Non-road Diesel Air Emission Case Study

Sydney Metro Northwest
Tunnels and Station Civil Project

This case study highlights strategies to reduce diesel emissions using engineering design, procurement and behavioural change approaches.

Project overview

The $8.3-billion Sydney Metro Northwest is the first stage of Sydney Metro. The $1.15-billion Tunnels and Station Civil (TSC) contract was awarded to **CPB John Holland Dragados (CPBJHD)**, formerly known as Thiess John Holland Dragados (TJHD), in June 2013, to design and construct the 15-kilometre twin tunnels. It also included civil works for five new stations, two services facilities and an onsite precast facility to manufacture the tunnel segments used to line the tunnels.

The tunnelling contractor has delivered 70 per cent of Australia's major underground infrastructure in the last decade and 1,200 kilometres of tunnels worldwide.

CPBJHD has implemented a clear vision and communicated the values and underpinning behaviours expected of all who undertake TSC works. CPBJHD's **Ahead of the Game** vision is based on extensive experience on similar projects in Sydney which has proven the critical importance of developing an aligned culture that fosters and delivers the desired behaviours and outcomes.

'CPBJHD has a ground-breaking vision for sustainable infrastructure delivery. It has worked to ensure worker health and safety, reduce environmental impacts, maximise social benefits in delivering a high quality, value-for-money asset for the people of NSW, ahead of schedule.'

TERRY SLEIMAN,
CPBJHD Project Director

The Ahead of the Game vision and guiding values of One Team, Integrity and Accountability, focus effort towards proactively identifying and managing potential issues and opportunities, well ahead of construction. It is a multidisciplinary and collaborative approach that involves designers, manufacturers, suppliers, engineers and workers.

This case study draws from the collective experience in managing non-road diesel emissions over many projects and gives an overview of how CPBJHD managed non-road diesel emissions while delivering the TSC works. The monitoring and adaptive management approach applied to the TSC works is a step-change in minimising workers' and community exposure to harmful diesel emissions.

Context and key drivers

The TSC works involved construction of the longest rail tunnels in Australia. The mainline tunnels were excavated with four purpose-built tunnel-boring machines (TBMs). Between Cherrybrook and Epping there are six-kilometre-long tunnels which were supported from the Cherrybrook worksite. Therefore, the temporary tunnel ventilation design and air quality management strategy had to successfully address this extremely long tunnel drive.

CPBJHD's strategy needed to cover not only the operational tunnelling phase, but also required active management during establishment at eight surface sites, including the onsite precast facility at Kellyville. The construction work at these sites could be compared to setting up a large factory and digging basements for seven very large buildings in highly urbanised environments.

Diesel combustion produces a range of air contaminants, including diesel particulate matter (DPM) which has fine particles of elemental carbon with an aerodynamic diameter of less than 2.5 micrometres (PM2.5). These fine particles are at the lower end of the respirable size range and can be transported deep to the alveoli of the lungs. This can result in adverse health effects ranging from respiratory irritation and neurophysiological symptoms, to more chronic illnesses like chronic respiratory inflammation and lung cancer.

There is nothing more important to CPBJHD than our people and the communities surrounding our worksites. The use of diesel-powered machinery was necessary to deliver the TSC works. Therefore, mitigation and management measures were needed to reduce the risk of exposure to diesel emissions for both the workforce and the community. Putting health and safety first, being environmentally responsible and supporting our host communities, means CPBJHD has been Ahead of the Game in delivering a world-class project for the people of NSW.

Management strategy
Project stages

The control of diesel emissions has been considered across different stages of the TSC works as shown in *Figure 1*.

