

## Road Tunnels and Filtration- The main issues

The rapid development of road tunnels in Sydney has given rise to considerable debate about the need for ventilation stacks and their location, the potential for adverse health effects from increased exposure to vehicle emissions and the necessity for filtration to limit pollutant exposure both inside the tunnel and from the stack emissions. This debate is separate from and different to wider planning and transport issues, and especially the merits of public transport and the effects of motorways on traffic and communities.

The problems with tunnel fumes both inside the M5 East (for drivers) and for those who live and work near its single stack and the tunnel exits (portals) have certainly focused attention on better ways of dealing with the design and regulation of Sydney's tunnels.

The importance of this consideration is shown by the fact that on a typical working day in Sydney, motorists travel over 1,000,000 kms inside road tunnels.

This paper deals with some of the main issues, and common questions raised:

- Impact of Motorways and Tunnels on external air quality
- Air quality inside the tunnel
- Research evidence of harmful effects
- Why is there suddenly a problem with these new tunnels?
- Technical possibilities
- Economic implications
- Are stacks necessary?

### Impact of Motorways and Tunnels on external air quality

Motorways can have a generally beneficial impact on regional air quality if they free up traffic flow and reduce stop-start driving. This benefit lasts only as long as traffic flow remains smooth and disappears as traffic growth increases to fill the available road space.

In the M5 East, total traffic volume has increased markedly since it opened in December 2001. The original predictions for traffic volumes were 50000 at the time of the EIS rising to 70000 when the tunnel opened. Growth was predicted to be 1% per year however for the first 2-3 years it was closer to 1% per month. In September 2006 the weekday mean traffic was over 100000 vpd, of which 'medium' vehicles made up 4.6% and 'long' vehicles, 4.8%. Around midday, commercial vehicles, mainly diesel, make up approximately 20% of vehicles in the tunnel..

A 30 tonne diesel truck (Euro 1) produces 75 times as much nitrogen dioxide and more than 500 times as much particulate pollution as does a petrol car,

Measurements of the fumes exhausted from the M5 stack show that total PM10 emissions from the tunnel increased by 15% between October 2002 and October 2004, in spite of improvements in fuel quality and a campaign against smoky trucks using the tunnel.

After an initial drop, traffic returned to local streets as drivers avoided the congested tunnel, however some traffic lanes had been closed so these streets are less able to cope with the increased traffic. In addition, the upgrading of the Botany Bay port freight terminal will at least double the numbers of trucks using the Sydney orbital network despite improvements to the rail service to/from the port terminal. It is inevitable that this additional pollution will exacerbate the deterioration of air quality associated with the tunnels already built or under construction.

Road tunnels concentrate vehicle exhaust to a much higher level than that experienced along an open road. These emissions are then blown from one (or more) stacks and it is the degree of dispersal achieved which determines the impact on local residents. The concentration of particulate matter leaving the single M5East stack is between 900 and 1000  $\mu\text{g}/\text{m}^3$  during all working daytime hours and has exceeded 1400  $\mu\text{g}/\text{m}^3$  on occasions. (Consent conditions for the Cross City and Lane Cove tunnels permit in-stack PM10 concentrations up to 1600  $\mu\text{g}/\text{m}^3$ )

Affected community groups argue that any possible benefit to the many from reducing overall emissions is bought at the cost of the few who are exposed to the emissions from the stack and that this is intolerable in our society.

It is inevitable that under the weather conditions common in Sydney, stack emissions will sometimes impact on the ground at relatively high concentrations.<sup>i</sup>

In addition to the established harmful effects of vehicle pollution, estimated to cost Sydney over \$1.5 billion annually and now shown to cause twice as many deaths as those lost through motor vehicle accidents in Australia, it is also possible that vehicle exhaust held over longer periods of time at high concentrations in the confined space of the tunnel becomes even more harmful through chemical interaction.

Residents living close to both the Eastern Distributor and M5East tunnel stacks report that they can clearly smell the tunnel exhaust, and have noticed the increase in grimy dust. They have continued to report significant adverse impacts on their health, for example,

eye, nose and throat irritation, headaches and breathing problems. Some have been forced to sell their homes and move because of the impact on their health and the health of their children.

