Regulation of pollutants in Sydney tunnels

The NSW RTA routinely claims that the air quality inside their tunnels meets either the 'regulations', the 'standards' or 'international standards of best practice'.

From the context of the RTA statements the regulations or standards refer to either the WHO goals for carbon monoxide and the provisions of the PIARC (World Road Association) Committee on Road tunnels.

The clear implication is that these standards or regulations for tunnel operation are nationally or internationally applicable or accepted and are appropriate for this purpose.

In fact there are no such standards specifically for tunnels and similar environments.

The only 'regulations' which may be legally enforceable in NSW are the minister's conditions of approval for the project. These conditions refer to a number of 'goals', based either on the WHO or the Australian NEPM ambient goals.

The WHO goals are not standards, however they may be adopted by national and international legislation as standards. They have been given regulatory force by the European Union mainly in relation to ambient air quality and have been accepted as the basis for the Australian NEPM as ambient goals in some cases.

NEPM standards are legislative entities and apply only to the ambient background, and a population of 25,000 people. They do not and should not be applied to a point source such as a tunnel stack.

The NEPM documentation clearly states that these goals should be used ONLY for the assessment of ambient conditions and specifically refer to their unsuitability for use in the case of '*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'*. from NEPM 1998 p13

In practical terms, this caveat applies more to particulate matter and other pollutants than to carbon monoxide as the mode of action of carbon monoxide in the body is largely independent of other pollutants.

The unsuitability of carbon monoxide as a sole regulatory measure or marker for tunnels arises from fact that the quantity of carbon monoxide in motor exhaust has decreased by 70 to 75% since the widespread use of exhaust gas catalytic converters. Other harmful components have not decreased by the same proportion and it can be argued that some have actually increased. This means that the 'rule of thumb', which held that if carbon monoxide was held to acceptable levels then the levels of other harmful components would also be acceptable, no longer holds.

The difference between maintaining 'Health' and maintaining 'Safe Conditions'.

Providers of infrastructure such as tunnels have the responsibility to provide projects which are both safe and free from risk, especially to the health of both motorists and local residents.

There is a real difference between 'safety' and 'health' in the context of tunnel pollution.

Safety is about "being free from danger". On the other hand, 'health' is about bodily and mental well-being.

Of all the toxic pollutants in the airstream of a traffic tunnel, the levels of carbon monoxide are crucial for 'safety' rather than 'health' since, in the context of a likely tunnel atmosphere, carbon monoxide is the only pollutant able to cause unconsciousness very quickly.

Once carbon monoxide combines with haemoglobin it takes up to 9 hours for this to be displaced when the person breathes clean air, however urban motorists are not exposed to 'clean' air whilst driving. Hence there is also a potential 'safety' problem with multiple exposures, especially to professional drivers.

All the other pollutants have importance relating mainly to 'health', although the particle/nitrogen dioxide mixture in tunnel atmospheres can also provide a 'safety' problem through its ability to promote rapid onset of debilitating asthmatic symptoms (or even severe sneezing episodes). These sorts of problems have been reported in the M5East tunnel, where motorists have reported the loss of their ability to control their vehicles.

Conversely, carbon monoxide induced unconsciousness is also a health issue as are the impacts of high carboxyhaemoglobin levels on the foetus and on persons with respiratory problems such as emphysema.

This is a subtle difference. Whilst the other gaseous pollutants and particles, either alone or in combination, can impact on health, especially in those persons with underlying risk-conditions e.g., heart and respiratory diseases, these do not normally present a 'safety' risk to a motorist in the tunnel as great as that from carbon monoxide, at least in the ACUTE phase.

The issues of the health impacts and the appropriate standards are complex for the other pollutants. Unlike the UK. there still is no standard for the highly toxic and carcinogenic 1,3-butadiene in the NEPM system in Australia, nor is there any health based standard for short term exposure to fine particles.

Additionally, it is of concern that no attempt has been made to address the impacts of pollutants in combination, except to note that there is a potential for such impacts.

Regulations Applying in Sydney Tunnels

Carbon monoxide.