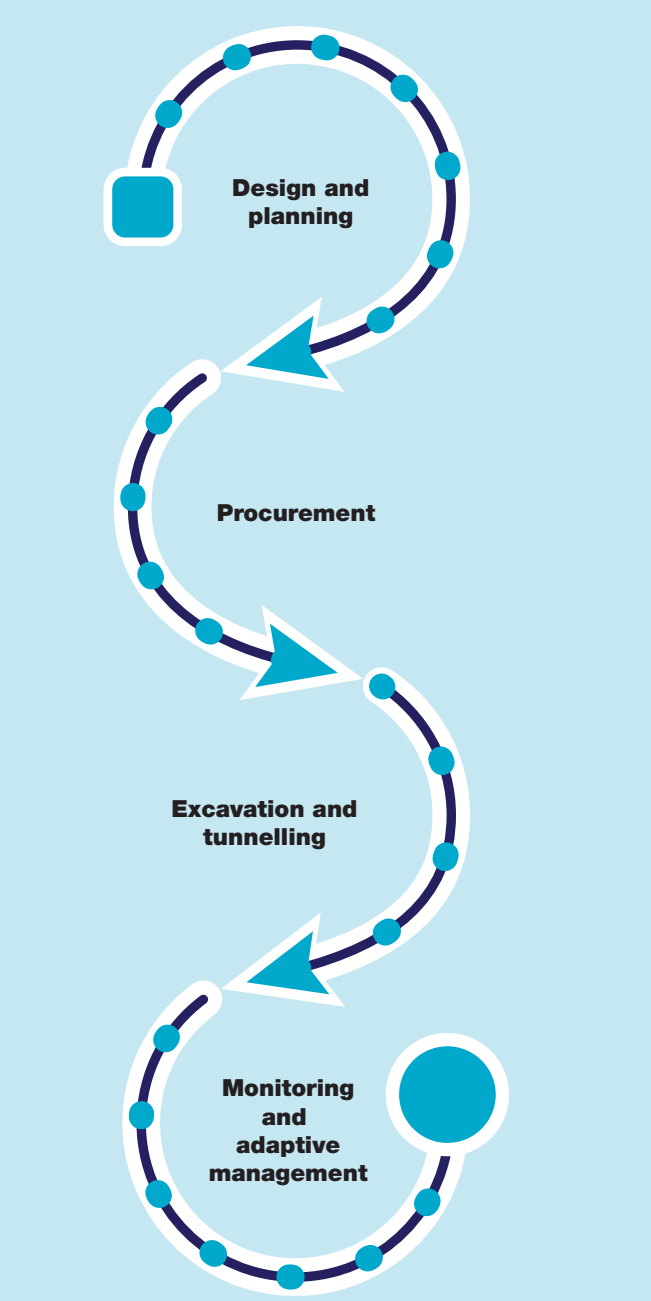

Figure 1: *Diesel emission controls were considered at each stage of the TSC works.*

Design of the tunnel ventilation system

Figure 2: *The ventilation bag (top left) carried fresh air from the surface to the tunnel boring machine.*

Risk identification and control

Risk assessments were completed collaboratively by CPBJHD staff, workers and subcontractors to identify potential hazards, assess the risk of exposure to workers and subcontractors and the community, and determine risk control measures to be used. CPBJHD applied the **hierarchy of risk controls** to:

1. **eliminate exposure to hazards during design**
2. **substitute, isolate or reduce the risk through engineering controls during planning and procurement**
3. **reduce exposure using administrative (procedural) controls and personal protective equipment (PPE).**

- **Fresh air in the tunnels was supplied through a vent bag that reached from the portal at the surface to the back of the TBM. The ventilation system was designed to provide fresh air to the front of the TBM.**
- **Two electric extraction fans mounted on the TBM gantries helped to direct the airflow. The electric extraction fans were designed to remove the same amount of air provided by the primary fan system.**
- **Electric jet fans were used to keep air moving through the open tunnels.**
- **Electric scrubbers remove suspended particulates in the air at all TBM and mined tunnel sites and for all cross passage excavation works.**
- **Specially designed brattice curtains were used to improve the ventilation system in the mined tunnels.**

At each stage, hazards were identified and appropriate risk controls determined. Risks that could not be eliminated during design were carried through to the planning and procurement phases. This process was integral to investigating and selecting the most effective suite of control measures.

Control measures that provided the highest level of protection and reliability were prioritised when CPBJHD considered approaches to reduce risk exposure.

Design, planning and procurement

The TSC works have been significantly different from other major infrastructure design and construction contracts in Australia as CPBJHD directly procured the TBMs, road headers and other plant and equipment used to excavate the tunnels, rather than via subcontracts. The first TBM arrived in Australia in July 2014, one year after contract award, and tunnelling started in September 2014.