As documented by three Parliamentary Inquiries,<sup>ii</sup> the air quality monitoring system set up to measure the pollution impacts is totally inappropriate as it is based on the NEPM (National Environment Protection Measure) which was specifically designed for ambient regional monitoring, not to measure the effects of a point source of pollution. The monitoring does not specifically measure the fine particle component which is the major cause of the ill effects from the tunnel and does not represent the impact of 'peak' events.<sup>iii</sup>

In 2003, NSW Health, after strong community pressure, carried out a study where residents around the M5 East stack were examined by specialists. The first stage of this study<sup>iv</sup> found a strong likelihood that the stack was the cause of the reported health impacts. The second stage of the study,<sup>v</sup> released in 2004, which used a random telephone survey and asked residents closed questions about their health over the previous four weeks, found otherwise, however this study was seriously flawed in its design and execution and can be demonstrated to be unreliable and invalid.

One of the many flaws identified was that the study did not measure the actual degree to which individuals interviewed in the telephone survey were exposed to stack pollutants but used an 'annual average' map of pollutant exposure to estimate the exposure of interviewees during the 4 weeks of the survey. This is obviously an invalid study method which is equivalent to assuming that, because Sydney receives an average of 1200mm of rain per year, it will receive 100mm of rain in any one month.

A detailed report on the second stage of this health study, commissioned by Lane Cove Council and prepared by three experts (air quality, epidemiology and statistics and experimental design), recommended that: "*the Council not accept the findings of the Phase 2 report and we strongly contest their relevance to other tunnel situations. Whilst the NSW Health efforts are welcome, the disparity of the conclusions from Phases 1 and 2 and the considerable number of potential flaws in the Phase 2 design and conclusions are significant enough to request withdrawal or substantial revision of the current Phase 2 report.*" The expert report is available on the Lane Cove council web site.<sup>vi</sup>

NSW Health re-examined its findings in the light of the new information about the actual levels and distribution of pollution but was still unable to reach any firm conclusions about causal relationships between the stack (or portal) emissions and reported symptoms, but warned against interpreting this finding as a demonstration of a lack of such a relationship.<sup>vii</sup>

### **Air quality inside the tunnel.**

There are constant complaints about the air quality inside the M5East tunnel and it certainly fails the 'smell' test, probably the most reliable indication of the potentially harmful nature of the atmosphere in the tunnel.

Currently, the only enforceable regulation relating to pollutant levels inside a tunnel is for carbon monoxide. For the M5 the condition reads: *70. The tunnel ventilation system(s) must be designed and operated so that the World Health Organisation (WHO) 15-minute carbon monoxide (CO) goal of 87 ppm is not exceeded under any conditions.*

Following a number of exceedences of this goal in the M5East tunnel, the RTA has attempted to redefine this goal. This means that if a person thought that they had been exposed to higher levels of carbon monoxide they would have to establish the exposure lasted for longer than 15 minutes rather than being able to rely on the instrumentation installed in the tunnel.

Despite objections by community groups, similar goals incorporating the concept of personal exposure, have been set in the conditions of approval for other later tunnels. The ability to enforce them is yet to be demonstrated.

There are no other enforceable standards set for Sydney tunnels, however the tunnel operators claim to observe the visibility standards suggested by PIARC, the world road tunnelling association, to ensure drivers can see far enough to avoid obstacles. According to PIARC, this standard leads to a 'very uncomfortable atmosphere'.

This is in spite of the fact that fine particulate matter from diesel engines is now known to be a more potent carcinogen (on a weight basis) than cigarette smoke.

In - tunnel air quality limits for new tunnels being built in Brisbane and Melbourne are significantly more strict. For the Brisbane a PEAK carbon monoxide concentration of 70ppm (15 minutes) . This prohibits a CO concentration in excess of 70ppm for 15 minutes at any monitor, irrespective of motorist exposure. In the new Melbourne EastLink tunnel , carbon monoxide exposure will be limited to 50ppm (15 minutes). Both of these limits will lead to a significantly cleaner tunnel than the M5 (or other Sydney tunnels).