The conditions of approval for Sydney tunnels refer to the World Health Organisation 15 and 30 minute 'goals' of 87ppm and 50 ppm. This is the only numerical goal specified for conditions in the M5 tunnel.

This is in spite of the fact that the PIARC documents on road tunnel ventilation state that carbon monoxide is no longer suitable as a sole determinant of tunnel ventilation. *"Classically most ventilation control systems are based on CO measurements in tunnel. Due to the decrease of CO emissions, these measurements are no longer sufficient to control the ventilation".* 'Pollution by nitrogen dioxide in road tunnels' PIARC (AIPCR, 05.09.B.2000)

The PIARC 1995 publication 'Road Tunnels: Emissions, Ventilation, Environment' upon which the M5 design is largely based notes: *'In this publication new design information and some references are given for dimensioning a longitudinal and a semi-transverse ventilation system.'*

It contains the following table which is the basis of the 'regulations' the RTA claims to follow.

Table 2.3

Traffic situation	CO-concentration		Visibility	
	Design year dimensionnement		Extinction coefficient K	Transmission s (beam length: 100 m)
	1995	2010		
	ppm	ppm	10-3 . m⁻¹	%
Fluid peak traffic 50 - 100 km/h	100	70	5	60
Daily congested traffic, standstill on all lanes	100	70	7	50
Exceptional congested traffic, standstill on all lanes	150	100	9	40
Planned maintenance work in a tunnel under traffic	30	20	3	75
Closing of the tunnel	250	200	12	30

The wide range of 'permissible concentrations' for CO is clearly not in the nature of a 'standard'.

The CO level is noted to correspond to the then-current WHO recommendation (100ppm) for short term exposures, however, this level falls to 70ppm under some conditions in 2010, lower than the current WHO recommendation of 87ppm.

The regulation for Norwegian longitudinally ventilated tunnels assumes that pollutant levels rise steadily along the tunnel

CO C_{co} = 200 ppm	In operation a concentration of 100 ppm is only occasionally reached in the tunnel and must not be exceeded. If the CO measuring instrument in the mid-tunnel registers 100 ppm for more than 15 minutes, the tunnel must be closed to traffic. During normal traffic the CO content in the air will be essentially lower. This is achieved by controlling the ventilation equipment such that the ventilators are coupled in groups and in stages. For example, the first stage will operate at 25 ppm, the second stage at 50 ppm and all three at 75 ppm. This applies to control by the CO measuring instrument in the mid-tunnel. Corresponding values at each end of the tunnel are twice that of the concentration in the middle.

The 'peak' concentration at any point is 200ppm and the effective mean concentration for the whole tunnel is 100ppm (as measured at the center of the tunnel). Importantly, there is no consideration of motorist 'exposure' as the assumption is that the motorist will transit the tunnel quickly, however the tunnel must be closed if the CO center concentration is over 100ppm for 15 minutes.

Under these conditions, any trip in excess of 13 minutes would involve motorist exposure in excess of the WHO guidelines.

Norway also prescribes center and peak levels for NO_2 are 0.75ppm and 1.5ppm respectively and the visibility (anywhere) is limited to 1.5 mg/m^3 (1500 µg'm^3).

The 'permissible' concentrations are considerably higher than Australia has been prepared to allow. Even in 1992 the CO limits for the Sydney Harbour tunnel were set at 100ppm/15 minutes and 150ppm/3 minutes at any location.

Previously, actions taken to provide 'safe' conditions, in relation to carbon monoxide asphyxia, were thought to be sufficient to also protect motorists' from other pollutants. Clearly this is no longer the case.