It was only about 15 months from contract award to arrival of the first TBM. CPBJHD therefore had to assess options and make decisions which directly impacted on air quality during the tender process.

> ‘By procuring plant and equipment with lower diesel emissions and implementing engineering controls, we significantly reduced the amount of diesel emissions produced during construction.’

DR CAITLIN RICHARDS,
CPBJHD Approvals, Environment and Sustainability Manager

We set the target for in-tunnel airflow in the tunnels to well beyond the minimum 0.5 metres per second in the underground environment to reduce airborne contaminants, such as diesel emissions. A ventilation rate of 0.75 metres per second was adopted for the longest Cherrybrook to Epping tunnel drive. This provided more air to remove and dilute the contaminants away from the work area, even though this increased both plant and running costs.

See the difference

Behavioural safety training

Working on a project like the TSC works involves a large number of high-risk construction activities. This makes safe behaviour a priority in everything that is done in the workplace every day.

To ensure health and safety was always front of mind, in addition to the training on health impacts, management and monitoring of airborne contaminants, all CPBJHD construction workers took part in a new behavioural safety training program called **See the Difference**.

The program aims to reinforce a strong safety culture at all project levels — whether you are on the management team, operating a TBM or on the tools in a station site. Professional facilitators delivered the health and safety program through a series of workshops.

The program involved managers, engineers and workers experiencing how a workplace injury or illness can effect them and how difficult it is to perform everyday tasks at home and work. It focuses on the behavioural aspects of safety and decision making.

Safety should never be an afterthought—it must be a critical part of the thought process before you start each and every task—no matter how many times you have done it before.

It is too easy to convince yourself that taking the odd risk with safety only affects you – so that’s okay. You need to remember that if something does go wrong it could result in an injury or illness that affects you and others for the rest of your lives. It could mean your family no longer sees you walk through the door at the end of the day. Or you might have to cope with the tragic consequences, if your actions lead to a colleague being injured, getting ill or even worse.