Pollutant levels outside the M5East tunnel mostly remain between 20-40 $\mu\text{g}/\text{m}^3$  PM10 and 20 -90  $\mu\text{g}/\text{m}^3$  NO<sub>2</sub> (over a 24hour average). Inside the tunnel, they can be over 1400 $\mu\text{g}/\text{m}^3$  PM10 and 800 $\mu\text{g}/\text{m}^3$  nitrogen dioxide (NO<sub>2</sub>). Mean exposure levels, as estimated by the NSW Health study into in-tunnel air quality,<sup>viii</sup> were NO<sub>2</sub> : 370 $\pm$ 60 $\mu\text{g}/\text{m}^3$  and PM2.5 388 $\pm$ 106  $\mu\text{g}/\text{m}^3$ . These levels were reduced by about 75% by closing car windows and recirculating air inside the car, but still exceeded the NEPM standards for background air pollution.

As these levels are above the range of exposures and concentrations known to trigger delayed asthmatic attacks in sensitive individuals, the NSW Health report suggested that these people, and drivers in open vehicles and motorcyclists should avoid using

the tunnel and that motorists should close car windows before entering the tunnel. In addition NSW Health as early as February 2002 suggested that the RTA should warn motorists by means of signs but as yet the RTA refuses to do so.

The NSW Health in-tunnel air quality study failed to examine the impact of repeated trips through the tunnel and of the interaction of different pollutants, especially that of NO<sub>2</sub> and PM<sub>2.5</sub>. This is a major deficiency.

The observation made by members of the team carrying out the in-tunnel measurements that they suffered distress and illness during the collection of the data was removed from the final report of the study on the request of the RTA on the basis that the observation was 'unscientific'.

Other potentially harmful components of in-tunnel air include volatile organic compounds (VOC), of which benzene is probably the major contributor of risk, and carcinogenic and genotoxic poly cyclic aromatic hydrocarbons (PAH). In the tunnel atmosphere many of these volatile components are captured on the surface of fine carbon particles (PM<sub>2.5</sub>), increasing the toxicity associated with an increased surface area on a weight basis (compared to large coarse particles) and because the fine respirable particles are mainly soluble in the lungs.

Repeated measurements taken in the M5 and other city tunnels have led to the conclusion that regular usage of tunnels will result in a significant increase in the exposure of motorists to pollution. In general, each minute spent in a city tunnel will produce an exposure equivalent to 5 to 15 minutes of travel on a congested city motorway.

The reduction of travel time by use of the tunnel does not compensate for the increase of exposure. The mean PM<sub>10</sub> exposure of motorists on trips between Bexley North and Falcon St North Sydney was about 100 µg/m<sup>3</sup> while the exposure on the open parts of the motorway during the trip was about 25 µg/m<sup>3</sup>. This is a significant addition to the total daily exposure of these motorists to PM<sub>10</sub>. Furthermore, since the pollution in a traffic tunnel is generated mainly from tail-pipe emissions, for equivalent concentrations of PM<sub>10</sub>, the proportion of toxic fine particles in the tunnel PM<sub>10</sub> fraction is several times greater than that in background PM<sub>10</sub>.

Hence tunnel pollution, on an equal weight basis, is inherently much more toxic than ambient background atmosphere composed of PM <sub>10</sub> derived from a variety of sources.
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### Air pollution changes.

In a 2002 article in the Lancet, leading air pollution expert Professor Bert Brunekreef, of the University of Utrecht in the Netherlands noted what he called "A new era of air pollution research"<sup>ix</sup> calling attention to the fact that the very nature of air pollution had changed in recent years:

*'20 years ago, the era of successful abatement of traditional air pollutants culminated in a voluminous review of the health effects of ambient particulates. At concentrations seen in the late 1970s in the developed world, adverse health effects were then regarded as unlikely. In the two decades since then, however, air pollution has re-emerged as a major environmental health issue. One reason is that, although air pollution from combustion of traditional fossil fuel is now present in much lower concentrations than 50 years ago, other components have gained prominence. Photochemical air pollution, characterised by high ozone concentration% during warm and sunny weather, was found to occur not only in places like Los Angeles and Mexico City, but also in large areas of Europe. Oxides of nitrogen produced by the ever rising number of motorised vehicles have increased until recently. Airborne particles have changed size distribution and composition, altering their toxicity.'*

The implication of this observation is that there needs to be a reassessment of attitudes and responses to air pollution and especially to particulate pollution and that regulation and standards based on established guidelines and measurement techniques are no longer adequate or appropriate, because the essential nature of the pollutant has changed.

