1 Introduction

This interim guidance note is produced as a result of an agreement made between HSE and the Tunnelling Industry at a meeting convened by the British Tunnelling Society in March 2006 and attended by representatives from all sectors of the Industry. The meeting was called in response to representations by HSE (in December 2005) to the Tunnelling Industry with regard to the implementation of CHAN 28.

This note has been issued as interim guidance pending completion of a Best Practice Guidance note and is in direct response to the Chemical Hazard Alert Notice (CHAN) 28 – nitrogen monoxide, issued by the Health and Safety Executive in April 2003, revised in July 2004.

The Notice highlighted that the HSE had withdrawn the Nitrogen Monoxide (NO) Occupational Exposure Standards (OES) from EH40. The Notice states that "…., *long term (8-hour TWA) exposures to nitrogen monoxide should not exceed 1ppm*". The Notice also advised, "… *employers should determine their own working practice and in house standards for control so that repeated exposure does not cause ill health*".

With the withdrawal of the EH40 OES for NO of 25ppm (8-hour time weighted average) the Control of Substances Hazardous to Health (COSHH) Regulations became the controlling legislation for occupational exposure to NO. Therefore ALARP principles should be applied throughout scheme planning, design, construction, operation and maintenance phases to minimise the risk of ill health from occupational exposure to NO.

NO exists at background levels within the atmosphere. It is produced in the exhaust gases from diesel and petrol engines, is also formed during welding and cutting processes and is present in the fumes generated by blasting operations.

Emphysema has been found in laboratory animals exposed to NO but it is not known if this occurs in humans exposed to NO. In the UK, by far the most common cause of emphysema is cigarette smoking. It is not possible at this stage to determine reliably if occupational exposures or exposure to cigarette smoke is the cause of an individual's emphysema.

The purpose of this note is to recommend simple planning and operational guidelines to minimise and monitor the occupational exposure to NO within tunnels.

This guidance note is intended for Clients, Designers, Contractors and Operators and is applicable to work carried out in a tunnel environment where activities can result in the emission of NO or are carried out in the presence of NO created by others. Such workplaces will include those associated with the following:

- New build
- Remediation, refurbishment and upgrading
- Operation and maintenance

The following table is a summary of conclusions from a review of available data on the health effects of exposure to NO. This data suggests that occupational exposure to NO should be as low as reasonably practicable and should not exceed 5 ppm (8 hour time weighted average) with peak NO levels not exceeding three times this level (15ppm as a 15 minute mean). Emerging findings from ongoing research may eventually indicate lower target levels should be adopted.

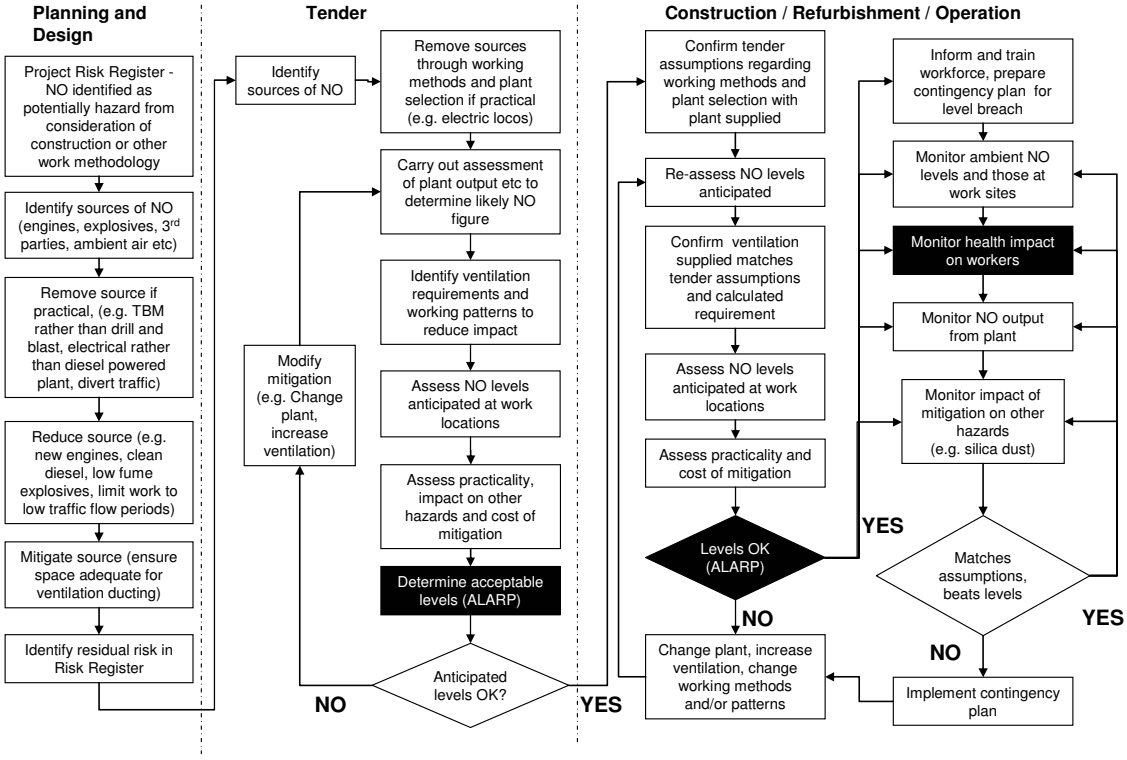
Inferred exposure-response information for NO based on the reviewed studies in animals and humans.

