation of emission treatment technology in a major road tunnel in Paris*

Spain

- *Three ESPs and two* NO_2 *treatment plants are to be included in the M30 Project in Madrid, Spain.*

Italy

- *ECCO air cleaning equipment supplied by Aigner Technologies is to be installed at each portal of the Cesena Tunnel. This will be the first installation of emission treatment technology in a European (non-Scandinavian) road tunnel.*

Norway

- *The Stromsas and Bragernes Tunnels are operating with what is reported to be enhanced electrostatic precipitation equipment supplied by CTA International and Xtor respectively. Performance data on these new installations is not yet available*

United States

- *United States authorities are reported to be considering the use of emission treatment systems in the Boston Arterial project, and in a "truck only" road tunnel to be constructed in the Chicago area.*

The following summary and conclusions have been extracted from the report and detailed below:

a) *The installation of electrostatic precipitators has been confirmed in more than forty road tunnels in Japan. The use of this equipment appears to be based on a number of related factors, including the improvement of visibility and the associated enhancement of ventilation performance, and the management of air quality more generally.*

b) *Technology for the removal of nitrogen dioxide and potentially other oxides of nitrogen has been successfully developed and trialled in Japan, and the future use of such technology has now been approved in Japanese road tunnels.*

c) *The performance of electrostatic precipitators in Norwegian tunnels has been mixed. Technical and operational shortcomings appear to have been experienced with early versions of the technology. The Stromsas and Bragernes Tunnels, which opened in 2001 and 2002 respectively, involve upgraded and new versions of the technology. Results of operational performance tests on these systems, when available, will provide an important guide to the future direction of emission treatment in Norway.*

d) *The Aigner ECCO air cleaning system, involving a combination of enhanced electrostatic precipitation and continuous fibre media filtration, has been further developed in Austria. The installation of this technology in the Cesena Tunnel in Italy is now understood to have been committed, and this will be the first use of emission treatment technology in European (non-Scandinavian) road tunnels.*

e) *The Alstom NO2 removal system was successfully trialled in 1992, and is installed in the Laerdal Tunnel in Norway. Low traffic and therefore low pollution levels have meant that this system has not yet been operationally tested. On the basis of trial and commissioning tests, and its installation in the Laerdal Tunnel, the Alstom system is included as an established emission treatment technology in road tunnel applications.*

f) *FILTRONtec have successfully developed and trialled another denitrification system in Germany, but no commercial application has yet taken place. The results of pilot testing of the FILTRONtec system have been highly promising.*

g) *Denitrification systems involving catalytic processes, or the use of activated carbon, can remove hydrocarbon vapours from contaminated air.*

h) *The balance of these factors indicate that progress has been made in the field of emission treatment technology, and that viable technologies are now available to remove suspended particles, nitrogen dioxide, some portion of other oxides of nitrogen, and hydrocarbon vapours from road tunnel exhaust air.*

i) *A number of other emission treatment technologies have been considered, many with demonstrated performance in other applications. These technologies have not yet been successfully demonstrated in road tunnel applications, but offer a range of alternative emission treatment options that may be of relevance in road tunnel applications.*

j) *A potential basis for the cost-effective use of emission treatment technology in road tunnels has been identified. Confirmation of this potential will require a more detailed consideration of the specific circumstances associated with individual tunnels.*

k) *The use of emission treatment technology in road tunnels would require detailed consideration of ventilation and air quality issues specific to each individual tunnel.*

l) *It should also be noted that:*

  (i) *The existence or availability of a viable technology cannot alone be taken as a reason for its use;*

  (ii) *If circumstances favouring the use of emission treatment technology in any particular are established, then very careful consideration should be given to the type of equipment that would be most operationally and cost effective, and what installation strategy should be adopted; and*

  (iii) *The suitability of emission treatment technology in one particular tunnel situation does not automatically imply that such an approach is valid in other* *road tunnel or ventilation scenarios.*

m) *Road tunnels need to be considered on an individual basis.*

5.6 Conclusions drawn from Australian Studies

While the findings of these various Australian inquiries are not determinative of whether it would be appropriate to use contaminant removal technology in the EastLink tunnels, the fact that each inquiry has separately and independently concluded that the use of such technologies is not warranted is consistent with the view formed by TJH with respect to the EastLink tunnels.

6. References

- *Facilitators Report: International Workshop on Tunnel Ventilation 7 to 9 June 2000 – Sydney, Australia*, 26 July 2000, A Dix, Partner, Maddock Lonie and Chisholm
- *Review of Emission Control Technology on City Link Tunnels*, Bernard Bongiorno, QC, November 2000
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