### Research evidence of harmful effects

Exposure to fine particles, especially the ultra fine particles below PM<sub>2.5</sub>, results in adverse short term effects such as cough, phlegm, mild to severe irritation of eyes and upper airways and exacerbation of asthma, and long term effects such as cancer, heart disease and premature deaths. Increased levels of particulate pollution are directly related to increases in hospital admissions, city wide. There is no safe threshold for exposure to particles, especially those associated with diesel engine exhaust.

A recent report (October 2004) in the New England Journal of Medicine<sup>x</sup> found that the risk of myocardial infarction was increased three fold by recent exposure to vehicle pollution . An accompanying article described a credible explanation of the mechanisms involved noting that the article provided . *"compelling epidemiologic evidence that particulate air pollution from traffic may trigger the abrupt onset of acute myocardial infarction. An understanding of air pollution in the larger context of triggering of the entire process of atherosclerosis suggests, in addition, that air pollution plays a more complex and multifaceted role in the development of cardiovascular disease over the longer term."*

In the December 2004 issue of the journal *Occupational Environmental Medicine*. 2004; **61** : 956-961, the reported association between short term variations in air pollution and risk of death upon exposure to levels of pollution lower than the NEPM standard of 50µg/M<sup>3</sup> has been confirmed in a study of 968,514 deaths. The association appeared quite linear.

At least 50 new papers have appeared in peer reviewed medical and environmental journals every year since 2000 on the adverse impacts of particulate matter and vehicle pollution. Adverse impacts, relating to developmental, respiratory, cardiac and cancer pathology, have been identified in utero, amongst infants, children, young adults, the mature aged and the elderly.

Another major component of vehicle exhaust and tunnel air is nitrogen dioxide. It is a strong irritant causing eye and lung irritation and can trigger asthma. Research<sup>xi</sup> carried out in Sweden since 1996 for PIARC has identified a significant impact on sensitive (healthy allergic asthmatic) individuals exposed to tunnel air.

Experimental subjects were exposed to common tunnel pollutants as follows:

- NO<sub>2</sub> levels of 500µg/m<sup>3</sup> for half an hour
- NO<sub>2</sub> levels of 500µg/m<sup>3</sup> for three 15 minute periods over 2 days
- in a road tunnel to NO<sub>2</sub> levels of 300 µg/m<sup>3</sup> together with PM<sub>2.5</sub> levels of 100µg/m<sup>3</sup>.

(It is not technically feasible to expose people to 'realistic' PM<sub>2.5</sub> in the absence of other pollutants, but nitrogen dioxide is available as a pure gas, able to be used in an exposure chamber).

In each case there was a similar increase in sensitivity (hyper-responsiveness) to allergen which occurred some time after the actual exposure.

The response to NO<sub>2</sub> is not surprising, considering the known irritant effect of the gas, however there are two other conclusions of significance to tunnel ventilation design:

- short exposure times act cumulatively over periods likely to be experienced by commuters.
- nitrogen dioxide and fine particles (PM<sub>2.5</sub>) act additively.

Significantly higher levels of NO<sub>2</sub> and PM<sub>2.5</sub> are experienced in the M5 tunnel than those found in the Swedish study but the exposure time in the M5E is shorter. The result of the three 15 minute exposures in two days is representative of reactions to the exposures likely in Sydney tunnels.

Following the publication of these results the Vagverket (Swedish National Roads Administration 2003) examined the implications of regulation of nitrogen dioxide at 4 different levels,

Exposure level	Assessment of suitability
1000µg/m <sup>3</sup>	inappropriate as it gives no protective margin for sensitive individuals
500µg/m <sup>3</sup>	inappropriate as it gives no protective margin for sensitive individuals
300µg/m <sup>3</sup> / 30 min exposure	at best, marginal because higher levels of particles could be experienced in the tunnel which would add to the impact, especially with asthmatic individuals who may be in a state of heightened sensitivity
150-180µg/m <sup>3</sup> / for 15 to 30 min	judged to contain a margin of safety for all but the most sensitive individuals in the presence of particles but noted that it lacked experimental verification.