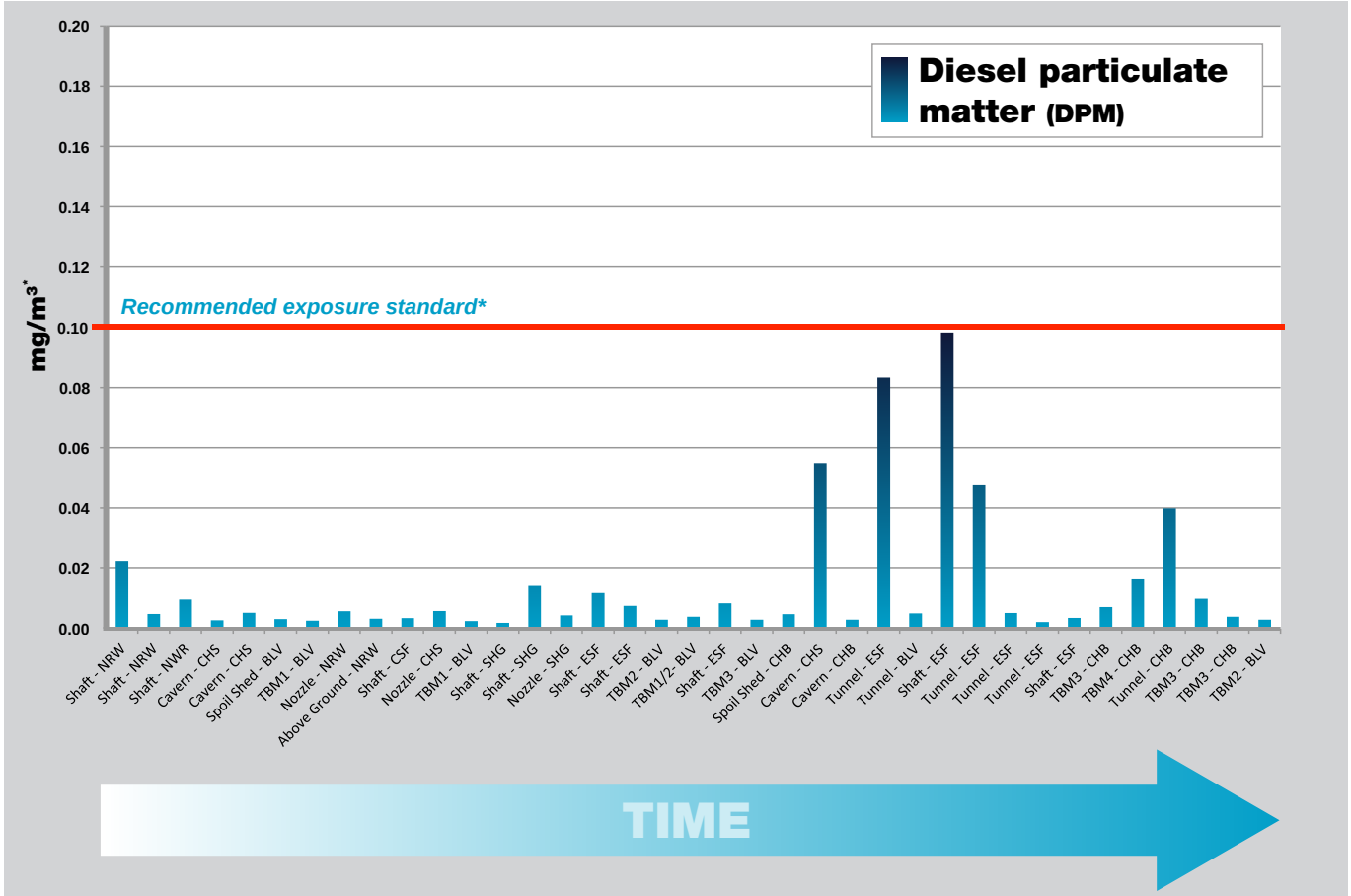

Figure 3: *Summary of diesel particulate matter (DPM), as elemental carbon, measured in air on the TSC project. It covers the period from 28 August 2014 through to 22 September 2015. The results represent personal exposure measurements collected over a represented period of the worker's shift for comparison to the eight hour time-weighted average exposure standard.*

‡milligrams per cubic metre

CPBJHD started to research the latest procurement options for key items of heavy plant and equipment early in the planning and design phase. There was a strong focus on the potential to reduce emissions in line with our Workplace Health and Safety and Environment and Sustainability policies. Diesel-powered heavy plant and equipment was substituted with electric powered plant where practicable.

This resulted in a lower reliance on diesel-powered heavy plant, including crucial items such as tunnel boring machines (TBMs), road headers, shotcrete rigs, jumbo drills, mini excavators and concrete pumps.

While diesel power was needed to relocate some plant, electric powered machinery was primarily used in the tunnels. If diesel-powered plant was necessary, CPBJHD ensured that all items of heavy plant were either new, or fitted with new engines to conform to the latest European standards at the time of design (in 2013). These were the Stage IIIB emission standards.

In 2014, the NSW Government Resource Efficiency Policy (GREP) was released, which included air emission standards for mobile non-road diesel plant and equipment. The GREP specified Stage IIIA emission standards for engines bought from 1 January 2015, however CPBJHD adopted internal emissions standards that were stricter than required.

Fifteen Caterpillar diesel-powered Metalliance products were purchased, which comply with the Stage IIIB emission standards, and were used underground. The engines emit 50 per cent lower diesel particulate matter concentrations and 10 per cent lower gaseous emissions than specified in the GREP.

Routine emission testing was conducted to ensure that emission levels were not deteriorating with use.

Correct use of respiratory protective equipment policy

CPBJHD has devoted considerable resources to ensure the safest workplace possible, using the hierarchy of controls. However, independent regular monitoring showed that for some areas and activities, extra controls were needed to reduce exposure, such as use of respiratory protection like dust masks and air-fed respirators. As with all personal protective equipment, they must be used correctly for them to be effective. CPBJHD reinforced respiratory safety with the following initiatives:

- Clean Shaven policy, including poster campaign and coverage in internal television program and newsletter
- respirator fit testing program to check correct fit of dust masks for all workers who need to wear them
- specific training on the use and limitations of respiratory equipment.