Carbon monoxide goals and their 'reinterpretation'

The crucial part of the M5 Condition 70 which relates to operation states *"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."*

The WHO publication 'Environmental Health Criteria 213 - CARBON MONOXIDE – 2nd ed. states as follows:

'Recommended WHO guidelines

The following guideline values (ppm values rounded) and periods of time-weighted average exposures have been determined in such a way that the carboxyhaemoglobin level of 2.5% is not exceeded, even when a normal subject engages in light or moderate exercise:
100 mg/m3 (87 ppm) for 15 min
60 mg/m3 (52 ppm) for 30 min
30 mg/m3 (26 ppm) for 1 h
10 mg/m3 (9 ppm) for 8 h'

An attempt has been made by the RTA to hold that Condition 70 is not breached unless it can be shown that a tunnel user has been exposed to a carbon monoxide concentration in excess of 87ppm for more than 15 minutes, on the grounds that the WHO goal is an exposure goal.

The Cross City Tunnel conditions of approval were changed during the planning and consultation period and reflect this RTA position. This change occurred after the M5East Tunnel opened and the problems with that tunnel became evident

Initially the Minister's Conditions of Approval for the Cross City Tunnel (October 2001) used a slightly more specific version of the M5 condition. The specification of a 'rolling average' removed a problem seen in the M5 condition, where the CO averaging was reported on the basis of a clock 15 min period..

The condition read:

Air Quality - In-Tunnel Limits

89. The concentration of carbon-monoxide (CO) inside the Cross City Tunnel must not exceed the concentration limits specified for that pollutant in Table 2 at any location in the tunnel.

Table 2

Pollutant	Units of measure	Averaging period	100% Limit
CO	ppm	Rolling 15-minute	87

This condition refers clearly a single point concentration measurement. It was simple and enforceable.

The problems with the ventilation system in the M5 quickly became obvious after its opening in December 2001 with no less than 8 exceedences of the carbon monoxide goal between then and August 2002. It appeared that the tunnel ventilation design was incapable of meeting the carbon monoxide goals under extreme operational conditions.

The NSW Health study of conditions inside the M5 tunnel carried out measurements of pollutant concentrations inside the tunnel between the 30th October and the 12th December 2002. The analysis of the initial results took several weeks and the study was released in July 2003.

After vigorous legal argument by the RTA about the way in which the condition in the M5 should be interpreted, a revised set of Minister's Conditions of Approval for the Cross City Tunnel dated 12 December 2002 was issued.

The RTA argument for the reinterpretation of the condition is based on a legalistic argument about words, not a consideration of inherent safety or health values.

New conditions:
In-Tunnel Air Quality Limits

258. The tunnel ventilation system must be operated so that the concentration of carbon-monoxide (CO) for exposure to any motorist inside the Tunnel must not exceed the concentration limits specified for that pollutant in Table 5 under all conditions (including fully congested conditions).

Table 5 – In-Tunnel CO Individual Exposure Limits

Pollutant	Units of measurement	Averaging period	Limit
CO	ppm	Rolling 30 – minute	50
CO	ppm	Rolling 15-minute	87

For the purposes of interpreting compliance with the rolling average periods specified in Table 5, the Proponent shall install appropriate real time systems to the satisfaction of the Director- General in consultation with NSW Health and the EPA, to enable as *accurate as possible estimate of time spent inside the tunnel by motorists and corresponding CO levels The Proponent must justify that the measuring points present an accurate representation of the CO profile and shall provide data/evidence including appropriate modelling to support that justification. The pollution concentrations outside the vehicle cabin shall be assumed to be equivalent to the pollution concentration within the cabin for the purposes of interpreting compliance. Emergency services, Proponent or Company personnel shall be dealt with under occupational health and safety procedures.*

259. The tunnel ventilation system must be operated so that the concentration of carbon-monoxide (CO) as measured at any single point in the tunnel must not exceed the concentration limit specified for that pollutant in Table 6 under all conditions (including fully congested conditions).

Table 6 – In-Tunnel CO Single Point Limits

Pollutant	Units of measurement	Averaging period	Limit
CO	ppm	Rolling 3-minute	200

Condition 258 is effectively unenforceable and an acceptable formula for the calculation of exposure has still not been produced. Condition 259 is enforceable but is significantly less stringent than the equivalent regulation applied to the Sydney Harbour Tunnel (150ppm – peak sample point).

What is wrong with this new interpretation?