The limit of 180µg/m<sup>3</sup> NO<sub>2</sub> for half an hour correlates with to the proposed Swedish EPA level for ambient NO<sub>2</sub> of 90µg/m<sup>3</sup>/1hr. (The Australian NEPM goal is 250µg/m<sup>3</sup>/1hr and the WHO ambient goal is 200µg/m<sup>3</sup>/1hr)

Nitrogen dioxide exposure levels in the M5 tunnel rarely exceed 500µg/m<sup>3</sup> however the level 300µg/m<sup>3</sup> is exceeded during the majority of day time hours. This level also occurs in the presence of PM<sub>2.5</sub> levels of up to 3 times those experienced in the Swedish experimental exposure. Based on these observations, it is clear that the levels currently existing in the M5 and other Sydney tunnels are higher than is desirable or safe.

Although it is obviously desirable to reduce exposure to both of these pollutants, the removal of either would lead to a significant reduction of the risk to drivers in the tunnel. This is a justification for using in-tunnel electrostatic precipitators to remove particles along the length of the tunnel.

### Why is there suddenly a problem with these new tunnels?

It is frequently suggested that these problems were not experienced in older road tunnels. The reason for this is both simple and very complex and relates both to changes in vehicle emissions and tunnel ventilation technology.

Until recently, the volumes of air required for tunnel ventilation were determined entirely by the need to dilute carbon monoxide to safe levels. The other pollutant of major concern was lead from compounds used to increase the octane rating of petrol. Until recently, experience had generally shown that if carbon monoxide was successfully controlled, other pollutants would be kept to safe or at least acceptable levels.

The only exceptions were in Japan which had an exceptionally high level of diesel vehicles and in Norway where road dust generated by studded tyres was a problem. Experiments in these countries led to the development of electrostatic precipitator filtration for dust and particulate matter, first installed in the Taruga tunnel in Japan in 1979. Currently there are about 60 installations world wide.

Over the last 20 years there has been a significant change in vehicle emissions due to the use of unleaded petrol and catalytic converters:

- Lead levels have been reduced to negligible levels
- Carbon monoxide levels have been reduced by about 85% in light petrol engines.
- Sulphur dioxide levels have dropped due to the use of low sulphur fuels
- Nitrogen dioxide levels have tended to increase due to the introduction of more efficient engines.

The 'Euro' requirements for the reduction of PM10 emissions from diesel engines have led to a progressive reduction in particulate matter however this has had an unforeseen adverse impact on the potential for harm from particulate emissions. Although PM10 levels have been reduced by up to 60% (by weight), the number of fine and ultrafine particles has increased significantly, thus making diesel exhaust more harmful than it previously was because it can now penetrate more deeply into the lungs. A very large proportion of particles in tunnel air are less than 1 micron in diameter. Diesel exhaust is now known to be a cause of lung and other cancer.

The result of the sum of these changes can be seen in the history of the design of the M5East tunnel. Up until 1997, the ventilation volume for the tunnel was planned to be 2000 m<sup>3</sup>/sec. This volume was appropriate on the basis of the traffic volumes predicted and using the old carbon monoxide emission figures. At the time of the politically driven change from 3 stacks to one, the ventilation volume was reduced to a maximum (congested traffic) of 856 m<sup>3</sup>/sec. The reduction was justified by factoring in the expected 'improvements' in emissions which would occur during the life of the tunnel (also assuming a 1% per annum traffic growth!).

The inadequacy of this ventilation volume became obvious as soon as the tunnel opened and attempts were made to increase the volumes of air used. The practical limit was found to be about 900-920 m<sup>3</sup>/sec, at which stage the side blast of air in the centre of the tunnel became dangerous to motorcyclists and trucks had their loads dislodged. This is the main cause of the problems both inside and outside the M5 tunnel, as the air volume is inadequate to dilute the pollution levels to acceptable levels.

The 2000 guidelines for tunnel ventilation by PIARC, the international road tunnelling association, state that as a result of these changes carbon monoxide is no longer a suitable 'marker' for tunnel air quality. As a proportion of tunnel air related to carbon monoxide, the harmful components nitrogen dioxide and PM2.5 have increased by a factor of about 3.