Figure 4: *Safety poster used to support CPBJHD's Clean Shaven Policy.*

Excavation and tunnelling

Administrative controls were also used to promote behavioural changes and ensure diesel emissions and associated health risks were reduced to as low as possible.

These included:

- use of low sulphur biodiesel (B5) and self-cleaning fuel to reduce particulate emissions
- deploying plant and equipment producing the lowest emissions to sites operating near sensitive populations, such as schools and hospitals
- restrictions on the number of plant items working in areas at one time. Risk assessments were used to identify where overcrowding plant may cause excessive emission levels, and place a limit on how many machines operate in one tunnel at the same time
- idling reduction programs, including an onsite idling reduction policy and an offsite heavy haulage vehicle no idling policy, implemented through a heavy vehicle driver code of conduct
- comprehensive monthly inspection and maintenance program with emissions testing of diesel-powered plant
- regular and ongoing exposure monitoring of the air quality both on the surface and in the tunnel. This was done through collecting DPM and gaseous samples to assess the effectiveness of controls and encourage continual improvement.

Managing diesel awareness

All underground workers completed a pre-employment medical to ensure they were fit for assigned duties and received comprehensive training on diesel emissions, including measures to reduce them.

The **key messages** in training included the:

- toxic nature of diesel exhaust
- importance of the numerous control measures to reduce exposure on an ongoing basis
- situations when respiratory protective equipment is needed and how to fit and use it correctly.

Exposure monitoring and adaptive management

Independent occupational hygienists conducted regular exposure assessments across all the TSC worksites. These assessments were used to check if the various control measures were effectively reducing exposure to diesel emissions. While the focus was on worker exposure, emission reductions ultimately benefit the surrounding communities as well.

Samples to assess occupational exposure to DPM were collected in line with the NIOSH Method 5040 Diesel Particulate Matter (as elemental carbon). Samples were collected from the worker's breathing zone over a time that represents the worker's exposure period. An independent NATA–accredited laboratory analysed all the samples.

Although no Workplace Exposure Standard for DPM currently exists in NSW, outside of a mining environment, personal exposure data was compared to a value of 0.1 milligrams per cubic metre (measured as submicron elemental carbon) as recommended by the Australian Institute of Occupational Hygienists and the NSW Department of Primary Industries.

If DPM concentrations were measured within 50 per cent of that value, additional control measures were put in place to further reduce exposure. These included increased ventilation and filtration, further reduction in idle times and the use of P2 respiratory protection as a final control measure. The effectiveness of those control measures was then assessed through follow-up testing. It was this process of ongoing adaptive management that resulted in data that showed DPM concentrations continued to remain below the recommended guideline. *(see figure 3, page 5)*

Achievements

Since the TSC works started, monitoring has found that the DPM concentrations workers are exposed to are below recommended industry guidelines.

CPBJHD's strategy of designing-out primary sources of DPM, procuring low emission equipment and implementing stringent management procedures have achieved this positive result. The continued effectiveness of these control measures will be confirmed through ongoing exposure monitoring to verify their adequacy over time.

Figure 5: *Martin Bell Plant Manager*

Lessons learnt

Using the longest length of tunnel to drive the entire ventilation design on the TSC works meant that the ventilation on other shorter tunnel lengths went beyond best practice; even though this was not required to achieve air quality standards. I am passionate about ensuring that exposure to all airborne contaminants for workers and staff is minimised at all times.

I have worked in tunnel construction for 25 years and have silicosis, an occupational lung disease caused by inhalation of crystalline silica dust. In hindsight, I wish we had the focus on avoiding and minimising particle emissions that we do today, when I started working in this industry.

Information in this case study has been provided by CPB John Holland Dragados (CPBJHD) as participant in the Non-road Diesel Air Emissions Project.

This case study was developed with funding provided to Infrastructure Sustainability Council of Australia (ISCA) by the State of NSW Environmental Protection Authority (EPA) from the Waste and Environment Levy

Published by:
Environment Protection Authority
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EPA 2016/0829

May 2016

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