Concentration of NO ppm	Effects of short term exposure	Effects of repeated exposure	Comments
0.2	Small reversible effects on cellular function in the lungs in a small proportion of individuals	None expected	Inhalation of less than 0.1 ppm NO affects exhaled NO concentrations suggesting interference with endogenous NO; Concentrations of NO of 0.1 ppm have been shown to be of therapeutic benefit to some individuals with severe respiratory illness; some evidence that NO in ambient air (concentrations typically less than 0.1 ppm) may be associated with a small loss of life expectancy and increased risk of respiratory symptoms
1	Small effects on cellular function in the lungs in many individuals; small effects on respiratory function in a small proportion of individuals	None expected	Inhalation of low concentrations of NO may interfere with endogenous NO processes in the lung leading to an adaptive response. In a human volunteer experiment, effects on airways conductance were observed in some individuals at 1 ppm. No association was found between NO and respiratory ill health in miners with long term exposure to about 1 ppm, although effects may have been masked by concurrent exposure to dust.
2-5	Effects on cellular function in the lungs in a large proportion of individuals	Small risk of irreversible changes in the lung predisposing to emphysema or lung fibrosis, possible long term decline in lung function; increased risk of the development of respiratory illness as a result of co-exposure to other substances	Emphysema-like changes in the lung have been reported in rats exposed continuously to 0.5 ppm with twice daily peaks of 1.5 ppm although similar effects were not observed in rats exposed continuously to 6 ppm. Emphysema like changes were also observed in dogs exposed continuously to 1.6 ppm with concurrent exposure to 0.3 ppm NO_2. Damage to epithelial cells has been observed following long-term exposure of rats to 2 ppm. Effects on lung function reported in tunnel workers with long term mean exposures to NO_2 of about 0.5 ppm that are likely to have been associated with concurrent exposures to NO of about 2.5-5 ppm. There is no specific information about the effects of co-exposure to NO and other pollutants but endogenous NO has been shown to be important in mediating the inflammatory response to mineral dust.
10	Reversible effects on cellular function in the lungs in a large proportion of individuals,	Risk of irreversible changes leading to emphysema or lung fibrosis, long term decline in lung function, increased risk of the development of respiratory illness as a result of co-exposure to other substances	Mice exposed to 10 ppm NO for 2 hours/day, 5 days/week for 30 weeks developed emphysema. Effects on natural killer cell activity were observed in workers exposed to concentrations of about 9 ppm with concurrent exposure to about 3 ppm NO_2.
25	Reversible effects on cellular function in the lungs in most individuals, effects on lung function in a high proportion of individuals	More substantial risk of irreversible changes in the lung leading to emphysema or lung fibrosis, increased risk of the development of respiratory illness as a result of co-exposure to other substances	Tunnel workers with short term exposures to NO that are likely to have exceeded 25 ppm showed a measurable decline in lung function over an 11 day period

The refining of best practice to minimise and manage occupational exposure to NO will be developed over the next year and published as a best practice guide.

2 Principles to be Adopted

The normal COSHH three-step approach (removing the source, mitigating the hazard and managing exposure) should be followed and documented. An indicative process is shown diagrammatically in the following flow chart.



Action indicates an action for which specialist advice should be sought

The acceptable levels of NO may be different for different projects and will depend on such factors as duration of exposure, ambient levels of NO in the environment, the impact of NO reduction measures on other hazards and the disproportionate cost of reducing the levels further.

2.1 Removing the Source

Decisions taken during the feasibility, design and work planning phases should aim to minimise the generation of NO and the exposure to NO of personnel engaged in the construction phase and subsequent operation and maintenance phases. Such decisions might include the selection of structure form, the location of equipment remote from road traffic and making adequate provision for temporary or permanent extraction ventilation.