### Technical possibilities

Technology to remove fine particles is now highly developed with manufacturers in both Japan and Norway having achieved efficiencies of removal of fine particles of between 80 and 95% with air flow velocities in excess of 10m/s. Other manufacturers are also prepared to offer similar equipment but this has not been proven in actual installations. A number of manufacturers also offer nitrogen dioxide removal systems but only one, that developed by Alstom Power Norway, has been installed operationally in a tunnel.

During 2005 there were two highly significant advances in road tunnel air cleaning.

- In Spain, it was announced that, in response to community concern about external air quality, the ventilation stacks of the 55km of tunnels making up the Calle 30 ring route in Madrid would be filtered.
- In Denmark the Copenhagen tunnel project is approved. The 15.5 km tunnel complex will be completely filtered and will take advantage of the benefits of filtration in its ventilation system.<sup>xii</sup>

In the Madrid Calle 30 system contracts in the first two tunnels to be completed (the 'By-pass' and the 'River' tunnels) were awarded to 4 major suppliers of filtration equipment, in what is effectively a giant experiment to select the most suitable equipment for the remainder of the project. The contractors are Mitsubishi, Siemens, Filtrontec, Aigner and CTA (Clean Tunnel Air) and the first filtration systems will commence operation in April or May 2007.

Ventilation stations contain either electrostatic precipitator equipment alone or electrostatic precipitators and nitrogen dioxide removal equipment to treat air before it is released through very short stacks

The various NO<sub>2</sub> removal systems, all of which claim removal efficiencies around 80%, are also claimed to remove a significant proportion of volatile organic compounds. All NO<sub>2</sub> removal systems require the installation of electrostatic precipitator filtration equipment to remove particles from the air before it enters the gas removal system

The main problem in the M5East tunnel comes from the fact that it is undersized for the volume of traffic now using it, and it uses a single stack as the outlet. It is not feasible to further increase air flows within the tunnel to increase dilution of the pollutants as this would lead to dangerously high air flow speeds at the centre of the tunnel. Emission of pollutants from the portals is prohibited by the conditions of approval, except during emergencies.

In October 2005, the RTA submitted a proposal to the Department of Planning to 'improve' air quality. This proposal included a 'trial' of filtration to remove pollution from the west end of the westbound tunnel and the use of extensive portal emissions for up to 14 hours per day to enable extra fresh air to be introduced into the tunnel.

Although the plan would achieve improvements inside the tunnel, it would lead inevitably to a significant degrading of air quality around the tunnel portals at Bexley North and Marsh St, Arncliffe, with significant increases in respiratory and cardiac health and cancer risks to local residents.

This part of the RTA plan has been seriously criticised and rejected by the local community, however these criticisms could be overcome by the installation of air cleaning stations near the portals on the basis of the Madrid developments. These air cleaning stations would remove both particles (by use of electrostatic precipitators) and nitrogen dioxide (presumably by the use of the most appropriate technology identified in Madrid). The only remaining toxic component would be a low level of carbon monoxide (lighter than air) which could be safely dispersed vertically into the air.

Community organizations have made a submission to the RTA and the Department of Planning, suggesting an alternative scheme involving the treatment of 250 m<sup>3</sup>/sec of air at both portals and the progressive cleaning of air for particles only using electrostatic precipitator equipment installed in the fan niches currently occupied by jet fans in the westbound tunnel.

The proposal is based on established electrostatic precipitator technology used to progressively clean the air in ceiling mounted units as it moves along the tunnel. This technique is being increasingly used overseas, most recently in the Stromsas tunnel in Norway and the Aqua Line tunnel under Tokyo Bay in Japan. This type of installation has become possible as electrostatic filtration systems have now been designed to deal with high air velocities, thus reducing the size of the installation.

This would require extensive study and consultation to ensure that no further risks or impacts occur for the local community.

### Economic implications

It has been regularly, and wrongly, claimed that the installation and use of electrostatic precipitator equipment is prohibitively expensive, both to install and run.

Both major users of the technology, the Japanese and the Norwegians claim an overall economic benefit from the use of the filtration technology, above and beyond that which accrues from the improvement of external air quality. Specifically, the Japanese claim a whole of life reduction in ventilation cost, as compared to 'traditional' methods of ventilation, in excess of 30%. The saving occurs when ventilation systems are designed to take advantage of the technology (rather than it being fitted to an existing design) and comes from the reduction in the size and number of ventilation fans required and the reduction in maintenance and running costs.