The interpretation of M5 condition 70 (and similar conditions for the Cross City and Lane Cove Tunnels) which requires a person to have been exposed to the stated concentration of carbon monoxide for the stated time before the condition is breached must be rejected for the following reasons:

Specifically for the M5 East:

- The condition has a clear 'plain English' meaning which is that the tunnel must be operated in such way that a carbon monoxide concentration in excess of 87ppm for a time in excess of 15 minutes (or its equivalent) does not occur under any circumstances.
- The community had been given to understand during community consultation that the condition would be interpreted as written and that the occurrence of a carbon monoxide concentration in excess of 87ppm for a time in excess of 15 minutes (or its equivalent) would be a breach of the condition.
- There is no apparent explanation for the use of the words 'under any conditions' other than to make it clear that the carbon monoxide level must be kept below 87ppm over a 15 minute average at all times and during all situations and occurrences which occur while the tunnel is in operation.

Relating to all tunnels:

- The prohibition of the occurrence of a carbon monoxide concentration in excess of 87ppm for a time in excess of 15 minutes (or its equivalent) is consistent with good safety practice, which holds that the best way to control an unsafe condition or situation is to prevent the unsafe condition or event from ever occurring. This is consistent with the use of the words 'under any conditions' .
- The reinterpretation of the condition as one requiring exposure leads directly to the possibility of creating an unsafe condition. The occurrence of a particular concentration inside the tunnel is necessarily a result of a situation in existence before exposure has occurred. Once the required concentration is in existence in the tunnel then the exposure of a person depends on the ability of the operator to control access of motorists or workers or to remove them from the scene. It is clear that neither of these actions can be guaranteed under every circumstance.
- If the 'exposure' interpretation were to be strictly adhered to then it would be allowable for the operator of the tunnel to maintain carbon monoxide far above the 'safe' 87ppm concentration if it is held that the tunnel management systems are such that no motorist should be in the tunnel for the required period of time. As an example, if it could be claimed that no motorist could be in the tunnel for more than 7 minutes then the carbon monoxide level could be held at 185ppm. This is clearly unacceptable and contrary to good safety practice.

Not only does the 'plain English' interpretation of the M5East condition ensure safe conditions at all times but the reinterpreted condition is inconsistent with good practice and can lead directly to inherently unsafe situations.

Administrative and operational convenience must not be allowed to force the acceptance of an operating protocol which is inherently unsafe. In addition it is far from clear that it is possible to correctly estimate exposure or to rule out the possibility that someone has been exposed.

Fundamental flaw in the 'interpretation'

The whole of the reinterpretation of Condition 70 and other similar conditions ignores the fact that, besides being to protect against excessive exposure to carbon monoxide, <u>it is also being used to attempt to ensure safe levels of other pollutants</u>.

This use is in the knowledge that this form of regulation is inadequate for this purpose. The PIARC documents clearly note this anomaly in the use of carbon monoxide as a marker and suggest that other components should also be controlled, but in the case of the M5 they are not, so the carbon monoxide level is the sole regulatory protection.

In fact, the PIARC 1995 document, upon which the tunnel design is based, does not use the concept of exposure.

Under 'Admissible Concentrations', it notes:

"Table 2 3 gives CO design-values, taken in conjunction with the maximum traffic and the type of traffic regime. The 100 ppm value corresponds to the WHO recommendation for short term-exposures . In order to avoid excessive fresh air demands for a rarely

occurring congested traffic, a higher CO concentration can then be admitted."

- The reference to *' the 100ppm value'* is followed immediately by the suggestion *'a higher CO concentration can then be admitted.'* (Note: If CO exposure was meant then the reference would be that *'a higher CO exposure can then be admitted*')
- Clearly the carbon monoxide design values are used in the sense of concentrations not in the sense of personal exposure, otherwise the provision "*a higher CO concentration can then be admitted*" would lead inevitably to an exceedence of the WHO goal, an inconceivable suggestion given general European adherence to the WHO goals.
- Nowhere in this otherwise comprehensive document is there any method given by which measured carbon monoxide concentrations can be used to estimate motorists' exposure, yet this is a mathematically and technically difficult procedure requiring constant tunnel supervision and a high level of information relating to traffic speeds and driver behaviour.