In an existing facility all parties should aim to eliminate the need for work being undertaken in areas exposed to NO emissions from road or other traffic. If the removal of traffic from an existing tunnel is not practicable or introduces additional risks or disproportional costs that outweigh the benefits then consideration should be given to undertaking the work during periods of low traffic flow.

All parties should also aim to carry out the works with plant which can operate without production of NO such as electrically powered plant. An example of this would be to use

conveyors as opposed to diesel powered trucks for muck haulage. If this is not possible or practicable or introduces additional risks or disproportional costs which outweigh the benefits, then dual powered plant that uses diesel engines to travel and electrical power for operation should be used. Only when these options are not practicable or have disproportional costs should the third choice of diesel powered plant be used. The diesel plant selected should preferably be powered by new or recently manufactured engines compliant with the latest EU Tier standards.

The use of explosives, flame cutting and welding should be eliminated or at least minimised unless this is impracticable or introduces disproportional costs.

2.2 Mitigating the Hazard

If the source of NO in the workplace is not eliminated then working methods should be developed to mitigate the hazard.

NO emissions from construction plant should be minimised to as low as reasonably practicable by such methods as**:**

- Selecting suitably sized plant to minimise unnecessary vehicle movement
- Sequencing construction activities to minimise the amount of NO producing plant operating at any one time
- Regular servicing of plant to help maintain efficient fuel burn
- Using Ultra Low Sulphur diesel or other clean fuels instead of standard diesel and low sulphur diesel
- Adopting low fume explosives for drill and blast operations
- Operating a policy to reduce plant idling time
- Installation of exhaust after treatment on diesel plant

Where practicable and costs are not disproportionate to the benefit then personnel should be screened from NO by such methods as:

- Localised ventilation and extraction for flame cutting and welding activities
- Sealing plant cabs and installing air re-circulation systems.

NO concentrations in the workplace should be diluted by the use of forced ventilation to increase the airflow through the workplace. In developing a ventilation system the following should be considered.

- NO concentrations should be kept as low as reasonably practicable without increasing other hazards due to air velocity (such as dust or low temperatures within the tunnel) to unacceptable levels.
- Air intakes should be located to minimise recirculation and to optimize the supply air quality.

- Air exhausts should be directed away from work areas.
- The use of pilot tunnels for improving ventilation systems.

2.3 Managing Workforce Exposure

Having fully explored removal of source and mitigation measures consideration should then be given to controlling the exposure of personnel to NO. Examples of this are as follows

- Sequencing construction work to minimise the operative's exposure
- Reduced shift durations
- Reduced number of workforce exposed to areas of high NO concentrations
- Only allowing authorised personnel* in areas of high NO concentrations
- Increased time for breaks during the working shift
- Circulating the workforce through a number of different work locations that have different NO concentration levels
- Introducing fresh air bases for the workforce

* *Authorised personnel could be those subject to health surveillance and least susceptible to the effects of NO*.

3 Compliance Monitoring

Having determined the management and mitigation measures to be applied ongoing monitoring should then be carried out to ensure that they are being complied with and that the assumptions used in the development of the procedures remain valid.

As part of routine maintenance diesel engine emissions should be monitored and ventilation systems should be checked for compliance with design airflow requirements.

Anticipated NO levels should be determined and contingency measures developed for implementation at pre-determined concentrations. Actual levels of NO at the various work places should be monitored to confirm exposure assumptions and initiate the contingency measures.

Where appropriate, exposure should be monitored and recorded using fixed gas monitors located in workplaces and at ventilation intakes. The location of fixed gas monitors will depend on the length and function of the tunnel. For major schemes and operational tunnels consideration should be given to the monitors being integrated into a tunnel safety system via a SCADA link or similar data collection system.

In areas of high risk the workforce should use local portable gas monitors, with built in alarms set at appropriate levels, to monitor and confirm their personal exposure to NO.

4 Occupational Health Monitoring

On major tunnelling projects and for other activities where health surveillance is concluded necessary the minimum level of health surveillance recommended is the keeping of a health

record. Consideration should also be given to a full health screening, including respiratory health surveillance, prior to starting, on an annual basis and at the end of the project. The respiratory health surveillance should include a validated respiratory questionnaire, and lung function tests (spirometry).

The health surveillance and screening should include a review of causes of sickness absence to try to determine if patterns of disease are present.

5 Training

All personnel should be briefed on the risks involved, measures taken and procedures implemented to minimise their exposure to NO.

Appropriate personnel should be trained regarding portable gas monitoring (if applicable), safety procedures, and contingency plans to follow when alarm levels are triggered

All plant operatives, fitters, welders and other specialist trades should receive appropriate training in NO reduction measures.