In the case of the Laerdal tunnel in Norway, the use of combined filtration and nitrogen dioxide removal eliminated the necessity to drive an exhaust stack through 1100 metres of rock. The system is capable of cleaning 180 cubic meters of air a second and the total cost (2000) was \$US6 million, of which less than half was from the electrostatic precipitator. This cost was regarded as high because the whole system was installed 6km into the tunnel and 1100 metres under ground in a very remote area.

On the basis of costs in Madrid, the filtration and gas cleaning equipment, installed and operational, but excluding the civil costs of excavation etc, cost between €1.2 and 1.6 million per 100m<sup>3</sup>/sec of air cleaned, in this large scale installation.

As a cost comparison, the decision to move from the original 3 stack proposal for the M5East to the single stack at Turrella cost an additional \$30 million and added an additional \$1 million per year to the running cost of the tunnel. The additional ventilation tunnel for the Cross City tunnel, which would be unnecessary if filtration was used, is costed at \$40 million, similarly for the longer Lane Cove tunnel with its two stacks, the cost is \$60mill. The M5East tunnel uses about 40 Gigawatt hours (million Kwhrs) of electricity per year costing over \$3 million per year. This is equivalent to 55,000 tonnes of greenhouse gases per year. Electrostatic precipitators to clean 900 cubic meters of air a second in the M5 tunnel would only consume 30Kw. Annual energy consumption would be about 1 Gigawatt hour per year, but fan usage may be reduced.

### Are stacks necessary?

Road tunnels can be designed which do not need stacks, especially those located in rural and remote areas, where traffic volumes are generally low. Rural tunnels up to 4 km in length are often ventilated through their portals at ground level. Except in unusual circumstances, large tunnels constructed in existing urban areas will require some sort of structure to disperse exhaust gases since there is no technology currently available to remove carbon monoxide.

Under present regulatory standards, the volume of air needed inside the tunnel is to a large degree determined by carbon monoxide levels, the size and nature of these dispersal structures is determined almost entirely by particulate matter. An impact of 5 - 10µg/m<sup>3</sup> of PM10 for 1 hour from a tunnel would be unacceptable, however this represents a 200 fold dilution of the stack emissions. Such impacts are predicted to occur around the M5East stack. A similar dilution of carbon monoxide, even if present in the stack exhaust at the maximum allowable concentration of 87ppm would represent a ground level concentration of 0.4ppm, negligible in impact when compared to the recommended 1 hour WHO exposure level of 25ppm.

The structures required for the dispersal of the carbon monoxide alone contained in the tunnel exhaust can be much simpler and smaller than those required for particulate matter and nitrogen dioxide. They would be closer in size to those used to ventilate city car parks and their actual size is more likely to be determined by the need to safely disperse fumes in the case of fire than by any other consideration.

## Conclusion

Road tunnels are a useful way to improve access within cities and have the potential to provide actual benefit., however they must be made free of harm to users and to those otherwise affected by them. The rapid development of medical knowledge has shown that many of the health impacts of vehicle pollutants have been underestimated in the past. It is fortunate that technology now exists to remove most of the major components of vehicle pollution which cause harm.

The state of knowledge is now such that the proposers and constructors of tunnels will be seen as failing in their duty of care if they do not fit appropriate and effective equipment to reduce pollution impacts to the greatest degree possible both inside and outside of tunnels. It is of crucial importance that these technologies be deployed immediately, during the construction phase of Sydney's tunnels, rather than attempting to fit them later at great expense. Existing tunnels must be fitted with appropriate air cleaning equipment to bring them to an acceptable state of safety and amenity.