Reinterpreting the carbon monoxide goal as an exposure goal rather than a measured concentration undoubtedly weakens the protection provided for carbon monoxide and this weakening also applies to the protection from other components, for which carbon monoxide is acting as a marker or proxy, perhaps to an even greater extent.

Thus it is unsafe and contrary to accepted international practice to reinterpret or to actively use an exposure approach to the carbon monoxide goal in the regulation of any tunnel.

Other components

No other components of tunnel atmospheres are subject to the conditions of approval for the M5.

The only PIARC recommendation which relates in any way to particles is the reference to visibility where the requirement is related to the distance required for a vehicle to stop in front of a stationary object. This recommendation clearly does not consider smoke/particulate matter as a health hazard.

The 1995 PIARC document notes that *' Usually the fresh air demand for diesel-smoke dilution is quite higher* (sic) *than for the CO-dilution, but in countries where the N02 limits will be adopted the fresh air demand is even higher than for diesel smoke dilution.'*

It appears to be RTA policy that the visibility levels should be kept so that the extinction coefficient (K) does not exceed the lowest figure noted ($K = 0.005\ m^{-1}$) This is equivalent to a smoke concentration which will absorb 40% of a beam of light in 100 meters. This level is probably the 'regulation' the RTA claims to meet, but the conditions of approval do not set a specific figure.

As the smoke concentration increases the proportion of light absorbed becomes higher. The document notes that even when there is enough visibility for a car to stop safely, the conditions inside the tunnel will be 'most uncomfortable'.

The 1995 PIARC document notes that *'in a few countries, nitrogen dioxide is taken into account and the threshold values following the WHO recommendations are considered.*

The later 2000 PIARC discussion document 'Pollution by nitrogen dioxide in road tunnels' examines the effect of nitrogen dioxide (reflecting, mainly, the concerns of the French about this gas) however the Swedish experimental work described clearly shows that nitrogen dioxide interacts with particulate matter and that, under tunnel conditions, it is likely that particle levels equivalent to 100 $\mu g/m^3$ PM2.5 are equivalent to NO_2 concentrations of around 200 $\mu g/m^3$ and that the two components interact additively inside tunnels.

Other research on nitrogen dioxide carried out in the same laboratory but not reported in the PIARC document demonstrates the ability of repeated, relatively short (15 minute) exposures to nitrogen dioxide to act cumulatively over periods between 24 and 48 hours.

Situation in Sydney tunnels

In relation to particulate matter, an anomaly became evident during planning for the Cross City tunnel.

An examination of the pollution data from the M5 tunnel showed that the particulate matter concentrations measured by several different methods inside the tunnel and in the stack did not correspond to the levels calculated using a relationship developed by PIARC between visibility and PM10 concentrations, using European data.

This relationship suggests that a visibility extinction coefficient of $K = 0.005\ m^{-1}$ is equivalent to a PM10 concentration of 1000$\mu g/m^3$.

A series of measurements carried out in the M5 showed that the PIARC relationship did not hold in the M5 (and presumably in other tunnels), and that this level of visibility was , in fact equivalent to a PM10 level of more than 2000 $\mu g/m^3$. The study noted "Experience by the RTA indicates that the haze in the M5 tunnel becomes unacceptable when the extinction coefficient as reported in the stack opacity monitor exceeds 0.003 m^{-1}.

It follows that the control of 'visibility' at the levels envisaged by PIARC gives rise to PM10 levels almost twice those which would be experienced under the same control in Europe. There is no reason to expect that it would not also be twice as harmful to motorists.

It is clear that the air quality inside the M5East tunnel is unacceptable to many motorists and there have been repeated reports of people suffering discomfort and actual adverse health outcomes as a result. The current control methods being used, even if they fit within the reinterpreted conditions of approval, are leading to an unacceptable and potentially harmful outcome to motorists and local residents.

Mark Curran for RAPS