Mark Curran

Revised 16<sup>th</sup> April 2007

## Footnotes

<sup>i</sup> An animation of 'ground strike' from a stack exhaust plume is illustrated at <http://www.dar.csiro.au/pollution/Meander/index.html>

<sup>ii</sup> 1999 inquiry <http://www.parliament.nsw.gov.au/prod/PARLMENT/Committee.nsf/0/58908A6040C5DFD0CA256CF4002108C7>

2001 inquiry <http://www.parliament.nsw.gov.au/prod/PARLMENT/Committee.nsf/0/E4C65A96CE634A9ACA256A9100833268>

2002 inquiry <http://www.parliament.nsw.gov.au/prod/PARLMENT/Committee.nsf/0/44F450FBD993CFCECA256C8600055EA8>

<sup>iii</sup> From: "Residents Against Polluting Stacks (Inc) Submission to the NSW Department of Planning in response to the NSW RTA's M5 East Tunnel - Partial Portal Emissions and Trial of Tunnel Filtration Technology Environmental Assessment Report, Application for Modification of the Approval. October 2006"

### **Regulation, NEPM goals and the operational protocol**

There has been a continuing argument about the appropriateness of using the NEPM goals (for particles) as a regulatory mechanism for assessing the air quality impacts of the stack and tunnel. The frequency with which the argument reappears in public debate, including the 2005 NSW Auditor General's report into air quality and the 2006 Parliamentary Inquiry into the Health Impacts of air pollution in the Sydney Basin is a measure of its significance, especially given the increasing knowledge of the health risks caused by fine diesel particles.

While the regulation based on the NEPM goals may have been adequate when portal emissions were effectively prohibited, it is clearly not adequate for control of planned and deliberate emissions at ground level for 14 hours per day, and the experience of local residents during the 2003-4 portal emissions demonstrated this inadequacy.

The NEPM documentation contains the following stricture: '*Conversely, the air quality of some localised areas within major airsheds are dominated by local activities such as that experienced in a road tunnel or a heavily trafficked canyon street. Air quality management in these areas is complex and needs a different approach to that directed at meeting ambient standards intended to reflect the general air quality in the airshed*' (p 13 from NEPM 1998)

It excludes the use of the goal figure and notes that '*air quality management needs a different approach*' in other words the whole concept of 'addition', which counts the added portion in the same way as the existing background, is invalid. Therefore, it should not be used.

In an attempt to clarify the issue, some time ago we approached the Executive Director of the National Environment Protection Council, Dr. Bruce Kennedy, for an assessment. The reply he gave us leaves no room for disagreement: '*The NEPM PM10 standard...is a legislative entity and applies only to the ambient background, and a population of 25,000 people. It does not and should not, be applied to a point source such as a tunnel stack from which an entirely different composition of pollutant arises.*'

The salient points are:

- The NEPM standards apply only to background and a population of 25000 people.
- It does not and should not be applied to a point source such as a tunnel.
- The reason why it does not apply is because of the entirely different composition of pollutant which arises.

To us this is quite clear; there is no justification for the use of the NEPM standard in the way in which it is used and, in fact, it is dangerous to do so. After all, asbestos is distributed in the air as particulate matter, much of which falls within the PM10 classification. The NEPM goals would certainly not be suitable for assessing asbestos exposure!

<sup>iv</sup> Phase1 report [http://www.health.nsw.gov.au/pubs/m/pdf/m5\\_stackreport.pdf](http://www.health.nsw.gov.au/pubs/m/pdf/m5_stackreport.pdf)

<sup>v</sup> Phase 2 report <http://www.health.nsw.gov.au/public-health/ehb/buildings/m5east/phase2report.pdf>

<sup>vi</sup> at <http://www.lanecove.nsw.gov.au> under "Lane Coves' Future - You're Say - Lane Cove Tunnel Project.

<sup>vii</sup> Re-analysis of Phase 2 report [http://www.health.nsw.gov.au/pubs/2006/m5\\_health\\_impact.html](http://www.health.nsw.gov.au/pubs/2006/m5_health_impact.html)

<sup>viii</sup> M5East In-tunnel study <http://www.health.nsw.gov.au/pubs/a/m5rep2003.htm>

<sup>ix</sup> Brunekreef, Bert, Holgate, ST. Air pollution and health. Lancet 2002 vol 360.p1233-42

<sup>x</sup> Peters, Annette et al. Exposure to Traffic and the Onset of Myocardial Infarction. NEJM 2004 vol. 351 no. 17.

<sup>xi</sup> Svartengren M, Strand V, et al. Short-term exposure to air pollution in a road tunnel enhances the asthmatic response to allergen. European Respiratory Journal(2000)15.(4)p716-724

<sup>xii</sup> Copenhagen tunnel details: <http://www.kobenhavertunnelen.dk/Billeder/Copenhagen-tunnel-city-group.doc> -